BUY SMART. BUILD BETTER.

JOB ORDER CONTRACT
TECHNICAL SPECIFICATIONS

BOOK 4 OF 5 CSI DIVISIONS 23 - 26 JANUARY 2016

COUNTY OF LOS ANGELES
INTERNAL SERVICES DEPARTMENT

GORDIAN
JOC SOLUTIONS

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SECTION 23 01 10 00 - SEQUENCE OF OPERATION

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for sequence of operation. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes control sequences for HVAC systems, subsystems, and equipment.

C. Definitions
1. DDC: Direct digital control.
2. VAV: Variable air volume.

D. Heating Control Sequences
1. Heating-Water Supply Temperature Control:
a. Input Device: Thermostat **OR** Thermistor temperature sensor **OR** Resistance temperature sensor, **as directed**.
b. Output Device: Control valve.
c. Action: Modulate control valve to maintain heating-water supply temperature.
d. Display:
1) Heating-water supply temperature.
2) Heating-water supply temperature set point.
3) Control-valve position.
2. Heating-Water Supply Temperature Reset:
a. Input Device: Electric, outdoor-air-reset controller **OR** Outdoor-air sensor, **as directed**.
b. Output Device: Unitary controller **OR** DDC system software, **as directed**.
c. Action: Reset heating-water supply temperature in straight-line relationship with outdoor-air temperature for the following conditions:
1) 195 deg F (90 deg C) heating water when outdoor-air temperature is minus 30 deg F (minus 35 deg C).
2) 130 deg F (54 deg C) heating water when outdoor-air temperature is 75 deg F (24 deg C).
3) 150 deg F (65 deg C) minimum, heating-water temperature.
d. Display:
1) Outdoor-air temperature.
2) Heating-water supply temperature.
3) Heating-water supply temperature set point.
3. Control Primary Circulating Pump(s):
a. Input Device: Thermostat **OR** DDC system, **as directed**.
b. Output Device: Starter **OR** DDC system command to starter, **as directed**, relay.
c. Action: Energize pump(s) at outdoor-air temperatures below 65 deg F (18 deg C).
d. Display:
1) Outdoor-air temperature.
2) Operating status of primary circulating pump(s).

E. Central Refrigeration Equipment Sequences
1. Start and Stop Condenser-Water Pump(s):
a. Enable: Allow pump to start when water is in cooling tower:
1) Input Device: Water pressure transducer.

2) Output Device: Hard wired through motor starter; DDC system binary output, **as directed**.
3) Action: Confirm water in cooling-tower sump.

b. Enable: When outdoor-air temperature conditions are met:
1) Input Device: Space thermostat **OR** DDC system outdoor-air temperature, **as directed**.
2) Output Device: Hard wired through motor starter; DDC system binary output, **as directed**.
3) Action: Confirm outdoor-air temperature is above 50 deg F (10 deg C).

c. Enable: When demand conditions are met:
1) Input Device: DDC system software demand.
2) Action: Confirm cooling demand from ventilation system(s).

d. Initiate:
1) Input Device: Time clock **OR** DDC system time schedule, **as directed**.
2) Output Device: Time clock **OR** Binary output, **as directed**.
3) Action: Energize pump(s).

e. Display:
1) Low-level cooling-tower sump alarm.
2) Outdoor-air temperature.
3) Cooling (software) demand indication.
4) Time and time schedule.
5) Condenser-water pump(s) on-off status.
6) Condenser-water pump(s) on-off indication.

2. Start and Stop Chilled-Water Pump(s):
a. Input Device: Flow switch in condenser-water circuit.
b. Output Device: Starter **OR** DDC system command to starter, **as directed**, relay.
c. Action: Energize pump(s).
d. Display:
1) Chilled-water flow indication.
2) Chilled-water pump(s) on-off status.
3) Chilled-water pump(s) on-off indication.

3. Start and Stop Cooling-Tower Fans(s):
a. Input Device: Flow switch in condenser-water circuit.
b. Output Device: Starter **OR** DDC system command to starter, **as directed**, relay.
c. Action: Energize fan(s).
d. Display:
1) Condenser-water flow indication.
2) Cooling-tower fan(s) on-off indication.

4. Start and Stop Refrigeration Machine(s):
a. Input Device: Flow switch in condenser-water circuit. Flow switch in chilled-water circuit, **as directed**.
b. Output Device: Refrigeration **OR** DDC system command to refrigeration, **as directed**, machine terminal strip.
c. Action: Energize refrigeration machine(s) internal control circuit.
d. Display:

e. Condenser-water flow indication.
f. Chilled-water flow indication.
g. Refrigeration machine on-off indication.
h. Chilled-water supply and return temperature.
i. Chilled-water temperature control-point adjustment.

5. Start and Stop Chiller(s):
a. Input Device: Flow switches in condenser-water and chilled-water circuit.
b. Output Device: Chiller **OR** DDC system command to chiller, **as directed**, terminal strip.
c. Action: Energize chiller internal control circuit.

d. Display:
   1) Condenser-water flow indication.
   2) Chilled-water flow indication.
   3) Chiller(s) on-off status.
   4) Chiller(s) on-off indication.
   5) Chilled-water supply and return temperature.
   6) Chilled-water temperature control-point adjustment.

6. Alternate Chiller(s):
   a. Input Device: Electric alternator **OR** DDC system software, **as directed**.
   b. Output Device: Chiller **OR** DDC system command to chiller, **as directed**, terminal strip.
   c. Action: Operate chiller(s) on lead-lag, alternating each startup.
      OR
      Action: Adding and dropping chiller(s) as follows: <**Insert sequence and parameters**.>
   d. Display: Chiller(s) on-off indication.
7. Alarm Chiller(s) Start Failure:
   a. Input Device: Chiller control panel terminal strip contact **OR** software signal, **as directed**.
   b. Output Device: Analog control panel **OR** DDC system alarm, **as directed**.
   c. Action: Signal alarm.
   d. Display: Chiller "failure-to-start" indication.
8. Chilled-Water Level:
   a. Input Device: Expansion tank level switch **OR** liquid sensor, **as directed**.
   b. Output Device: Electric relay signal to alarm panel **OR** DDC system alarm, **as directed**.
   c. Action: Signal alarm.
   d. Display: Expansion tank low-level alarm.
9. Chilled-Water Supply Temperature:
   a. Input Device: Temperature sensor **OR** transmitter, **as directed**, in common chilled-water supply piping.
   b. Output Device: Integral chiller controls **OR** DDC system signal to chiller control panel, **as directed**.
   c. Action: Maintain constant leaving chilled-water temperature reset according to highest cooling demand, **as directed**.
      1) Display: Chilled-water supply temperature.
10. Condenser-Water Temperature:
   a. Input Device: Temperature sensor **OR** transmitter, **as directed**, in cooling-tower sump.
   b. Output Device: Bypass control valve **OR** Cooling-tower fan starter relay **OR** DDC system command to cooling-tower fan starter relay, **as directed**.
   c. Action: Modulate control valve open to cooling tower and closed to bypass and cycle tower fan(s) on and off **OR** and to low speed and then to high speed, **as directed**, to maintain 65 deg F (18 deg C) **OR** 70 deg F (21 deg C), **as directed**, sump temperature. Close valve when unoccupied, **as directed**.
   d. Display:
      1) Condenser-water sump (return) control-point temperature.
      2) Condenser-water sump (return) temperature.
      3) Control-valve position.
      4) Cooling-tower fan(s) on-off indication.
      5) Condenser-water supply temperature.
11. Cooling-Tower Sump Heater:
   a. Input Device: Sump temperature sensor **OR** transmitter, **as directed**.
   b. Output Device: Electric relay **OR** DDC system command to electric relay**,** as directed**,** and solenoid valve, **as directed**.
   c. Action: Energize sump heater; drain sump on low temperature, **as directed**.
   d. Display:
      1) Cooling-tower sump temperature.
      2) Cooling-tower sump heater on-off indication.
      3) Cooling-tower dump indication.
12. Operator Station Display: Indicate the following on operator workstation display terminal:

a. DDC system graphic.
b. DDC system status, on-off.
c. Low-level cooling-tower sump alarm.
d. Outdoor-air temperature.
e. Cooling (software) demand indication.
f. Time and time schedule.
g. Condenser-water pump(s) on-off status.
h. Condenser-water pump(s) on-off indication.
i. Condenser-water flow indication.
j. Chilled-water pump(s) on-off status.
k. Chilled-water pump(s) on-off indication.
l. Cooling-tower fan(s) on-off indication.
m. Chilled-water flow indication.
n. Refrigeration machine on-off indication.
o. Chilled-water supply temperature.
p. Chilled-water return temperature.
q. Chilled-water temperature control-point adjustment.
r. Chiller(s) on-off status.
s. Chiller(s) on-off indication.
t. Chiller "failure-to-start" indication.
u. Expansion tank low-level alarm.
v. Condenser-water sump (return) control-point temperature.
w. Condenser-water sump (return) temperature.
x. Condenser-water control-valve position.
y. Cooling-tower fan(s) on-off indication.
z. Condenser-water supply temperature.
aa. Cooling-tower sump temperature.
bb. Cooling-tower sump heater on-off indication.
cc. Cooling-tower dump indication.
dd. Chilled-water pressure drop through chiller.
ee. Entering condenser-water temperature.
ff. Leaving condenser-water temperature.
gg. Condenser-water pressure drop through chiller.
hh. Chiller condenser-water supply and return temperature.
ii. Chiller chilled-water supply and return temperature.
jj. System capacity in tons.

F. Air-Handling-Unit Control Sequences
1. Start and Stop Supply Fan(s):
a. Enable: Freeze Protection:
1) Input Device: Duct-mounted averaging element thermostat, located before supply fan.
2) Output Device: Hard wired through motor starter; analog alarm panel **OR** DDC system alarm, **as directed**.
3) Action: Allow start if duct temperature is above 37 deg F (3 deg C); signal alarm if fan fails to start as commanded.
b. Enable: High-Temperature Protection:
1) Input Device: Duct-mounted thermostat, located in return air.
2) Output Device: Hard wired through motor starter; analog alarm panel **OR** DDC system alarm, **as directed**.
3) Action: Allow start if duct temperature is below 300 deg F (150 deg C).
c. Enable: Smoke Control:
1) Input Device: Duct-mounted smoke detector, located in return **OR** supply, **as directed**, air.

2) Output Device: Hard wired through motor starter; analog alarm panel **OR** DDC system alarm, **as directed**.
3) Action: Allow start if duct is free of products of combustion.

d. Initiate: Occupied Time Schedule:
1) Input Device: Time clock **OR** DDC system time schedule, **as directed**.
2) Output Device: Time clock **OR** Binary output, **as directed**, to motor starter.
3) Action: Energize fan(s).

e. Initiate: Unoccupied Time Schedule:
1) Input Device: Room thermostat **OR** DDC system demand, **as directed**.
2) Output Device: Room thermostat **OR** Binary output, **as directed**, to motor starter.
3) Action: Energize fan(s).

f. Unoccupied Ventilation:
1) Input Device: Time clock and room thermostat **OR** DDC system time schedule and output, **as directed**.
2) Output Device: Room thermostat **OR** DDC system binary output, **as directed**, to motor starter.
3) Action: Cycle fan(s) during unoccupied periods.

g. Display: Supply-fan on-off indication.

2. Supply Fan(s) Variable-Volume Control:

a. Occupied Time Schedule:
1) Input Device: Time clock **OR** DDC system time schedule, **as directed**.
2) Output Device: Time clock **OR** Binary output, **as directed**.
3) Action: Enable control.

b. Volume Control (for fans equipped with variable inlet vanes):
1) Input Device: Static-pressure transmitter **OR** Differential-pressure switch, **as directed**, sensing supply-duct static pressure referenced to conditioned-space static pressure.
2) Output Device: Receiver controller **OR** DDC system analog output **OR** DDC system analog output to digital-to-pneumatic transducer, **as directed**, to modulating damper actuator. Set inlet guide vanes to minimum **OR** closed, **as directed**, position when fan is stopped.
3) Action: Maintain constant supply-duct static pressure.

c. Volume Control (for fans equipped with variable-speed drives):
1) Input Device: Static-pressure transmitter **OR** Differential-pressure switch, **as directed**, sensing supply-duct static pressure referenced to conditioned-space static pressure.
2) Output Device: Receiver controller **OR** DDC system analog output, **as directed**, to motor speed controller. Set variable-speed drive to minimum speed when fan is stopped.
3) Action: Maintain constant supply-duct static pressure.

d. High Pressure:
1) Input Device: Static-pressure transmitter sensing supply-duct static pressure referenced to static pressure outside the duct.
2) Output Device: Receiver controller **OR** DDC system binary output, **as directed**, to alarm panel **OR** motor starter, **as directed**.
3) Action: Stop fan and signal alarm when static pressure rises above excessive-static-pressure set point.

e. Display:
1) Supply-fan-discharge static-pressure indication.
2) Supply-fan-discharge static-pressure set point.
3) Supply-fan airflow rate.
4) Supply-fan inlet vane position **OR** speed, **as directed**.

3. Start and Stop Return Fan(s):

a. Initiate: Occupied Time Schedule:
1) Input Device: Time clock **OR** DDC system time schedule, **as directed**.
2) Output Device: Time clock **OR** Binary output, **as directed**, to motor starter.

3) Action: Energize fans when supply fans are energized.

b. Initiate: Unoccupied Time Schedule:
1) Input Device: Room thermostat **OR** DDC system demand, **as directed**.
2) Output Device: Room thermostat **OR** Binary output, **as directed**, to motor starter.
3) Action: Energize fans when supply fans are energized.

c. Unoccupied Ventilation:
1) Input Device: Time clock and room thermostat **OR** DDC system time schedule and output, **as directed**.
2) Output Device: Room thermostat **OR** DDC system binary output, **as directed**, to motor starter.
3) Action: Cycle fan(s) during unoccupied periods.

d. Display: Return-fan on-off indication.

4. Return Fan(s) Variable-Volume Control:

a. Occupied Time Schedule:
1) Input Device: Time clock **OR** DDC system time schedule, **as directed**.
2) Output Device: Time clock **OR** Binary output, **as directed**.
3) Action: Enable control.

b. Volume Control (for fans equipped with variable inlet vanes):
1) Input Device: Static-pressure transmitter **OR** Differential-pressure switch, **as directed**, sensing building static pressure referenced to outdoor static pressure.
2) Output Device: Receiver controller **OR** DDC system analog output **OR** DDC system analog output to digital-to-pneumatic transducer, **as directed**, to modulating damper actuator. Set inlet guide vanes to minimum **OR** closed, **as directed**, position when fan is stopped.
3) Action: Maintain constant building static pressure.

c. Volume Control (for fans equipped with variable-speed drives):
1) Input Device: Static-pressure transmitter **OR** Differential-pressure switch, **as directed**, sensing building static pressure referenced to outdoor static pressure.
2) Output Device: Receiver controller **OR** DDC system analog output, **as directed**, to motor speed controller. Set variable-speed drive to minimum speed when fan is stopped.
3) Action: Maintain constant building static pressure.

d. Display:
1) Return-air static-pressure indication.
2) Return-air static-pressure set point.
3) Return-fan airflow rate.
4) Return-fan inlet vane position **OR** speed, **as directed**.
5) Building static-pressure indication.
6) Building static-pressure set point.

5. Return Fan(s) Variable-Volume Control:

a. Occupied Time Schedule:
1) Input Device: Time clock **OR** DDC system time schedule, **as directed**.
2) Output Device: Time clock **OR** Binary output, **as directed**.
3) Action: Enable control.

b. Volume Control (for fans equipped with variable inlet vanes):
1) Input Device: Static-pressure transmitter **OR** Differential-pressure switch, **as directed**, sensing building static pressure referenced to outdoor static pressure.
2) Output Device: Receiver controller **OR** DDC system analog output **OR** DDC system analog output to digital-to-pneumatic transducer, **as directed**, to modulating damper actuator. Set inlet guide vanes to minimum **OR** closed, **as directed**, position when fan is stopped.
3) Action: Maintain constant building static pressure.

c. Volume Control (for fans equipped with variable-speed drives):
1) Input Device: Static-pressure transmitter **OR** Differential-pressure switch, **as directed**, sensing building static pressure referenced to outdoor static pressure.

2) Output Device: Receiver controller **OR** DDC system analog output, **as directed**, to motor speed controller. Set variable-speed drive to minimum speed when fan is stopped.
3) Action: Maintain constant building static pressure.

d. Display:
1) Return-fan-discharge static-pressure indication.
2) Return-fan-discharge static-pressure set point.
3) Return-fan airflow rate.
4) Return-fan inlet vane position **OR** speed, **as directed**.

6. Preheat Coil:
a. Freeze Protection:
1) Input Device: Duct-mounted averaging element thermostat, located after preheat coil.
2) Output Device: Hard wired through motor starter; analog alarm panel **OR** DDC system alarm, **as directed**.
3) Action: Allow start if duct temperature is above 33 deg F (1 deg C).

b. Occupied Time Schedule:
1) Input Device: Time clock **OR** DDC system time schedule, **as directed**.
2) Output Device: Time clock **OR** Binary output, **as directed**, to motor starter.
3) Action: Energize coil circulating pump(s).

c. Supply **OR** Discharge, **as directed**,-Air Temperature:
1) Input Device: Time clock and duct-mounted thermostat **OR** DDC system time schedule and electronic temperature sensor, **as directed**.
2) Output Device: Modulating control valve.
3) Action: Maintain air temperature set point of 55 deg F (13 deg C).

d. Unoccupied Time Schedule:
1) Input Device: Time clock and duct-mounted thermostat mounted in outdoor air **OR** DDC system time schedule and outdoor-air temperature, **as directed**.
2) Output Device: Time clock **OR** Binary output, **as directed**, to motor starter.
3) Action: Energize coil circulating pump(s) when outdoor-air temperature falls below 35 deg F (2 deg C).

e. Display:
1) Preheat-coil air-temperature indication.
2) Preheat-coil air-temperature set point.
3) Preheat-coil pump operation indication.
4) Preheat-coil control-valve position.

7. Mixed-Air Control:
a. Occupied Time Schedule:
1) Input Device: Time clock **OR** DDC system time schedule, **as directed**.
2) Output Device: Pneumatic relay **OR** DDC system output, **as directed**.
3) Action: Enable control.

b. Minimum Position:
1) Input Device: Time clock **OR** DDC system time schedule, **as directed**.
2) Output Device: Receiver controller **OR** DDC system analog output **OR** DDC system analog output to digital-to-pneumatic transducer, **as directed**, to modulating damper actuator(s).
3) Action: Open minimum outdoor-air dampers **OR** outdoor-air dampers to minimum position, **as directed**.

c. Heating Reset:
1) Input Device: Room thermostat **OR** DDC system software, **as directed**.
2) Output Device: Receiver controller **OR** DDC system analog output **OR** DDC system analog output to digital-to-pneumatic transducer, **as directed**, to modulating damper actuator(s).
3) Action: Close minimum outdoor-air dampers **OR** Set outdoor-air dampers to minimum position, **as directed**.

d. Supply **OR** Mixed, **as directed**,-Air Temperature:

1) Input Device: Duct-mounted thermostat **OR** Electronic temperature sensor, **as directed**.
2) Output Device: Receiver controller **OR** DDC system analog output **OR** DDC system analog output to digital-to-pneumatic transducer, **as directed**, to modulating damper actuator(s).
3) Action: Modulate outdoor-, return-, and relief-air dampers to maintain air temperature set point of 55 deg F (13 deg C).

e. Cooling Reset:
1) Input Device: Outdoor- and return-air, duct-mounted thermostats **OR** electronic temperature sensors, **as directed**.
2) Output Device: Receiver controller **OR** DDC system analog output **OR** DDC system analog output to digital-to-pneumatic transducer, **as directed**, to damper actuator(s).
3) Action: Set outdoor-air dampers to minimum position when outdoor-air temperature exceeds return-air temperature **OR** enthalpy exceeds return-air enthalpy, **as directed**.

f. Unoccupied Time Schedule:
1) Input Device: Time clock **OR** DDC system time schedule, **as directed**.
2) Output Device: Receiver controller **OR** DDC system analog output **OR** DDC system analog output to digital-to-pneumatic transducer, **as directed**, to modulating damper actuator(s).
3) Action: Position outdoor- and relief-air dampers closed and return-air dampers open.

g. Display:
1) Mixed-air-temperature indication.
2) Mixed-air-temperature set point.
3) Mixed-air damper position.

8. Humidifier:
a. Occupied Time Schedule:
1) Input Device: Time clock **OR** DDC system time schedule, **as directed**, and airflow switch
2) Output Device: Pneumatic relay **OR** DDC system output, **as directed**.
3) Action: Enable control.

b. Humidity:
1) Input Device: Room humidistat **OR** Return-air, duct-mounted humidistat **OR** DDC system, **as directed**.
2) Output Device: Receiver controller **OR** DDC system analog output **OR** DDC system analog output to digital-to-pneumatic transducer, **as directed**, enables humidifier **OR** modulates control valve to maintain humidity **OR** cycles pump to maintain humidity **OR** cycles pump and modulates control valve to maintain humidity, **as directed**, in straight-line relationship for the following conditions:
a) 20 percent when outdoor-air temperature is minus 30 deg F (minus 35 deg C).
b) 40 percent when outdoor-air temperature is 75 deg F (24 deg C).
3) Action: Modulate outdoor-, return-, and relief-air dampers to maintain air temperature set point of 55 deg F (13 deg C).

c. Display:
1) Relative humidity indication.
2) Relative humidity set point.
3) Relative humidity control-valve position.

9. Filters: During occupied periods, when fan is running, differential air-pressure transmitters exist.
a. Occupied Time Schedule:
1) Input Device: Time clock **OR** DDC system time schedule, **as directed**.
2) Output Device: Electric relay **OR** DDC system output, **as directed**.
3) Action: Enable control.

b. Differential Pressure:

1) Input Device: Differential-pressure switches **OR** Pressure transmitter, **as directed**.
2) Output Device: Analog alarm panel **OR** DDC system alarm, **as directed**.
3) Action: Signal alarm on low- and high-pressure conditions.

c. Display:
1) Filter air-pressure-drop indication.
2) Filter low-air-pressure set point.
3) Filter high-air-pressure set point.

10. Hydronic **OR** Steam, **as directed**, Heating Coil:
a. Occupied Time Schedule:
1) Input Device: Time clock **OR** DDC system time schedule, **as directed**.
2) Output Device: Time clock **OR** Binary output, **as directed**.
3) Action: Enable control.

b. Supply **OR** Discharge, **as directed**,-Air Temperature:
1) Input Device: Duct-mounted thermostat **OR** Electronic temperature sensor, **as directed**.
2) Output Device: Normally open **OR** closed, **as directed**, modulating control valve.
3) Action: Maintain supply-air temperature set point of 55 deg F (13 deg C).

c. Temperature Reset (for constant-temperature supply-air systems):
1) Input Device: Duct-mounted thermostat **OR** Electronic temperature sensor, **as directed**, in return air.
2) Output Device: Direct to receiver controller **OR** DDC system, **as directed**, in straight-line relationship for the following conditions:
a) 65 deg F (18 deg C) when return-air temperature is 70 deg F (21 deg C).
b) 55 deg F (13 deg C) when return-air temperature is 75 deg F (24 deg C).
3) Action: Reset supply-air temperature set point of 55 deg F (13 deg C).

d. Temperature Reset (for multizone or dual-duct supply-air systems):
1) Input Device: Load analyzer **OR** DDC system, **as directed**, with input from room thermostats **OR** temperature sensors, **as directed**.
2) Output Device: Direct to receiver controller **OR** DDC system, **as directed**.
3) Action: Reset supply-air temperature in response to greatest heating demand.

e. Unoccupied Time Schedule:
1) Input Device: Time clock and room thermostat **OR** DDC system time schedule and output, **as directed**.
2) Output Device: Room thermostat (cycling fan) **OR** DDC system binary output, **as directed**.
3) Action: Enable normal control **OR** Return valve to normal position, **as directed**, when fan is cycled on.

f. Display:
1) Fan-discharge air-temperature indication.
2) Fan-discharge air-temperature set point.
3) Heating-coil air-temperature indication.
4) Heating-coil air-temperature set point.
5) Heating-coil pump operation indication.
6) Heating-coil control-valve position.
7) Hot-deck air-temperature indication.
8) Hot-deck air-temperature set point.

11. Hydronic Cooling Coil:
a. Occupied Time Schedule:
1) Input Device: Time clock **OR** DDC system time schedule, **as directed**.
2) Output Device: Time clock **OR** Binary output, **as directed**.
3) Action: Enable control.

b. Supply **OR** Discharge, **as directed**,-Air Temperature:
1) Input Device: Duct-mounted thermostat **OR** Electronic temperature sensor, **as directed**.
2) Output Device: Normally open **OR** closed, **as directed**, modulating control valve.
3) Action: Maintain supply-air temperature set point of 55 deg F (13 deg C).

c. Temperature Reset (for constant-temperature systems):
   1) Input Device: Duct-mounted thermostat **OR** Electronic temperature sensor, **as directed**, in return air.
   2) Output Device: Direct to receiver controller **OR** DDC system, **as directed**, in straight-line relationship for the following conditions:
      a) 65 deg F (18 deg C) when return-air temperature is 70 deg F (21 deg C).
      b) 55 deg F (13 deg C) when return-air temperature is 75 deg F (24 deg C).
   3) Action: Reset supply-air temperature set point of 55 deg F (13 deg C).

d. Temperature Reset (for multizone or dual-duct supply-air systems):
   1) Input Device: Load analyzer **OR** DDC system, **as directed**, with input from room thermostats **OR** temperature sensors, **as directed**.
   2) Output Device: Direct to receiver controller **OR** DDC system, **as directed**.
   3) Action: Reset supply-air temperature in response to greatest heating demand.

e. Unoccupied Time Schedule:
   1) Input Device: Time clock **OR** DDC system time schedule, **as directed**.
   2) Output Device: Time clock **OR** Binary output, **as directed**.
   3) Action: Disable control.

f. Display:
   1) Fan-discharge air-temperature indication.
   2) Fan-discharge air-temperature set point.
   3) Cooling-coil air-temperature indication.
   4) Cooling-coil air-temperature set point.
   5) Cooling-coil control-valve position.
   6) Cold-deck air-temperature indication.
   7) Cold-deck air-temperature set point.

12. Multizone Damper Control:
   a. Occupied Time Schedule:
      1) Input Device: Time clock **OR** DDC system time schedule, **as directed**.
      2) Output Device: Time clock **OR** Binary output, **as directed**.
      3) Action: Enable control.
   b. Room Temperature:
      1) Input Device: Room thermostat **OR** Electronic temperature sensor, **as directed**.
      2) Output Device: Damper actuator.
      3) Action: Maintain room temperature.
   c. Display:
      1) Room temperature indication.
      2) Room temperature set point.
      3) Multizone damper position.

13. Coordination of Air-Handling Unit Sequences: Ensure that preheat, mixed-air, heating-coil, and cooling-coil controls have common inputs and do not overlap in function.

14. Operator Station Display: Indicate the following on operator workstation display terminal:
   a. DDC system graphic.
   b. DDC system on-off indication.
   c. DDC system occupied/unoccupied mode.
   d. Outdoor-air-temperature indication.
   e. Supply-fan on-off indication.
   f. Supply-fan-discharge static-pressure indication.
   g. Supply-fan-discharge static-pressure set point.
   h. Supply-fan airflow rate.
   i. Supply-fan inlet vane position **OR** speed, **as directed**.
   j. Return-fan on-off indication.
   k. Return-air static-pressure indication.
   l. Return-air static-pressure set point.
   m. Return-fan airflow rate.
   n. Return-fan inlet vane position **OR** speed, **as directed**.

o. Building static-pressure indication.
p. Building static-pressure set point.
q. Preheat-coil air-temperature indication.
r. Preheat-coil air-temperature set point.
s. Preheat-coil pump operation indication.
t. Preheat-coil control-valve position.
u. Mixed-air-temperature indication.
v. Mixed-air-temperature set point.
w. Mixed-air damper position.
x. Relative humidity indication.
y. Relative humidity set point.
z. Relative humidity control-valve position.
aa. Filter air-pressure-drop indication.
bb. Filter low-air-pressure set point.
cc. Filter high-air-pressure set point.
dd. Fan-discharge air-temperature indication.
ee. Fan-discharge air-temperature set point.
ff. Heating-coil air-temperature indication.
gg. Heating-coil air-temperature set point.
hh. Heating-coil pump operation indication.
ii. Heating-coil control-valve position.
jj. Hot-deck air-temperature indication.
kk. Hot-deck air-temperature set point.
ll. Cooling-coil air-temperature indication.
mm. Cooling-coil air-temperature set point.
nn. Cooling-coil control-valve position.
oo. Cold-deck air-temperature indication.
pp. Cold-deck air-temperature set point.
qq. Room temperature indication.
rr. Room temperature set point.
ss. Multizone damper position.

G. Terminal Unit Operating Sequence
1. Cabinet Unit Heater, Hydronic **OR** Steam, **as directed**:
   a. Room Temperature:
      1) Input Device: Room thermostat **OR** Electronic temperature sensor, **as directed**.
      2) Output Device: Room thermostat **OR** DDC system binary output, **as directed**.
      3) Action: Cycle fan to maintain temperature.
   b. Low-Temperature Safety:
      1) Input Device: Line-voltage, on-off thermostat, pipe mounted.
      2) Output Device: Hard wired.
      3) Action: Stop fan when return heating-water **OR** condensate, **as directed**, temperature falls below 35 deg F (2 deg C).
   c. Display:
      1) Room temperature indication.
      2) Room temperature set point.
2. Cabinet Unit Heater, Electric: Room thermostat cycles fan and sequences stages of heating.
3. Unit Heater, Hydronic **OR** Steam, **as directed**:
   a. Room Temperature:
      1) Input Device: Room thermostat **OR** Electronic temperature sensor, **as directed**.
      2) Output Device: Room thermostat **OR** DDC system binary output, **as directed**.
      3) Action: Cycle fan to maintain temperature.
   b. Low-Temperature Safety:
      1) Input Device: Line-voltage, on-off thermostat, pipe mounted.
      2) Output Device: Hard wired.

3) Action: Stop fan when return heating-water **OR** condensate, **as directed**, temperature falls below 35 deg F (2 deg C).

c. Display:
1) Room temperature indication.
2) Room temperature set point.

4. Unit Heater, Electric: Room thermostat cycles fan and sequences stages of heating.
5. Combustion-Air Unit Heaters:
a. Room Temperature:
1) Input Device: Room thermostat **OR** Electronic temperature sensor, **as directed**.
2) Output Device: Pneumatic **OR** Electronic, **as directed**, control-valve operator.
3) Action: Modulate valve to maintain temperature.
b. Display:
1) Room temperature indication.
2) Room temperature set point.
3) Control-valve position.
6. Radiant Heating Cable, Electric: Room thermostat cycles power.
7. Radiant Heating Panel, Electric: Room thermostat cycles power.
8. Radiant Heating Panel, Hydronic:
a. Room Temperature:
1) Input Device: Room thermostat **OR** Electronic temperature sensor, **as directed**.
2) Output Device: Pneumatic **OR** Electronic, **as directed**, control-valve operator.
3) Action: Modulate valve to maintain temperature.
b. Display:
1) Room temperature indication.
2) Room temperature set point.
3) Control-valve position.
9. Two-Pipe, Single-Coil, Fan-Coil Unit:
a. Occupied Time Schedule:
1) Input Device: Fan switch **OR** Time clock **OR** DDC system time schedule, **as directed**.
2) Output Device: Time clock **OR** Binary output, **as directed**.
3) Action: Start and stop fan and enable control.
b. Room Temperature:
1) Input Device: Room thermostat **OR** Electronic temperature sensor, **as directed**, in room **OR** return air, **as directed**.
2) Output Device: Pneumatic **OR** Electronic, **as directed**, control-valve operator.
3) Action: Modulate valve to maintain temperature.
c. DDC System Changeover:
1) Input Device: Thermostat **OR** Electronic temperature sensor, **as directed**, in supply-water **OR** on supply-water piping **OR** DDC system, **as directed**.
2) Output Device: Hard-wired relay **OR** DDC system software, **as directed**.
3) Action: Reverse control-valve action to switch from heating to cooling.
d. Display:
1) DDC system graphic.
2) DDC system on-off indication.
3) DDC system occupied/unoccupied mode.
4) Room temperature indication.
5) Room temperature set point.
6) Control-valve position.
7) Supply-water temperature indication.
10. Four-Pipe, Hydronic Fan-Coil Unit:
a. Occupied Time Schedule:
1) Input Device: Fan switch **OR** Time clock **OR** DDC system time schedule, **as directed**.
2) Output Device: Time clock **OR** Binary output, **as directed**.

3) Action: Start and stop fan, and enable control.

b. Room Temperature:
1) Input Device: Room thermostat **OR** Electronic temperature sensor, **as directed**.
2) Output Device: Pneumatic **OR** Electronic, **as directed**, control-valve operators.
3) Action: Modulate multiport control valves to maintain temperature.

c. Display:
1) DDC system graphic.
2) DDC system on-off indication.
3) DDC system occupied/unoccupied mode.
4) Room temperature indication.
5) Room temperature set point.
6) Control-valve position.

11. Unit Ventilator: Room thermostat modulates heating-and-cooling control valves; airstream thermostats modulate outdoor- and return-air dampers as follows:

a. Occupied Time Schedule:
1) Input Device: Fan switch **OR** Time clock **OR** DDC system time schedule, **as directed**.
2) Output Device: Time clock **OR** Binary output, **as directed**.
3) Action: Start and stop fan, move outdoor- and return-air dampers to minimum **OR** maximum, **as directed**, outdoor-air position, and enable control.

b. Room Temperature - Valves:
1) Input Device: Room thermostat **OR** Electronic temperature sensor, **as directed**.
2) Output Device: Pneumatic **OR** Electronic, **as directed**, control-valve operators.
3) Action: Modulate heating-water supply control valve and chilled-water supply control valve in sequence to maintain temperature.

c. Room Temperature - Dampers:
1) Input Device: Thermostat **OR** Electronic temperature sensor, **as directed**, in mixed air.
2) Output Device: Pneumatic **OR** Electronic, **as directed**, control damper actuators.
3) Action: Modulate outdoor- and return-air dampers to maintain temperature.

d. Supply-Air Temperature Limit:
1) Input Device: Thermostat **OR** Electronic temperature sensor, **as directed**, in discharge air.
2) Output Device: Pneumatic **OR** Electronic, **as directed**, control-valve operators and control damper actuators.
3) Action: Override room thermostat to control valves and dampers to prevent discharge air from dropping below a minimum set point.

e. Warm-up Cycle:
1) Input Device: Time clock **OR** DDC system time schedule, **as directed**.
2) Output Device: Hard-wired relay **OR** DDC system binary output, **as directed**.
3) Action: Open heating-water supply control valve, close outdoor-air damper, and open return-air damper.

f. Display:
1) DDC system graphic.
2) DDC system on-off indication.
3) DDC system occupied/unoccupied mode.
4) Room temperature indication.
5) Room temperature set point.
6) Control-valve position.
7) Damper position.

12. Heating Coils, Hydronic **OR** Steam, **as directed**:

a. Room Temperature:
1) Input Device: Room thermostat **OR** Electronic temperature sensor, **as directed**.
2) Output Device: Pneumatic **OR** Electronic **OR** Electric, **as directed**, control-valve operators.
3) Action: Modulate **OR** Cycle, **as directed**, valve to maintain temperature.

b. Display:
   1) Room temperature indication.
   2) Room temperature set point.
   3) Control-valve position.

13. Heating Coils, Electric: Room thermostat cycles coils **OR** sequences stages of heating, **as directed**.
14. Radiators and Convectors, Hydronic **OR** Steam, **as directed**:
    a. Occupancy:
       1) Input Device: Occupancy sensor.
       2) Output Device: DDC system binary output.
       3) Action: Report occupancy and enable occupied temperature set point.
    b. Room Temperature:
       1) Input Device: Room thermostat **OR** Electronic temperature sensor, **as directed**.
       2) Output Device: Pneumatic **OR** Electronic **OR** Electric, **as directed**, control-valve operators.
       3) Action: Modulate **OR** Cycle, **as directed**, valve to maintain temperature.
          a) Occupied Temperature: 75 deg F (24 deg C).
          b) Unoccupied Temperature: 65 deg F (18 deg C).
    c. Display:
       1) Room/area served.
       2) Room temperature indication.
       3) Room temperature set point.
       4) Room temperature set point, occupied.
       5) Room temperature set point, occupied standby.
       6) Room temperature set point, unoccupied.
       7) Control-valve position as percent open.
15. Radiators and Convectors, Electric: Room thermostat cycles coils **OR** sequences stages of heating, **as directed**.
16. Constant-Volume, Terminal Air Units, Hydronic **OR** Steam, **as directed**:
    a. Occupancy:
       1) Input Device: Occupancy sensor.
       2) Output Device: DDC system binary output.
       3) Action: Report occupancy and enable occupied temperature set point.
          a) Occupied Temperature: 75 deg F (24 deg C).
          b) Unoccupied Temperature: 65 deg F (18 deg C).
    b. Room Temperature:
       1) Input Device: Room thermostat **OR** Electronic temperature sensor, **as directed**.
       2) Output Device: Pneumatic **OR** Electronic **OR** Electric, **as directed**, control-valve operators.
       3) Action: Modulate **OR** Cycle, **as directed**, valve to maintain temperature.
    c. Display:
       1) Room/area served.
       2) Room occupied/unoccupied.
       3) Room temperature indication.
       4) Room temperature set point.
       5) Room temperature set point, occupied.
       6) Room temperature set point, unoccupied.
       7) Control-valve position as percent open.
17. VAV, Terminal Air Units with Hydronic **OR** Steam, **as directed**, Coils:
    a. Occupancy:
       1) Input Device: Occupancy sensor.
       2) Output Device: DDC system binary output.
       3) Action: Report occupancy and enable occupied temperature set point.
          a) Occupied Temperature: 75 deg F (24 deg C).
          b) Unoccupied Temperature: 65 deg F (18 deg C).

b. Room Temperature:
   1) Input Device: Room thermostat **OR** Electronic temperature sensor, **as directed**.
   2) Output Device: Pneumatic **OR** Electronic, **as directed**, damper actuators and control-valve operators.
   3) Action: Modulate damper and valve to maintain temperature.
      a) Sequence damper from full open to minimum position, then valve from closed to fully open.

c. Display:
   1) Room/area served.
   2) Room occupied/unoccupied.
   3) Room temperature indication.
   4) Room temperature set point.
   5) Room temperature set point, occupied.
   6) Room temperature set point, unoccupied.
   7) Air-damper position as percent open.
   8) Control-valve position as percent open.

18. Dual-Duct, VAV, Terminal Air Units:

a. Occupancy:
   1) Input Device: Occupancy sensor.
   2) Output Device: DDC system binary output.
   3) Action: Report occupancy and enable occupied temperature set point.
      a) Occupied Temperature: 75 deg F (24 deg C).
      b) Unoccupied Temperature: 65 deg F (18 deg C).

b. Room Temperature:
   1) Input Device: Room thermostat **OR** Electronic temperature sensor, **as directed**.
   2) Output Device: Pneumatic **OR** Electronic, **as directed**, damper actuators.
   3) Action: Modulate dampers to maintain temperature.
      a) Sequence when space temperature is below set point: Close VAV damper to minimum position, open hot-deck dampers and close cold-deck dampers, then open VAV damper.
      b) Sequence when space temperature is above set point: Close VAV damper to minimum position, close hot-deck dampers and open cold-deck dampers, then open VAV damper.

c. Display:
   1) Room/area served.
   2) Room occupied/unoccupied.
   3) Room temperature indication.
   4) Room temperature set point.
   5) Room temperature set point, occupied.
   6) Room temperature set point, unoccupied.
   7) VAV damper position as percent open.
   8) Hot-deck damper position as percent open.
   9) Cold-deck damper position as percent open.

H. Ventilation Sequences

1. Combustion-Air, Makeup Unit Control, Electric: Start fan when served appliance burner starts; room thermostat sequences stages of heating.
2. Combustion-Air, Makeup Unit Control, Hydronic **OR** Steam, **as directed**: Start fan when served appliance burner starts; room thermostat cycles **OR** modulates, **as directed**, control valve.
3. Gravity Roof Ventilator: Occupancy sensor **OR** Room thermostat, **as directed**, opens dampers.
4. Exhaust Fan: Occupancy sensor **OR** Interlock with light switch **OR** Room thermostat, **as directed**, cycles fan.
5. Kitchen Exhaust Fan: Occupancy sensor starts fan and energizes makeup air unit.

1.2 PRODUCTS (Not Applicable)

1.3 EXECUTION (Not Applicable)

END OF SECTION 23 01 10 00

SECTION 23 01 10 00a - TESTING, ADJUSTING, AND BALANCING

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for testing, adjusting and balancing. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Balancing Air Systems:
1) Constant-volume air systems.
2) Dual-duct systems.
3) Variable-air-volume systems.
4) Multizone systems.
5) Induction-unit systems.
b. Balancing Hydronic Piping Systems:
1) Constant-flow hydronic systems.
2) Variable-flow hydronic systems.
3) Primary-secondary hydronic systems.

C. Definitions
1. AABC: Associated Air Balance Council.
2. NEBB: National Environmental Balancing Bureau.
3. TAB: Testing, adjusting, and balancing.
4. TABB: Testing, Adjusting, and Balancing Bureau.
5. TAB Specialist: An entity engaged to perform TAB Work.

D. Submittals
1. LEED Submittal:
a. Air-Balance Report for LEED Prerequisite EQ 1: Documentation of work performed for ASHRAE 62.1, Section 7.2.2, "Air Balancing."
2. Strategies and Procedures Plan: Within 30 **OR** 60 **OR** 90, **as directed**, days of Contractor's Notice to Proceed, submit TAB strategies and step-by-step procedures as specified in "Preparation" Article.
3. Certified TAB reports.

E. Quality Assurance
1. TAB Contractor Qualifications: Engage a TAB entity certified by AABC **OR** NEBB **OR** TABB, **as directed**.
a. TAB Field Supervisor: Employee of the TAB contractor and certified by AABC **OR** NEBB **OR** TABB, **as directed**.
b. TAB Technician: Employee of the TAB contractor and who is certified by AABC **OR** NEBB **OR** TABB, **as directed**, as a TAB technician.
2. Certify TAB field data reports and perform the following:
a. Review field data reports to validate accuracy of data and to prepare certified TAB reports.
b. Certify that the TAB team complied with the approved TAB plan and the procedures specified and referenced in this Specification.
3. TAB Report Forms: Use standard TAB contractor's forms approved by the Owner **OR** Commissioning Authority, **as directed**.
4. Instrumentation Type, Quantity, Accuracy, and Calibration: As described in ASHRAE 111, Section 5, "Instrumentation."

F. Project Conditions

1. Full the Owner Occupancy: the Owner will occupy the site and existing building during entire TAB period. Cooperate with the Owner during TAB operations to minimize conflicts with the Owner's operations.

   OR

   Partial the Owner Occupancy: the Owner may occupy completed areas of building before Final Completion. Cooperate with the Owner during TAB operations to minimize conflicts with the Owner's operations.

1.2 PRODUCTS (Not Applicable)

1.3 EXECUTION

A. Examination

1. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems' designs that may preclude proper TAB of systems and equipment.
2. Examine systems for installed balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers. Verify that locations of these balancing devices are accessible.
3. Examine the approved submittals for HVAC systems and equipment.
4. Examine design data including HVAC system descriptions, statements of design assumptions for environmental conditions and systems' output, and statements of philosophies and assumptions about HVAC system and equipment controls.
5. Examine ceiling plenums and underfloor air plenums used for supply, return, or relief air to verify that they meet the leakage class of connected ducts as specified in Division 23 Section(s) "Metal Ducts" OR "Nonmetal Ducts", **as directed**, and are properly separated from adjacent areas. Verify that penetrations in plenum walls are sealed and fire-stopped if required.
6. Examine equipment performance data including fan and pump curves.
   a. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.
   b. Calculate system-effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from the conditions used to rate equipment performance. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," or in SMACNA's "HVAC Systems - Duct Design." Compare results with the design data and installed conditions.
7. Examine system and equipment installations and verify that field quality-control testing, cleaning, and adjusting specified in individual Sections have been performed.
8. Examine test reports specified in individual system and equipment Sections.
9. Examine HVAC equipment and filters and verify that bearings are greased, belts are aligned and tight, and equipment with functioning controls is ready for operation.
10. Examine terminal units, such as variable-air-volume boxes, and verify that they are accessible and their controls are connected and functioning.
11. Examine strainers. Verify that startup screens are replaced by permanent screens with indicated perforations.
12. Examine three-way valves for proper installation for their intended function of diverting or mixing fluid flows.
13. Examine heat-transfer coils for correct piping connections and for clean and straight fins.
14. Examine system pumps to ensure absence of entrained air in the suction piping.
15. Examine operating safety interlocks and controls on HVAC equipment.
16. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

B. Preparation
1. Prepare a TAB plan that includes strategies and step-by-step procedures.
2. Complete system-readiness checks and prepare reports. Verify the following:
   a. Permanent electrical-power wiring is complete.
   b. Hydronic systems are filled, clean, and free of air.
   c. Automatic temperature-control systems are operational.
   d. Equipment and duct access doors are securely closed.
   e. Balance, smoke, and fire dampers are open.
   f. Isolating and balancing valves are open and control valves are operational.
   g. Ceilings are installed in critical areas where air-pattern adjustments are required and access to balancing devices is provided.
   h. Windows and doors can be closed so indicated conditions for system operations can be met.

C. General Procedures For Testing And Balancing
1. Perform testing and balancing procedures on each system according to the procedures contained in AABC's "National Standards for Total System Balance" **OR** ASHRAE 111 **OR** NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems" **OR** SMACNA's "HVAC Systems - Testing, Adjusting, and Balancing", **as directed**, and in this Section.
   a. Comply with requirements in ASHRAE 62.1, Section 7.2.2, "Air Balancing."
2. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary for TAB procedures.
   a. After testing and balancing, patch probe holes in ducts with same material and thickness as used to construct ducts.
      OR
      After testing and balancing, install test ports and duct access doors that comply with requirements in Division 23 Section "Air Duct Accessories".
   b. Install and join new insulation that matches removed materials. Restore insulation, coverings, vapor barrier, and finish according to Division 23 Section "Hvac Insulation".
3. Mark equipment and balancing devices, including damper-control positions, valve position indicators, fan-speed-control levers, and similar controls and devices, with paint or other suitable, permanent identification material to show final settings.
4. Take and report testing and balancing measurements in inch-pound (IP) **OR** metric (SI) **OR** inch-pound (IP) and metric (SI), **as directed,** units.

D. General Procedures For Balancing Air Systems
1. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Crosscheck the summation of required outlet volumes with required fan volumes.
2. Prepare schematic diagrams of systems' "as-built" duct layouts.
3. For variable-air-volume systems, develop a plan to simulate diversity.
4. Determine the best locations in main and branch ducts for accurate duct-airflow measurements.
5. Check airflow patterns from the outdoor-air louvers and dampers and the return- and exhaust-air dampers through the supply-fan discharge and mixing dampers.
6. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.
7. Verify that motor starters are equipped with properly sized thermal protection.
8. Check dampers for proper position to achieve desired airflow path.
9. Check for airflow blockages.
10. Check condensate drains for proper connections and functioning.
11. Check for proper sealing of air-handling-unit components.
12. Verify that air duct system is sealed as specified in Division 23 Section "Metal Ducts".

E. Procedures For Constant-Volume Air Systems
1. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

a. Measure total airflow.
   1) Where sufficient space in ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow.
b. Measure fan static pressures as follows to determine actual static pressure:
   1) Measure outlet static pressure as far downstream from the fan as practical and upstream from restrictions in ducts such as elbows and transitions.
   2) Measure static pressure directly at the fan outlet or through the flexible connection.
   3) Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from the flexible connection, and downstream from duct restrictions.
   4) Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.
c. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and -treating equipment.
   1) Report the cleanliness status of filters and the time static pressures are measured.
d. Measure static pressures entering and leaving other devices, such as sound traps, heat-recovery equipment, and air washers, under final balanced conditions.
e. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.
f. Obtain approval from the Owner **OR** Commissioning Authority, **as directed**, for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in Division 21 for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.
g. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload will occur. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

2. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows within specified tolerances.
   a. Measure airflow of submain and branch ducts.
      1) Where sufficient space in submain and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow for that zone.
   b. Measure static pressure at a point downstream from the balancing damper, and adjust volume dampers until the proper static pressure is achieved.
   c. Remeasure each submain and branch duct after all have been adjusted. Continue to adjust submain and branch ducts to indicated airflows within specified tolerances.
3. Measure air outlets and inlets without making adjustments.
   a. Measure terminal outlets using a direct-reading hood or outlet manufacturer's written instructions and calculating factors.
4. Adjust air outlets and inlets for each space to indicated airflows within specified tolerances of indicated values. Make adjustments using branch volume dampers rather than extractors and the dampers at air terminals.
   a. Adjust each outlet in same room or space to within specified tolerances of indicated quantities without generating noise levels above the limitations prescribed by the Contract Documents.
   b. Adjust patterns of adjustable outlets for proper distribution without drafts.

F. Procedures For Dual-Duct Systems
   1. Verify that the cooling coil is capable of full-system airflow, and set mixing boxes at full-cold airflow position for fan volume.

2. Measure static pressure in both hot and cold ducts at the end of the longest duct run to determine that sufficient static pressure exists to operate controls of mixing boxes and to overcome resistance in the ducts and outlets downstream from mixing boxes.
   a. If insufficient static pressure exists, increase airflow at the fan.
3. Test and adjust the constant-volume mixing boxes as follows:
   a. Verify both hot and cold operations by adjusting the thermostat and observing changes in air temperature and volume.
   b. Verify sufficient inlet static pressure before making volume adjustments.
   c. Adjust mixing boxes to indicated airflows within specified tolerances. Measure airflow by Pitot-tube traverse readings or by measuring static pressure at mixing-box taps if provided by mixing-box manufacturer.
4. Do not overpressurize ducts.
5. Remeasure static pressure in both hot and cold ducts at the end of the longest duct run to determine that sufficient static pressure exists to operate controls of mixing boxes and to overcome resistance in the ducts and outlets downstream from mixing boxes.
6. Adjust variable-air-volume, dual-duct systems in the same way as constant-volume, dual-duct systems; adjust maximum- and minimum-airflow setting of each mixing box.

G. Procedures For Variable-Air-Volume Systems
1. Compensating for Diversity: When the total airflow of all terminal units is more than the indicated airflow of the fan, place a selected number of terminal units at a minimum set-point airflow with the remainder at maximum-airflow condition until the total airflow of the terminal units equals the indicated airflow of the fan. Select the reduced-airflow terminal units so they are distributed evenly among the branch ducts.
2. Pressure-Independent, Variable-Air-Volume Systems: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:
   a. Set outdoor-air dampers at minimum, and set return- and exhaust-air dampers at a position that simulates full-cooling load.
   b. Select the terminal unit that is most critical to the supply-fan airflow and static pressure. Measure static pressure. Adjust system static pressure so the entering static pressure for the critical terminal unit is not less than the sum of the terminal-unit manufacturer's recommended minimum inlet static pressure plus the static pressure needed to overcome terminal-unit discharge system losses.
   c. Measure total system airflow. Adjust to within indicated airflow.
   d. Set terminal units at maximum airflow and adjust controller or regulator to deliver the designed maximum airflow. Use terminal-unit manufacturer's written instructions to make this adjustment. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.
   e. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow the same as described for constant-volume air systems.
      1) If air outlets are out of balance at minimum airflow, report the condition but leave outlets balanced for maximum airflow.
   f. Remeasure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.
      1) Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.
   g. Measure static pressure at the most critical terminal unit and adjust the static-pressure controller at the main supply-air sensing station to ensure that adequate static pressure is maintained at the most critical unit.
   h. Record final fan-performance data.
3. Pressure-Dependent, Variable-Air-Volume Systems without Diversity: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:
   a. Balance variable-air-volume systems the same as described for constant-volume air systems.
   b. Set terminal units and supply fan at full-airflow condition.

c. Adjust inlet dampers of each terminal unit to indicated airflow and verify operation of the static-pressure controller. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.
d. Readjust fan airflow for final maximum readings.
e. Measure operating static pressure at the sensor that controls the supply fan if one is installed, and verify operation of the static-pressure controller.
f. Set supply fan at minimum airflow if minimum airflow is indicated. Measure static pressure to verify that it is being maintained by the controller.
g. Set terminal units at minimum airflow and adjust controller or regulator to deliver the designed minimum airflow. Check air outlets for a proportional reduction in airflow the same as described for constant-volume air systems.
    1) If air outlets are out of balance at minimum airflow, report the condition but leave the outlets balanced for maximum airflow.
h. Measure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow.
    1) Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.

4. Pressure-Dependent, Variable-Air-Volume Systems with Diversity: After the fan systems have been adjusted, adjust the variable-air-volume systems as follows:
    a. Set system at maximum indicated airflow by setting the required number of terminal units at minimum airflow. Select the reduced-airflow terminal units so they are distributed evenly among the branch ducts.
    b. Adjust supply fan to maximum indicated airflow with the variable-airflow controller set at maximum airflow.
    c. Set terminal units at full-airflow condition.
    d. Adjust terminal units starting at the supply-fan end of the system and continuing progressively to the end of the system. Adjust inlet dampers of each terminal unit to indicated airflow. When total airflow is correct, balance the air outlets downstream from terminal units the same as described for constant-volume air systems.
    e. Adjust terminal units for minimum airflow.
    f. Measure static pressure at the sensor.
    g. Measure the return airflow to the fan while operating at maximum return airflow and minimum outdoor airflow. Adjust the fan and balance the return-air ducts and inlets the same as described for constant-volume air systems.

H. Procedures For Multizone Systems
1. Set unit at maximum airflow through the cooling coil.
2. Adjust each zone's balancing damper to achieve indicated airflow within the zone.

I. Procedures For Induction-Unit Systems
1. Balance primary-air risers by measuring static pressure at the nozzles of the top and bottom units of each riser to determine which risers must be throttled. Adjust risers to indicated airflow within specified tolerances.
2. Adjust each induction unit.

J. General Procedures For Hydronic Systems
1. Prepare test reports with pertinent design data, and number in sequence starting at pump to end of system. Check the sum of branch-circuit flows against the approved pump flow rate. Correct variations that exceed plus or minus 5 percent.
2. Prepare schematic diagrams of systems' "as-built" piping layouts.
3. Prepare hydronic systems for testing and balancing according to the following, in addition to the general preparation procedures specified above:
    a. Open all manual valves for maximum flow.
    b. Check liquid level in expansion tank.
    c. Check makeup water-station pressure gage for adequate pressure for highest vent.

d. Check flow-control valves for specified sequence of operation, and set at indicated flow.
e. Set differential-pressure control valves at the specified differential pressure. Do not set at fully closed position when pump is positive-displacement type unless several terminal valves are kept open.
f. Set system controls so automatic valves are wide open to heat exchangers.
g. Check pump-motor load. If motor is overloaded, throttle main flow-balancing device so motor nameplate rating is not exceeded.
h. Check air vents for a forceful liquid flow exiting from vents when manually operated.

K. Procedures For Constant-Flow Hydronic Systems
1. Measure water flow at pumps. Use the following procedures except for positive-displacement pumps:
a. Verify impeller size by operating the pump with the discharge valve closed. Read pressure differential across the pump. Convert pressure to head and correct for differences in gage heights. Note the point on manufacturer's pump curve at zero flow and verify that the pump has the intended impeller size.
1) If impeller sizes must be adjusted to achieve pump performance, obtain approval from the Owner **OR** Commissioning Authority, **as directed**, and comply with requirements in Division 23 Section "Hydronic Pumps".
b. Check system resistance. With all valves open, read pressure differential across the pump and mark pump manufacturer's head-capacity curve. Adjust pump discharge valve until indicated water flow is achieved.
1) Monitor motor performance during procedures and do not operate motors in overload conditions.
c. Verify pump-motor brake horsepower. Calculate the intended brake horsepower for the system based on pump manufacturer's performance data. Compare calculated brake horsepower with nameplate data on the pump motor. Report conditions where actual amperage exceeds motor nameplate amperage.
d. Report flow rates that are not within plus or minus 10 percent of design.
2. Measure flow at all automatic flow control valves to verify that valves are functioning as designed.
3. Measure flow at all pressure-independent characterized control valves, with valves in fully open position, to verify that valves are functioning as designed.
4. Set calibrated balancing valves, if installed, at calculated presettings.
5. Measure flow at all stations and adjust, where necessary, to obtain first balance.
a. System components that have Cv rating or an accurately cataloged flow-pressure-drop relationship may be used as a flow-indicating device.
6. Measure flow at main balancing station and set main balancing device to achieve flow that is 5 percent greater than indicated flow.
7. Adjust balancing stations to within specified tolerances of indicated flow rate as follows:
a. Determine the balancing station with the highest percentage over indicated flow.
b. Adjust each station in turn, beginning with the station with the highest percentage over indicated flow and proceeding to the station with the lowest percentage over indicated flow.
c. Record settings and mark balancing devices.
8. Measure pump flow rate and make final measurements of pump amperage, voltage, rpm, pump heads, and systems' pressures and temperatures including outdoor-air temperature.
9. Measure the differential-pressure-control-valve settings existing at the conclusion of balancing.
10. Check settings and operation of each safety valve. Record settings.

L. Procedures For Variable-Flow Hydronic Systems
1. Balance systems with automatic two- and three-way control valves by setting systems at maximum flow through heat-exchange terminals and proceed as specified above for hydronic systems.

M. Procedures For Primary-Secondary Hydronic Systems
1. Balance the primary circuit flow first and then balance the secondary circuits.

N. Procedures For Steam Systems
1. Measure and record upstream and downstream pressure of each piece of equipment.
2. Measure and record upstream and downstream steam pressure of pressure-reducing valves.
3. Check settings and operation of automatic temperature-control valves, self-contained control valves, and pressure-reducing valves. Record final settings.
4. Check settings and operation of each safety valve. Record settings.
5. Verify the operation of each steam trap.

O. Procedures For Heat Exchangers
1. Measure water flow through all circuits.
2. Adjust water flow to within specified tolerances.
3. Measure inlet and outlet water temperatures.
4. Measure inlet steam pressure.
5. Check settings and operation of safety and relief valves. Record settings.

P. Procedures For Motors
1. Motors, 1/2 HP and Larger: Test at final balanced conditions and record the following data:
   a. Manufacturer's name, model number, and serial number.
   b. Motor horsepower rating.
   c. Motor rpm.
   d. Efficiency rating.
   e. Nameplate and measured voltage, each phase.
   f. Nameplate and measured amperage, each phase.
   g. Starter thermal-protection-element rating.
2. Motors Driven by Variable-Frequency Controllers: Test for proper operation at speeds varying from minimum to maximum. Test the manual bypass of the controller to prove proper operation. Record observations including name of controller manufacturer, model number, serial number, and nameplate data.

Q. Procedures For Chillers
1. Balance water flow through each evaporator and condenser, **as directed**, to within specified tolerances of indicated flow with all pumps operating. With only one chiller operating in a multiple chiller installation, do not exceed the flow for the maximum tube velocity recommended by the chiller manufacturer. Measure and record the following data with each chiller operating at design conditions:
   a. Evaporator-water entering and leaving temperatures, pressure drop, and water flow.
   b. For water-cooled chillers, condenser-water entering and leaving temperatures, pressure drop, and water flow.
   c. Evaporator and condenser refrigerant temperatures and pressures, using instruments furnished by chiller manufacturer.
   d. Power factor if factory-installed instrumentation is furnished for measuring kilowatts.
   e. Kilowatt input if factory-installed instrumentation is furnished for measuring kilowatts.
   f. Capacity: Calculate in tons of cooling.
   g. For air-cooled chillers, verify condenser-fan rotation and record fan and motor data including number of fans and entering- and leaving-air temperatures.

R. Procedures For Cooling Towers
1. Shut off makeup water for the duration of the test, and verify that makeup and blowdown systems are fully operational after tests and before leaving the equipment. Perform the following tests and record the results:
   a. Measure condenser-water flow to each cell of the cooling tower.
   b. Measure entering- and leaving-water temperatures.
   c. Measure wet- and dry-bulb temperatures of entering air.
   d. Measure wet- and dry-bulb temperatures of leaving air.
   e. Measure condenser-water flow rate recirculating through the cooling tower.

f. Measure cooling-tower spray pump discharge pressure.
g. Adjust water level and feed rate of makeup water system.
h. Measure flow through bypass.

S. Procedures For Condensing Units
1. Verify proper rotation of fans.
2. Measure entering- and leaving-air temperatures.
3. Record compressor data.

T. Procedures For Boilers
1. Hydronic Boilers: Measure and record entering- and leaving-water temperatures and water flow.
2. Steam Boilers: Measure and record entering-water temperature and flow and leaving-steam pressure, temperature, and flow.

U. Procedures For Heat-Transfer Coils
1. Measure, adjust, and record the following data for each water coil:
a. Entering- and leaving-water temperature.
b. Water flow rate.
c. Water pressure drop.
d. Dry-bulb temperature of entering and leaving air.
e. Wet-bulb temperature of entering and leaving air for cooling coils.
f. Airflow.
g. Air pressure drop.
2. Measure, adjust, and record the following data for each electric heating coil:
a. Nameplate data.
b. Airflow.
c. Entering- and leaving-air temperature at full load.
d. Voltage and amperage input of each phase at full load and at each incremental stage.
e. Calculated kilowatt at full load.
f. Fuse or circuit-breaker rating for overload protection.
3. Measure, adjust, and record the following data for each steam coil:
a. Dry-bulb temperature of entering and leaving air.
b. Airflow.
c. Air pressure drop.
d. Inlet steam pressure.
4. Measure, adjust, and record the following data for each refrigerant coil:
a. Dry-bulb temperature of entering and leaving air.
b. Wet-bulb temperature of entering and leaving air.
c. Airflow.
d. Air pressure drop.
e. Refrigerant suction pressure and temperature.

V. Procedures For Testing, Adjusting, And Balancing Existing Systems
1. Perform a preconstruction inspection of existing equipment that is to remain and be reused.
a. Measure and record the operating speed, airflow, and static pressure of each fan.
b. Measure motor voltage and amperage. Compare the values to motor nameplate information.
c. Check the refrigerant charge.
d. Check the condition of filters.
e. Check the condition of coils.
f. Check the operation of the drain pan and condensate-drain trap.
g. Check bearings and other lubricated parts for proper lubrication.
h. Report on the operating condition of the equipment and the results of the measurements taken. Report deficiencies.

2. Before performing testing and balancing of existing systems, inspect existing equipment that is to remain and be reused to verify that existing equipment has been cleaned and refurbished. Verify the following:
   a. New filters are installed.
   b. Coils are clean and fins combed.
   c. Drain pans are clean.
   d. Fans are clean.
   e. Bearings and other parts are properly lubricated.
   f. Deficiencies noted in the preconstruction report are corrected.
3. Perform testing and balancing of existing systems to the extent that existing systems are affected by the renovation work.
   a. Compare the indicated airflow of the renovated work to the measured fan airflows, and determine the new fan speed and the face velocity of filters and coils.
   b. Verify that the indicated airflows of the renovated work result in filter and coil face velocities and fan speeds that are within the acceptable limits defined by equipment manufacturer.
   c. If calculations increase or decrease the air flow rates and water flow rates by more than 5 percent, make equipment adjustments to achieve the calculated rates. If increase or decrease is 5 percent or less, equipment adjustments are not required.
   d. Balance each air outlet.

W. Tolerances

X. Set HVAC system's air flow rates and water flow rates within the following tolerances:
   a. Supply, Return, and Exhaust Fans and Equipment with Fans: Plus or minus 10 percent.
   b. Air Outlets and Inlets: Plus or minus 10 percent.
   c. Heating-Water Flow Rate: Plus or minus 10 percent.
   d. Cooling-Water Flow Rate: Plus or minus 10 percent.

Y. Reporting
1. Initial Construction-Phase Report: Based on examination of the Contract Documents as specified in "Examination" Article, prepare a report on the adequacy of design for systems' balancing devices. Recommend changes and additions to systems' balancing devices to facilitate proper performance measuring and balancing. Recommend changes and additions to HVAC systems and general construction to allow access for performance measuring and balancing devices.
2. Status Reports: Prepare weekly **OR** biweekly **OR** monthly, **as directed**, progress reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.

Z. Final Report
1. General: Prepare a certified written report; tabulate and divide the report into separate sections for tested systems and balanced systems.
   a. Include a certification sheet at the front of the report's binder, signed and sealed by the certified testing and balancing engineer.
   b. Include a list of instruments used for procedures, along with proof of calibration.
2. Final Report Contents: In addition to certified field-report data, include the following:
   a. Pump curves.
   b. Fan curves.
   c. Manufacturers' test data.
   d. Field test reports prepared by system and equipment installers.
   e. Other information relative to equipment performance; do not include Shop Drawings and product data.
3. General Report Data: In addition to form titles and entries, include the following data:
   a. Title page.
   b. Name and address of the TAB contractor.

c. Project name.
d. Project location.
e. Architect's name and address.
f. Engineer's name and address.
g. Contractor's name and address.
h. Report date.
i. Signature of TAB supervisor who certifies the report.
j. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
k. Summary of contents including the following:
   1) Indicated versus final performance.
   2) Notable characteristics of systems.
   3) Description of system operation sequence if it varies from the Contract Documents.
l. Nomenclature sheets for each item of equipment.
m. Data for terminal units, including manufacturer's name, type, size, and fittings.
n. Notes to explain why certain final data in the body of reports vary from indicated values.
o. Test conditions for fans and pump performance forms including the following:
   1) Settings for outdoor-, return-, and exhaust-air dampers.
   2) Conditions of filters.
   3) Cooling coil, wet- and dry-bulb conditions.
   4) Face and bypass damper settings at coils.
   5) Fan drive settings including settings and percentage of maximum pitch diameter.
   6) Inlet vane settings for variable-air-volume systems.
   7) Settings for supply-air, static-pressure controller.
   8) Other system operating conditions that affect performance.

4. System Diagrams: Include schematic layouts of air and hydronic distribution systems. Present each system with single-line diagram and include the following:
   a. Quantities of outdoor, supply, return, and exhaust airflows.
   b. Water and steam flow rates.
   c. Duct, outlet, and inlet sizes.
   d. Pipe and valve sizes and locations.
   e. Terminal units.
   f. Balancing stations.
   g. Position of balancing devices.
5. Air-Handling-Unit Test Reports: For air-handling units with coils, include the following:
   a. Unit Data:
      1) Unit identification.
      2) Location.
      3) Make and type.
      4) Model number and unit size.
      5) Manufacturer's serial number.
      6) Unit arrangement and class.
      7) Discharge arrangement.
      8) Sheave make, size in inches (mm), and bore.
      9) Center-to-center dimensions of sheave, and amount of adjustments in inches (mm).
      10) Number, make, and size of belts.
      11) Number, type, and size of filters.
   b. Motor Data:
      1) Motor make, and frame type and size.
      2) Horsepower and rpm.
      3) Volts, phase, and hertz.
      4) Full-load amperage and service factor.
      5) Sheave make, size in inches (mm), and bore.
      6) Center-to-center dimensions of sheave, and amount of adjustments in inches (mm).
   c. Test Data (Indicated and Actual Values):
      1) Total air flow rate in cfm (L/s).

2) Total system static pressure in inches wg (Pa).
3) Fan rpm.
4) Discharge static pressure in inches wg (Pa).
5) Filter static-pressure differential in inches wg (Pa).
6) Preheat-coil static-pressure differential in inches wg (Pa).
7) Cooling-coil static-pressure differential in inches wg (Pa).
8) Heating-coil static-pressure differential in inches wg (Pa).
9) Outdoor airflow in cfm (L/s).
10) Return airflow in cfm (L/s).
11) Outdoor-air damper position.
12) Return-air damper position.
13) Vortex damper position.

6. Apparatus-Coil Test Reports:
   a. Coil Data:
      1) System identification.
      2) Location.
      3) Coil type.
      4) Number of rows.
      5) Fin spacing in fins per inch (mm) o.c.
      6) Make and model number.
      7) Face area in sq. ft. (sq. m).
      8) Tube size in NPS (DN).
      9) Tube and fin materials.
      10) Circuiting arrangement.
   b. Test Data (Indicated and Actual Values):
      1) Air flow rate in cfm (L/s).
      2) Average face velocity in fpm (m/s).
      3) Air pressure drop in inches wg (Pa).
      4) Outdoor-air, wet- and dry-bulb temperatures in deg F (deg C).
      5) Return-air, wet- and dry-bulb temperatures in deg F (deg C).
      6) Entering-air, wet- and dry-bulb temperatures in deg F (deg C).
      7) Leaving-air, wet- and dry-bulb temperatures in deg F (deg C).
      8) Water flow rate in gpm (L/s).
      9) Water pressure differential in feet of head or psig (kPa).
      10) Entering-water temperature in deg F (deg C).
      11) Leaving-water temperature in deg F (deg C).
      12) Refrigerant expansion valve and refrigerant types.
      13) Refrigerant suction pressure in psig (kPa).
      14) Refrigerant suction temperature in deg F (deg C).
      15) Inlet steam pressure in psig (kPa).
7. Gas- and Oil-Fired Heat Apparatus Test Reports: In addition to manufacturer's factory startup equipment reports, include the following:
   a. Unit Data:
      1) System identification.
      2) Location.
      3) Make and type.
      4) Model number and unit size.
      5) Manufacturer's serial number.
      6) Fuel type in input data.
      7) Output capacity in Btu/h (kW).
      8) Ignition type.
      9) Burner-control types.
      10) Motor horsepower and rpm.
      11) Motor volts, phase, and hertz.
      12) Motor full-load amperage and service factor.

13) Sheave make, size in inches (mm), and bore.
14) Center-to-center dimensions of sheave, and amount of adjustments in inches (mm).

b. Test Data (Indicated and Actual Values):
1) Total air flow rate in cfm (L/s).
2) Entering-air temperature in deg F (deg C).
3) Leaving-air temperature in deg F (deg C).
4) Air temperature differential in deg F (deg C).
5) Entering-air static pressure in inches wg (Pa).
6) Leaving-air static pressure in inches wg (Pa).
7) Air static-pressure differential in inches wg (Pa).
8) Low-fire fuel input in Btu/h (kW).
9) High-fire fuel input in Btu/h (kW).
10) Manifold pressure in psig (kPa).
11) High-temperature-limit setting in deg F (deg C).
12) Operating set point in Btu/h (kW).
13) Motor voltage at each connection.
14) Motor amperage for each phase.
15) Heating value of fuel in Btu/h (kW).

8. Electric-Coil Test Reports: For electric furnaces, duct coils, and electric coils installed in central-station air-handling units, include the following:
a. Unit Data:
1) System identification.
2) Location.
3) Coil identification.
4) Capacity in Btu/h (kW).
5) Number of stages.
6) Connected volts, phase, and hertz.
7) Rated amperage.
8) Air flow rate in cfm (L/s).
9) Face area in sq. ft. (sq. m).
10) Minimum face velocity in fpm (m/s).

b. Test Data (Indicated and Actual Values):
1) Heat output in Btu/h (kW).
2) Air flow rate in cfm (L/s).
3) Air velocity in fpm (m/s).
4) Entering-air temperature in deg F (deg C).
5) Leaving-air temperature in deg F (deg C).
6) Voltage at each connection.
7) Amperage for each phase.

9. Fan Test Reports: For supply, return, and exhaust fans, include the following:
a. Fan Data:
1) System identification.
2) Location.
3) Make and type.
4) Model number and size.
5) Manufacturer's serial number.
6) Arrangement and class.
7) Sheave make, size in inches (mm), and bore.
8) Center-to-center dimensions of sheave, and amount of adjustments in inches (mm).

b. Motor Data:
1) Motor make, and frame type and size.
2) Horsepower and rpm.
3) Volts, phase, and hertz.
4) Full-load amperage and service factor.
5) Sheave make, size in inches (mm), and bore.
6) Center-to-center dimensions of sheave, and amount of adjustments in inches (mm).

7) Number, make, and size of belts.

c. Test Data (Indicated and Actual Values):
1) Total airflow rate in cfm (L/s).
2) Total system static pressure in inches wg (Pa).
3) Fan rpm.
4) Discharge static pressure in inches wg (Pa).
5) Suction static pressure in inches wg (Pa).

10. Round, Flat-Oval, and Rectangular Duct Traverse Reports: Include a diagram with a grid representing the duct cross-section and record the following:
a. Report Data:
1) System and air-handling-unit number.
2) Location and zone.
3) Traverse air temperature in deg F (deg C).
4) Duct static pressure in inches wg (Pa).
5) Duct size in inches (mm).
6) Duct area in sq. ft. (sq. m).
7) Indicated air flow rate in cfm (L/s).
8) Indicated velocity in fpm (m/s).
9) Actual air flow rate in cfm (L/s).
10) Actual average velocity in fpm (m/s).
11) Barometric pressure in psig (Pa).

11. Air-Terminal-Device Reports:
a. Unit Data:
1) System and air-handling unit identification.
2) Location and zone.
3) Apparatus used for test.
4) Area served.
5) Make.
6) Number from system diagram.
7) Type and model number.
8) Size.
9) Effective area in sq. ft. (sq. m).
b. Test Data (Indicated and Actual Values):
1) Air flow rate in cfm (L/s).
2) Air velocity in fpm (m/s).
3) Preliminary air flow rate as needed in cfm (L/s).
4) Preliminary velocity as needed in fpm (m/s).
5) Final air flow rate in cfm (L/s).
6) Final velocity in fpm (m/s).
7) Space temperature in deg F (deg C).

12. System-Coil Reports: For reheat coils and water coils of terminal units, include the following:
a. Unit Data:
1) System and air-handling-unit identification.
2) Location and zone.
3) Room or riser served.
4) Coil make and size.
5) Flowmeter type.
b. Test Data (Indicated and Actual Values):
1) Air flow rate in cfm (L/s).
2) Entering-water temperature in deg F (deg C).
3) Leaving-water temperature in deg F (deg C).
4) Water pressure drop in feet of head or psig (kPa).
5) Entering-air temperature in deg F (deg C).
6) Leaving-air temperature in deg F (deg C).

13. Pump Test Reports: Calculate impeller size by plotting the shutoff head on pump curves and include the following:
    a. Unit Data:
        1) Unit identification.
        2) Location.
        3) Service.
        4) Make and size.
        5) Model number and serial number.
        6) Water flow rate in gpm (L/s).
        7) Water pressure differential in feet of head or psig (kPa).
        8) Required net positive suction head in feet of head or psig (kPa).
        9) Pump rpm.
        10) Impeller diameter in inches (mm).
        11) Motor make and frame size.
        12) Motor horsepower and rpm.
        13) Voltage at each connection.
        14) Amperage for each phase.
        15) Full-load amperage and service factor.
        16) Seal type.
    b. Test Data (Indicated and Actual Values):
        1) Static head in feet of head or psig (kPa).
        2) Pump shutoff pressure in feet of head or psig (kPa).
        3) Actual impeller size in inches (mm).
        4) Full-open flow rate in gpm (L/s).
        5) Full-open pressure in feet of head or psig (kPa).
        6) Final discharge pressure in feet of head or psig (kPa).
        7) Final suction pressure in feet of head or psig (kPa).
        8) Final total pressure in feet of head or psig (kPa).
        9) Final water flow rate in gpm (L/s).
        10) Voltage at each connection.
        11) Amperage for each phase.
14. Instrument Calibration Reports:
    a. Report Data:
        1) Instrument type and make.
        2) Serial number.
        3) Application.
        4) Dates of use.
        5) Dates of calibration.

AA. Inspections
1. Initial Inspection:
    a. After testing and balancing are complete, operate each system and randomly check measurements to verify that the system is operating according to the final test and balance readings documented in the final report.
    b. Check the following for each system:
        1) Measure airflow of at least 10 percent of air outlets.
        2) Measure water flow of at least 5 percent of terminals.
        3) Measure room temperature at each thermostat/temperature sensor. Compare the reading to the set point.
        4) Verify that balancing devices are marked with final balance position.
        5) Note deviations from the Contract Documents in the final report.
2. Final Inspection:
    a. After initial inspection is complete and documentation by random checks verifies that testing and balancing are complete and accurately documented in the final report, request that a final inspection be made by the Owner **OR** Commissioning Authority, **as directed**.

b. The TAB contractor's test and balance engineer shall conduct the inspection in the presence of the Owner **OR** Commissioning Authority, **as directed**.

c. the Owner **OR** Commissioning Authority, **as directed**, shall randomly select measurements, documented in the final report, to be rechecked. Rechecking shall be limited to either 10 percent of the total measurements recorded or the extent of measurements that can be accomplished in a normal 8-hour business day.

d. If rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."

e. If the number of "FAILED" measurements is greater than 10 percent of the total measurements checked during the final inspection, the testing and balancing shall be considered incomplete and shall be rejected.

3. TAB Work will be considered defective if it does not pass final inspections. If TAB Work fails, proceed as follows:

a. Recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes; resubmit the final report and request a second final inspection.

b. If the second final inspection also fails, the Owner may contract the services of another TAB contractor to complete TAB Work according to the Contract Documents and deduct the cost of the services from the original TAB contractor's final payment.

4. Prepare test and inspection reports.

BB. Additional Tests

1. Within 90 days of completing TAB, perform additional TAB to verify that balanced conditions are being maintained throughout and to correct unusual conditions.

2. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional TAB during near-peak summer and winter conditions.

END OF SECTION 23 01 10 00a

Task	Specification	Specification Description
23 01 20 00	23 01 10 00	Sequence Of Operation
23 01 20 00	23 01 10 00a	Testing, Adjusting, And Balancing

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SECTION 23 01 30 51 - AIR DUCT CLEANING

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for HVAC air-distribution system cleaning. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section includes cleaning HVAC air-distribution equipment, ducts, plenums, and system components.

C. Definitions
1. ASCS: Air systems cleaning specialist.
2. NADCA: National Air Duct Cleaners Association.

D. Submittals
1. Qualification Data: For an ASCS.
2. Strategies and procedures plan.
3. Cleanliness verification report.

E. Quality Assurance
1. ASCS Qualifications: A certified member of NADCA.
   a. Certification: Employ an ASCS certified by NADCA on a full-time basis.
   b. Supervisor Qualifications: Certified as an ASCS by NADCA.
2. UL Compliance: Comply with UL 181 and UL 181A for fibrous-glass ducts.
3. Cleaning Conference: Conduct conference at Project site.

1.2 PRODUCTS (Not Used)

1.3 EXECUTION

A. Examination
1. Examine HVAC air-distribution equipment, ducts, plenums, and system components to determine appropriate methods, tools, and equipment required for performance of the Work.
2. Perform "Project Evaluation and Recommendation" according to NADCA ACR 2006.
3. Prepare written report listing conditions detrimental to performance of the Work.
4. Proceed with work only after unsatisfactory conditions have been corrected.

B. Preparation
1. Prepare a written plan that includes strategies and step-by-step procedures. At a minimum, include the following:
   a. Supervisor contact information.
   b. Work schedule including location, times, and impact on occupied areas.
   c. Methods and materials planned for each HVAC component type.
   d. Required support from other trades.
   e. Equipment and material storage requirements.
   f. Exhaust equipment setup locations.
2. Use the existing service openings, as required for proper cleaning, at various points of the HVAC system for physical and mechanical entry and for inspection.

3. Comply with NADCA ACR 2006, "Guidelines for Constructing Service Openings in HVAC Systems" Section.

C. Cleaning
1. Comply with NADCA ACR 2006.
2. Remove visible surface contaminants and deposits from within the HVAC system.
3. Systems and Components to Be Cleaned:
   a. Air devices for supply and return air.
   b. Air-terminal units.
   c. Ductwork:
      1) Supply-air ducts, including turning vanes and reheat coils, to the air-handling unit.
      2) Return-air ducts to the air-handling unit.
      3) Exhaust-air ducts.
   d. Air-Handling Units:
      1) Interior surfaces of the unit casing.
      2) Coil surfaces compartment.
      3) Condensate drain pans.
      4) Fans, fan blades, and fan housings.
   e. Filters and filter housings.
4. Collect debris removed during cleaning. Ensure that debris is not dispersed outside the HVAC system during the cleaning process.
5. Particulate Collection:
   a. For particulate collection equipment, include adequate filtration to contain debris removed. Locate equipment downwind and away from all air intakes and other points of entry into the building.
   b. HEPA filtration with 99.97 percent collection efficiency for particles sized 0.3 micrometer or larger shall be used where the particulate collection equipment is exhausting inside the building,
6. Control odors and mist vapors during the cleaning and restoration process.
7. Mark the position of manual volume dampers and air-directional mechanical devices inside the system prior to cleaning. Restore them to their marked position on completion of cleaning.
8. System components shall be cleaned so that all HVAC system components are visibly clean. On completion, all components must be returned to those settings recorded just prior to cleaning operations.
9. Clean all air-distribution devices, registers, grilles, and diffusers.
10. Clean visible surface contamination deposits according to NADCA ACR 2006 and the following:
    a. Clean air-handling units, airstream surfaces, components, condensate collectors, and drains.
    b. Ensure that a suitable operative drainage system is in place prior to beginning wash-down procedures.
    c. Clean evaporator coils, reheat coils, and other airstream components.
11. Duct Systems:
    a. Create service openings in the HVAC system as necessary to accommodate cleaning.
    b. Mechanically clean duct systems specified to remove all visible contaminants so that the systems are capable of passing the HVAC System Cleanliness Tests (see NADCA ACR 2006).
12. Debris removed from the HVAC system shall be disposed of according to applicable Federal, state, and local requirements.
13. Mechanical Cleaning Methodology:
    a. Source-Removal Cleaning Methods: The HVAC system shall be cleaned using source-removal mechanical cleaning methods designed to extract contaminants from within the HVAC system and to safely remove these contaminants from the facility. No cleaning method, or combination of methods, shall be used that could potentially damage components of the HVAC system or negatively alter the integrity of the system.

1) Use continuously operating vacuum-collection devices to keep each section being cleaned under negative pressure.
2) Cleaning methods that require mechanical agitation devices to dislodge debris that is adhered to interior surfaces of HVAC system components shall be equipped to safely remove these devices. Cleaning methods shall not damage the integrity of HVAC system components or damage porous surface materials such as duct and plenum liners.

b. Cleaning Mineral-Fiber Insulation Components:
1) Fibrous-glass thermal or acoustical insulation elements present in equipment or ductwork shall be thoroughly cleaned with HEPA vacuuming equipment while the HVAC system is under constant negative pressure and shall not be permitted to get wet according to NADCA ACR 2006.
2) Cleaning methods used shall not cause damage to fibrous-glass components and will render the system capable of passing the HVAC System Cleanliness Tests (see NADCA ACR 2006).
3) Fibrous materials that become wet shall be discarded and replaced.

14. Coil Cleaning:
a. Measure static-pressure differential across each coil.
b. See NADCA ACR 2006, "Coil Surface Cleaning" Section. Type 1, or Type 1 and Type 2, cleaning methods shall be used to render the coil visibly clean and capable of passing Coil Cleaning Verification (see applicable NADCA ACR 2006).
c. Coil drain pans shall be subject to NADCA ACR 2006, "Non-Porous Surfaces Cleaning Verification." Ensure that condensate drain pans are operational.
d. Electric-resistance coils shall be de-energized, locked out, and tagged before cleaning.
e. Cleaning methods shall not cause any appreciable damage to, cause displacement of, inhibit heat transfer, or cause erosion of the coil surface or fins, and shall comply with coil manufacturer's written recommendations when available.
f. Rinse thoroughly with clean water to remove any latent residues.

15. Antimicrobial Agents, Coatings, and Sanitizers:
a. Apply antimicrobial agents, coatings, and sanitizers if active fungal growth is reasonably suspected or where unacceptable levels of fungal contamination have been verified. Apply antimicrobial agents and coatings according to manufacturer's written recommendations and EPA registration listing after the removal of surface deposits and debris.
b. When used, antimicrobial treatments, coatings, and sanitizers shall be applied after the system is rendered clean.
c. Apply antimicrobial agents, coatings, and sanitizers directly onto surfaces of interior ductwork. Fogging is prohibited.
d. Sanitizing agent products shall be registered by the EPA as specifically intended for use in HVAC systems and ductwork.

D. Cleanliness Verification
1. Verify cleanliness according to NADCA ACR 2006, "Verification of HVAC System Cleanliness" Section.
2. Verify HVAC system cleanliness after mechanical cleaning and before applying any treatment or introducing any treatment-related substance to the HVAC system, including biocidal agents, coatings, and sanitizers.
3. Perform visual inspection for cleanliness. If no contaminants are evident through visual inspection, the HVAC system shall be considered clean. If visible contaminants are evident through visual inspection, those portions of the system where contaminants are visible shall be re-cleaned and subjected to re-inspection for cleanliness.
4. Additional Verification:
a. Perform surface comparison testing or NADCA vacuum test.
b. Conduct NADCA vacuum gravimetric test analysis for nonporous surfaces.
5. Verification of Coil Cleaning:
a. Measure static-pressure differential across each coil.

b. Coil will be considered clean if cleaning restored the coil static-pressure differential within 10 percent of <**Insert inches wg (Pa)**>, the differential measured when the coil was first installed.
OR
Coil will be considered clean if the coil is free of foreign matter and chemical residue, based on a thorough visual inspection.

6. Prepare a written cleanliness verification report. At a minimum, include the following:
   a. Written documentation of the success of the cleaning.
   b. Site inspection reports, initialed by supervisor, including notation on areas of inspection, as verified through visual inspection.
   c. Surface comparison test results if required.
   d. Gravimetric analysis (nonporous surfaces only).
   e. System areas found to be damaged.
7. Photographic Documentation: Comply with requirements listed in Scope of Work.

E. Restoration
1. Restore and repair HVAC air-distribution equipment, ducts, plenums, and components according to NADCA ACR 2006, "Restoration and Repair of Mechanical Systems" Section.
2. Restore service openings capable of future reopening. Comply with requirements in Division 23 Section "Metal Ducts". Include location of service openings in Project closeout report.
3. Replace fibrous-glass materials that cannot be restored by cleaning or resurfacing. Comply with requirements in Division 23 Section(s) "Metal Ducts" AND "Nonmetal Ducts"
4. Replace damaged insulation according to Division 23 Section "Hvac Insulation",
5. Ensure that closures do not hinder or alter airflow.
6. New closure materials, including insulation, shall match opened materials and shall have removable closure panels fitted with gaskets and fasteners.
7. Reseal fibrous-glass ducts. Comply with requirements in Division 23 Section "Nonmetal Ducts".

END OF SECTION 23 01 30 51

Task	Specification	Specification Description
23 01 30 51	23 01 10 00	Sequence Of Operation
23 01 30 51	23 01 10 00a	Testing, Adjusting, And Balancing

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SECTION 23 01 50 00 - CAST-IRON BOILERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for cast-iron boilers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes packaged cast-iron boilers, trim, and accessories for generating hot water or steam with the following configurations and burners:
a. Factory and Field assembled.
b. Atmospheric gas, Sealed-combustion, gas, Forced-draft, gas, Oil, and Combination gas and oil burner.

C. Submittals
1. Product Data: Include performance data, operating characteristics, furnished specialties, and accessories.
2. Shop Drawings: For boilers, boiler trim, and accessories. Include plans, elevations, sections, details, and attachments to other work.
a. Design calculations and vibration isolation base details, signed and sealed by a qualified professional engineer.
1) Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
2) Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails and equipment mounting frames.
b. Wiring Diagrams: Power, signal, and control wiring.
3. Manufacturer Seismic Qualification Certification: Submit certification that boiler, accessories, and components will withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment". Include the following:
4. Source quality-control test reports.
5. Field quality-control test reports.
6. Operation and maintenance data.
7. Warranty: Special warranty specified in this Section.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. ASME Compliance: Fabricate and label boilers to comply with ASME Boiler and Pressure Vessel Code.
3. ASHRAE/IESNA 90.1 Compliance: Boilers shall have minimum efficiency according to "Gas and Oil Fired Boilers - Minimum Efficiency Requirements."
4. DOE Compliance: Minimum efficiency shall comply with 10 CFR 430, Subpart B, Appendix N, "Uniform Test Method for Measuring the Energy Consumption of Furnaces and Boilers."
5. I=B=R Compliance: Boilers shall be tested and rated according to HI's "Rating Procedure for Heating Boilers" and "Testing Standard for Commercial Boilers," with I=B=R emblem on a nameplate affixed to boiler.
6. UL Compliance: Test boilers for compliance with UL 726, "Oil-Fired Boiler Assemblies **OR** UL 726, "Oil-Fired Boiler Assemblies," and UL 795, "Commercial-Industrial Gas Heating

Equipment **OR** UL 795, "Commercial-Industrial Gas Heating Equipment", **as directed**. Boilers shall be listed and labeled by a testing agency acceptable to authorities having jurisdiction.

E. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace controls and heat exchangers of boilers that fail in materials or workmanship within specified warranty period.
   a. Warranty Period for Controls: Two years from date of Final Completion.
   b. Warranty Period for Heat Exchangers: Five **OR** 10 **OR** 20, **as directed**, years from date of Final Completion.

1.2 PRODUCTS

A. Manufactured Units
1. Description: Factory fabricated and assembled **OR** field assembled, **as directed**.
   a. Cast-iron sections shall be sealed pressure tight and held together with tie rods set on an insulated steel base, **as directed**; including insulated jacket and flue-gas vent connection.
   OR
   Ship cast-iron sections disassembled with all materials and equipment, including seals, tie rods, and insulated jacket and flue-gas vent connection for field assembly.
2. Cast-Iron Section Design:
   a. Configuration: Wet base **OR** back **OR** leg, **as directed**.
   b. Number of Passes: Single **OR** Multiple, **as directed**.
   c. Sectional Joints: High-temperature sealant to seal flue-gas passages not in contact with heating medium, tapered cast-iron push nipples, **OR** O-ring gaskets, **OR** fiber roping, **as directed**, and held together with tie rods.
   d. Drain and blowdown tappings.
   e. Return injection tube to equalize water flow to all sections.
   f. Crown inspection tappings with brass plugs.
   g. Built-in air separator.
3. Combustion Chamber: Equipped with ceramic-fiber target wall **OR** refractory **OR** insulation, **as directed**, and flame observation ports, front and back.
4. Casing:
   a. Jacket: Sheet metal **OR** Galvanized sheet metal, **as directed**, with snap-in or interlocking closures and baked-enamel **OR** powder-coated, **as directed**, protective finish.
   b. Insulation: Minimum 1-inch- (25-mm-) **OR** 2-inch- (50-mm-), **as directed**, thick, mineral-fiber insulation surrounding the heat exchanger.
   c. Combustion Chamber Access: Refractory lined, hinged, front.
   d. Access: For cleaning between cast-iron sections.
   e. Draft Hood: Flue canopy and top **OR** rear, **as directed**, flue connection shall be constructed of aluminized **OR** stainless, **as directed**, steel containing adjustable outlet damper assembly.
   f. Insulated base constructed of aluminized steel to permit boiler to be installed on combustible floor.
   g. Mounting Frame: Steel rails to mount assembled boiler package on concrete base.
      1) Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" when mounting base is anchored to building structure.
   h. Control Cabinet: Sheet metal casing shall cover all controls, gas train, and burner.
5. Draft Diverter: Steel assembly integral with boiler casing **OR** Separate galvanized-steel assembly, **as directed**.

B. Burner: For Atmospheric Gas Burners.

1. Burner Tubes and Orifices: Stainless steel **OR** Cast iron, **as directed**, for natural **OR** propane, **as directed**, gas.
2. Gas Train: Control devices and full-modulation **OR** on-off **OR** low-high-low, **as directed**, control sequence shall comply with requirements in ASME CSD-1 **OR** FMG **OR** IRI **OR** UL, **as directed**.
   OR
   Gas Train: Combination gas valve with manual shutoff, pressure regulator, and pilot adjustment.
3. Pilot: Standing **OR** Intermittent-electric-spark, **as directed**, pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.

C. Burner: For Residential-Size Boilers With Sealed-Combustion Burners.
1. Burner Tubes and Orifices: Stainless steel **OR** Cast iron, **as directed**, for natural **OR** propane, **as directed**, gas.
2. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
   a. Motors: Comply with requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
      1) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
3. Gas Train: Combination gas valve with manual shutoff, pressure regulator, and pilot adjustment.
4. Pilot: Standing **OR** Intermittent-electric-spark, **as directed**, pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.

D. Burner: For Forced-Draft Burners.
1. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for natural **OR** propane, **as directed**, gas.
2. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
   a. Motors: Comply with requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
      1) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
3. Gas Train: Control devices and modulating **OR** on-off **OR** low-high-low, **as directed**, control sequence shall comply with requirements in ASME CSD-1 **OR** FMG **OR** IRI **OR** UL, **as directed**.
4. Pilot: Intermittent **OR** Interrupted, **as directed**,-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.
5. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.
   a. Maximum Oxides of Nitrogen Emissions: 20 **OR** 30, **as directed**, ppm.

E. Burner: For Oil Burners.
1. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for fuel oil.
2. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
   a. Motors: Comply with requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
      1) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
3. Oil Supply: Control devices and modulating **OR** on-off **OR** low-high-low, **as directed**, control sequence shall comply with requirements in ASME CSD-1 **OR** FMG **OR** IRI **OR** UL, **as directed**.
   a. Oil Pump: Two-stage, gear-type oil pump integral to and directly driven by blower, **as directed**, shall be capable of producing 300-psig (2070-kPa) discharge pressure and 15-inch Hg (50.7-kPa) vacuum.
   b. Oil Piping Specialties:
      1) Suction-line, manual, gate valve.
      2) Removable-mesh oil strainer.
      3) 0- to 30-inch Hg (0- to 101.3-kPa) vacuum; 0- to 30-psig (0- to 207-kPa) vacuum-pressure gage.

4) 0- to 300-psig (0- to 2070-kPa) oil-nozzle pressure gage.
5) Nozzle-line, solenoid-safety-shutoff oil valve.

4. Pilot: Intermittent **OR** Interrupted, **as directed**,-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff solenoid using cadmium sulfide **OR** UV scanner, **as directed**, flame-safety control.
5. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.
   a. Maximum Oxides of Nitrogen Emissions: 30 ppm.

F. Burner: For Combination Gas And Oil Burners.
1. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for fuel oil and natural **OR** propane, **as directed**, gas.
2. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
   a. Motors: Comply with requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
      1) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
3. Oil Supply: Control devices and modulating **OR** on-off **OR** low-high-low, **as directed**, control sequence shall comply with requirements in ASME CSD-1 **OR** FMG **OR** IRI **OR** UL, **as directed**.
   a. Oil Pump: Two-stage, gear-type oil pump integral to and directly driven by blower, **as directed**, shall be capable of producing 300-psig (2070-kPa) discharge pressure and 15-inch Hg (50.7-kPa) vacuum.
   b. Oil Piping Specialties:
      1) Suction-line, manual, gate valve.
      2) Removable-mesh oil strainer.
      3) 0- to 30-inch Hg (0- to 101.3-kPa) vacuum; 0- to 30-psig (0- to 207-kPa) vacuum-pressure gage.
      4) 0- to 300-psig (0- to 2070-kPa) oil-nozzle pressure gage.
      5) Nozzle-line, solenoid-safety-shutoff oil valve.
4. Gas Train: Control devices and modulating **OR** on-off **OR** low-high-low, **as directed**, control sequence shall comply with requirements in ASME CSD-1 **OR** FMG **OR** IRI **OR** UL, **as directed**.
5. Gas Pilot: Intermittent **OR** Interrupted, **as directed**,-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.
6. Oil Pilot: Intermittent **OR** Interrupted, **as directed**,-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff solenoid with cadmium sulfide **OR** UV scanner, **as directed**, flame-safety control.
7. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.
   a. Maximum Oxides of Nitrogen Emissions: 20 **OR** 30, **as directed**, ppm.

G. Trim: For Hot-Water Boilers.
1. Include devices sized to comply with ANSI B31.9, "Building Services Piping."
2. Aquastat Controllers: Operating, firing rate, **as directed**, and high limit.
3. Safety Relief Valve: ASME rated.
4. Pressure and Temperature Gage: Minimum 3-1/2-inch- (89-mm-) diameter, combination water-pressure and -temperature gage. Gages shall have operating-pressure and -temperature ranges so normal operating range is about 50 percent of full range.
5. Boiler Air Vent: Automatic **OR** Manual, **as directed**.
6. Drain Valve: Minimum NPS 3/4 (DN 20) hose-end gate valve.
7. Tankless Heater: Carbon-steel header with copper-tube heat exchanger, mounted in an upper port of cast-iron sections and sealed with fiber gasket.
   a. Tappings NPS 2 (DN 50) and Smaller: Threaded ends according to ASME B1.20.1 for pipe threads.
   b. Tappings NPS 2-1/2 (DN 65) and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges, and according to ASME B16.24 for copper and copper-alloy flanges.

H. Trim: For Steam Boilers.
1. Include devices sized to comply with ANSI B31.9, "Building Services Piping."
2. Pressure Controllers: Operating, firing rate, **as directed**, and high limit.
3. Safety Relief Valve:
   a. Size and Capacity: As required for equipment according to ASME Boiler and Pressure Vessel Code.
   b. Description: Fully enclosed steel spring with adjustable pressure range and positive shutoff; factory set and sealed.
      1) Drip-Pan Elbow: Cast iron and having threaded inlet and outlet with threads complying with ASME B1.20.1.
4. Pressure Gage: Minimum 3-1/2-inch (89-mm) diameter. Gage shall have normal operating pressure about 50 percent of full range.
5. Water Column: Minimum 12-inch (300-mm) glass gage with shutoff cocks.
6. Drain Valves: Minimum NPS 3/4 (DN 20) or nozzle size with hose-end connection.
7. Blowdown Valves: Factory-installed bottom and surface, slow-acting blowdown valves same size as boiler nozzle.
8. Stop Valves: Boiler inlets and outlets, except safety relief valves or preheater inlet and outlet, shall be equipped with stop valve in an accessible location as near as practical to boiler nozzle and same size as or larger than nozzle. Valves larger than NPS 2 (DN 50) shall have rising stem.
9. Stop-Check Valves: Factory-installed, stop-check valve and stop valve at boiler outlet with free-blow drain valve factory installed between the two valves and visible when operating stop-check valve.
10. Tankless Heater: Carbon-steel header with copper-tube heat exchanger, mounted in an upper port of cast-iron sections and sealed with fiber gasket.
    a. Tappings NPS 2 (DN 50) and Smaller: Threaded ends according to ASME B1.20.1 for pipe threads.
    b. Tappings NPS 2-1/2 (DN 65) and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges, and according to ASME B16.24 for copper and copper-alloy flanges.

I. Controls
1. Refer to Division 23 Section "Instrumentation And Control For Hvac".
   OR
   Boiler operating controls shall include the following devices and features:
   a. Control transformer.
   b. Set-Point Adjust: Set points shall be adjustable.
   c. Operating Pressure Control for Steam Boilers: Factory wired and mounted to cycle burner.
   d. Low-Water Cutoff and Pump Control for Steam Boilers: Cycle feedwater pump(s) for makeup water control.
   e. Sequence of Operation for Hot-Water Boilers: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain space temperature in response to thermostat with heat anticipator located in heated space.
      OR
      Sequence of Operation for Hot-Water Boilers: Electric, factory-fabricated and field-installed panel to control burner firing rate to reset supply-water temperature inversely with outside-air temperature. At 0 deg F (minus 17 deg C) outside-air temperature, set supply-water temperature at 200 deg F (93 deg C); at 60 deg F (15 deg C) outside-air temperature, set supply-water temperature at 140 deg F (60 deg C).
   f. Sequence of Operation for Steam Boilers: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain a constant steam pressure. Maintain pressure set point plus or minus 10 percent.
      1) Include automatic, alternating-firing sequence for multiple boilers.
2. Burner Operating Controls: To maintain safe operating conditions, burner safety controls limit burner operation.
   a. High Cutoff: Manual **OR** Automatic, **as directed**, reset stops burner if operating conditions rise above maximum boiler design temperature **OR** pressure, **as directed**.

b. Low-Water Cutoff Switch: Electronic for hot-water boilers or Float and electronic for steam boilers probe shall prevent burner operation on low water. Cutoff switch shall be manual **OR** automatic, **as directed**,-reset type.
c. Blocked Vent Safety Switch for Atmospheric Burners: Manual-reset switch factory mounted on draft diverter.
d. Rollout Safety Switch for Atmospheric Burners: Factory mounted on boiler combustion chamber.
e. Audible Alarm: Factory mounted on control panel with silence switch; shall sound alarm for above conditions.

3. Building Automation System Interface: Factory install hardware and software to enable building automation system to monitor, control, and display boiler status and alarms.
   a. Hardwired Points:
      1) Monitoring: On/off status, common trouble alarm **OR** low water level alarm, **as directed**.
      2) Control: On/off operation, hot water supply temperature set-point adjustment **OR** steam pressure adjustment, **as directed**.
   b. A communication interface with building automation system shall enable building automation system operator to remotely control and monitor the boiler from an operator workstation. Control features available, and monitoring points displayed, locally at boiler control panel shall be available through building automation system.

J. Electrical Power
1. Controllers, Electrical Devices, and Wiring: Electrical devices and connections are specified in Division 22..
2. Single-Point Field Power Connection: Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to boiler.
   a. House in NEMA 250, Type 1 enclosure.
   b. Wiring shall be numbered and color-coded to match wiring diagram.
   c. Install factory wiring outside of an enclosure in a metal raceway.
   d. Field power interface shall be to wire lugs **OR** fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**.
   e. Provide branch power circuit to each motor and to controls with disconnect switch or circuit breaker, **as directed**.
   f. Provide each motor with overcurrent protection.

K. Source Quality Control
1. Test and inspect factory-assembled boilers, before shipping, according to ASME Boiler and Pressure Vessel Code.
2. Burner and Hydrostatic Test: Factory adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency; perform hydrostatic test.
3. Allow the Owner access to source quality-control testing of boilers. Notify the Owner 14 days in advance of testing.

1.3 EXECUTION

A. Boiler Installation
1. Install boilers level on concrete base. Concrete base is specified in Division 23 Section "Common Work Results For Hvac" and concrete materials and installation requirements are specified in Division 31..
2. Vibration Isolation: Elastomeric isolator pads **OR** mounts, **as directed**, with a minimum static deflection of 0.25 inch (6.35 mm). Vibration isolation devices and installation requirements are

specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
3. Install gas-fired boilers according to NFPA 54.
4. Install oil-fired boilers according to NFPA 31.
5. Assemble boiler sections in sequence and seal between each section if boiler is not delivered fully assembled.
6. Assemble and install boiler trim.
7. Install electrical devices furnished with boiler but not specified to be factory mounted.
8. Install control wiring to field-mounted electrical devices.

B. Connections
1. Piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
2. Install piping adjacent to boiler to allow service and maintenance.
3. Connect gas piping to boiler gas-train inlet with union. Piping shall be at least full size of gas train connection. Provide a reducer if required.
4. Connect oil piping full size to burner inlet with shutoff valve and union.
5. Connect hot-water piping to supply- and return-boiler tappings with shutoff valve and union or flange at each connection.
6. Connect steam and condensate piping to supply-, return-, and blowdown-boiler tappings with shutoff valve and union or flange at each connection.
7. Install piping from safety relief valves to nearest floor drain, for hot-water boilers.
8. Install piping from safety valves to drip-pan elbow and to nearest floor drain, for steam boilers.
9. Install piping from equipment drain connection to nearest floor drain. Piping shall be at least full size of connection. Provide an isolation valve if required.
10. Connect breeching full size to boiler outlet. Comply with requirements in Division 23 Section "Breechings, Chimneys, And Stacks" for venting materials.
11. Install flue-gas recirculation duct from vent to burner. Comply with requirements in Division 23 Section "Breechings, Chimneys, And Stacks" for recirculation duct materials.
12. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
13. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

C. Field Quality Control
1. Perform tests and inspections and prepare test reports.
   a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
2. Tests and Inspections:
   a. Perform installation and startup checks according to manufacturer's written instructions.
   b. Leak Test: Hydrostatic test. Repair leaks and retest until no leaks exist.
   c. Operational Test: Start units to confirm proper motor rotation and unit operation. Adjust air-fuel ratio and combustion.
   d. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
      1) Burner Test: Adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency.
      2) Check and adjust initial operating set points and high- and low-limit safety set points of fuel supply, water level and water temperature **OR** steam pressure, **as directed**.
      3) Set field-adjustable switches and circuit-breaker trip ranges as indicated.
3. Remove and replace malfunctioning units and retest as specified above.
4. Occupancy Adjustments: When requested within 12 months of date of Final Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other than normal occupancy hours for this purpose.

5. Performance Tests, **as directed**:
   a. Engage a factory-authorized service representative to inspect component assemblies and equipment installations, including connections, and to conduct performance testing.
   b. Boilers shall comply with performance requirements indicated, as determined by field performance tests. Adjust, modify, or replace equipment to comply.
   c. Perform field performance tests to determine capacity and efficiency of boilers.
      1) For dual-fuel boilers, perform tests for each fuel.
      2) Test for full capacity.
      3) Test for boiler efficiency at low fire 20, 40, 60, 80, 100, 80, 60, 40, and 20 percent of full capacity. Determine efficiency at each test point.
   d. Repeat tests until results comply with requirements indicated.
   e. Provide analysis equipment required to determine performance.
   f. Provide temporary equipment and system modifications necessary to dissipate the heat produced during tests if building systems are not adequate.
   g. Notify the Owner in advance of test dates.
   h. Document test results in a report and submit to the Owner.

D. Demonstration
   1. Train the Owner's maintenance personnel to adjust, operate, and maintain boilers.

END OF SECTION 23 01 50 00

Task	Specification	Specification Description
23 01 50 00	01 22 16 00	No Specification Required
23 01 50 00	22 11 16 00c	Hydronic Piping

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SECTION 23 01 60 00 - CONDENSING UNITS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for condensing units. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes air-cooled and water-cooled condensing units.

C. Submittals
1. Product Data: For each condensing unit, include rated capacities, operating characteristics, furnished specialties, and accessories. Include equipment dimensions, weights and structural loads, required clearances, method of field assembly, components, and location and size of each field connection.
2. Shop Drawings: Signed and sealed by a qualified professional engineer.
   a. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints, **as directed**, and for designing vibration isolation bases.
   b. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment.
   c. Wiring Diagrams: Power, signal, and control wiring.
3. Manufacturer Seismic Qualification Certification: Submit certification that condensing units, accessories, and components will withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment". Include the following:
   a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
4. Field quality-control test reports.
5. Operation and maintenance data.
6. Warranty: Special warranty specified in this Section.
7. LEED Submittal:
   a. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Fabricate and label refrigeration system according to ASHRAE 15, "Safety Code for Mechanical Refrigeration."
3. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
4. ASME Compliance: Fabricate and label water-cooled condensing units to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

E. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of condensing units that fail in materials or workmanship within specified warranty period.
   a. Failures include, but are not limited to, the following:
      1) Compressor failure.
      2) Condenser coil leak.

b. Warranty Period: Four **OR** Five **OR** 10, **as directed**, years from date of Final Completion.
c. Warranty Period (Compressor Only): Five **OR** 10, **as directed**, years from date of Final Completion.
d. Warranty Period (Condenser Coil Only): Five years from date of Final Completion.

1.2 PRODUCTS

A. Condensing Units, Air Cooled, 1 To 5 Tons (3.5 TO 17.6 kW)
1. Description: Factory assembled and tested, consisting of compressor, condenser coil, fan, motors, refrigerant reservoir, and operating controls.
2. Compressor: Scroll, hermetically sealed, with rubber vibration isolators.
a. Motor: Single **OR** Two, **as directed**, speed, and includes thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
b. Two-Speed Compressor: Include manual-reset, high-pressure switch and automatic-reset, low-pressure switch.
c. Accumulator: Suction tube.
d. Refrigerant Charge: R-407C **OR** R-410A, **as directed**.
3. Condenser Coil: Seamless copper-tube, aluminum-fin coil; circuited for integral liquid subcooler, with removable drain pan and brass service valves with service ports.
4. Condenser Fan: Direct-drive, aluminum propeller fan; with permanently lubricated, totally enclosed fan motor with thermal-overload protection and ball bearings, **as directed**.
5. Accessories:
a. Coastal Filter: Mesh screen to protect condenser coil from salt damage.
b. Crankcase heater.
c. Cycle Protector: Automatic-reset timer to prevent rapid compressor cycling.
d. Electronic programmable thermostat **OR** Low-voltage thermostat and subbase, **as directed**, to control condensing unit and evaporator fan.
e. Evaporator Freeze Thermostat: Temperature-actuated switch that stops unit when evaporator reaches freezing temperature.
f. Filter-dryer.
g. High-Pressure Switch: Automatic-reset switch cycles compressor off on high refrigerant pressure.
h. Liquid-line solenoid.
i. Low Ambient Controller: Cycles condenser fan to permit operation down to 0 deg F (minus 18 deg C) with time-delay relay to bypass low-pressure switch, **as directed**.
OR
Low Ambient Controller: Controls condenser fan speed to permit operation down to minus 20 deg F (minus 29 deg C) with time-delay relay to bypass low-pressure switch, **as directed**.
j. Low-Pressure Switch: Automatic-reset switch cycles compressor off on low refrigerant pressure.
k. PE mounting base to provide a permanent foundation.
l. Precharged and insulated suction and liquid tubing.
m. Sound Hood: Wraps around sound attenuation cover for compressor.
n. Thermostatic expansion valve.
o. Time-Delay Relay: Continues operation of evaporator fan after compressor shuts off.
6. Unit Casing: Galvanized steel, finished with baked enamel; with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Mount service valves, fittings, and gage ports on exterior of casing.

B. Condensing Units, Air Cooled, 6 To 120 Tons (21 TO 422 kW)
1. Description: Factory assembled and tested, air cooled; consisting of casing, compressors, condenser coils, condenser fans and motors, and unit controls.

2. Compressor: Hermetic or semihermetic compressor designed for service with crankcase sight glass, crankcase heater, and backseating service access valves on suction and discharge ports.
   a. Capacity Control: Cylinder unloading **OR** Hot-gas bypass, **as directed**.
   b. Refrigerant Charge: R-407C **OR** R-410A **OR** HFC-134a, **as directed**.
3. Condenser Coil: Seamless copper-tube, aluminum-fin coil, including subcooling circuit and backseating liquid-line service access valve. Factory pressure test coils, then dehydrate by drawing a vacuum and fill with a holding charge of nitrogen or refrigerant.
4. Condenser Fans: Propeller-type vertical discharge; either directly or belt driven. Include the following:
   a. Permanently lubricated ball-bearing motors.
   b. Separate motor for each fan.
   c. Dynamically and statically balanced fan assemblies.
5. Operating and safety controls include the following:
   a. Manual-reset, high-pressure cutout switches.
   b. Automatic-reset, low-pressure cutout switches.
   c. Low oil pressure cutout switch.
   d. Compressor-winding thermostat cutout switch.
   e. Three-leg, compressor-overload protection.
   f. Control transformer.
   g. Magnetic contactors for compressor and condenser fan motors.
   h. Timer to prevent excessive compressor cycling.
6. Accessories:
   a. Electronic programmable thermostat **OR** Low-voltage thermostat and subbase, **as directed**, to control condensing unit and evaporator fan.
   b. Low Ambient Controller: Cycles condenser fan to permit operation down to 0 deg F (minus 18 deg C) with time-delay relay to bypass low-pressure switch, **as directed**.
      OR
      Low Ambient Controller: Controls condenser fan speed to permit operation down to minus 20 deg F (minus 29 deg C) with time-delay relay to bypass low-pressure switch, **as directed**.
   c. Gage Panel: Package with refrigerant circuit suction and discharge gages.
   d. Hot-gas bypass kit.
   e. Part-winding-start timing relay, circuit breakers, and contactors.
7. Unit Casings: Designed for outdoor installation with weather protection for components and controls and with removable panels for required access to compressors, controls, condenser fans, motors, and drives. Additional features include the following:
   a. Steel, galvanized or zinc coated, for exposed casing surfaces; treated and finished with manufacturer's standard paint coating.
   b. Perimeter base rail with forklift slots and lifting holes to facilitate rigging.
   c. Gasketed control panel door.
   d. Nonfused disconnect switch, factory mounted and wired, for single external electrical power connection.
   e. Condenser coil hail guard **OR** grille, **as directed**, to protect coil from physical damage.

C. Condensing Units, Water Cooled
1. Description: Factory assembled and tested, water cooled; consisting of compressors, water-cooled condensers, bases, and unit controls.
2. Compressor: Hermetic or serviceable hermetic type; with oil pump, operating oil charge, and suction and discharge shutoff valves. Factory mounted on base using spring isolators. Include the following:
   a. Thermally protected compressor motor.
   b. Crankcase heater.
   c. Capacity control using cylinder unloading, suction pressure controlled and discharge pressure operated, designed for unloaded start.
   d. Refrigerant Charge: R-407C **OR** R-410A **OR** HFC-134a, **as directed**.

3. Condenser: Single-pass, tube-in-tube coaxial type; with seamless, integral-finned, copper tube and steel outer shell with water-regulating valve.
   OR
   Condenser: Multipass, shell-and-tube type; with replaceable, seamless, integral-finned copper tubes; positive-liquid subcooling circuit; pressure relief device; liquid-level test cock; purge connection; liquid-line shutoff valve; and angle valve for connection of water-regulating valve.
   a. Unit Construction: ASME stamped, **as directed**, for refrigerant-side working pressure of 385 psig (2650 kPa) and water-side working pressure of 250 psig (1720 kPa).
4. Accessories include the following:
   a. Discharge-line muffler.
   b. Gage panel containing gages for suction, discharge, and oil pressure.
   c. Electric solenoid cylinder unloaders.
   d. Pump-down relay package.
   e. Crankcase cover plates with equalizer connections.
5. Controls: Factory-mounted and -wired panel with the following:
   a. Timer to prevent short cycling.
   b. High- and low-refrigerant-pressure safety controls.
   c. Power- and control-circuit terminal blocks.
   d. Compressor motor starter.
   e. Control-circuit on-off switch.
   f. Control-circuit fuse.

D. Motors
1. General requirements for motors are specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
   b. Controllers, Electrical Devices, and Wiring: Electrical devices and connections are specified in Division 22.

E. Source Quality Control
1. Verification of Performance: Rate condensing units according to ARI 210/240, ARI 340/360, or ARI 365.
   a. Energy Efficiency: Equal to or greater than prescribed by ASHRAE/IESNA 90.1, "Energy Efficient Design of New Buildings except Low-Rise Residential Buildings."
2. Test and inspect shell and tube condensers according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
3. Testing Requirements: Factory test sound-power-level ratings according to ARI 270.

1.3 EXECUTION

A. Installation
1. Install units level and plumb, firmly anchored in locations indicated; maintain manufacturer's recommended clearances.
2. Install condensing units on concrete base. Concrete base is specified in Division 23 Section "Common Work Results For Hvac" and concrete materials and installation requirements are specified in Division 31.
3. Concrete Bases:
   a. Install dowel rods to connect concrete base to concrete slab. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around full perimeter of the base.
   b. For equipment supported on structural slab, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

d. Install anchor bolts to elevations required for proper attachment to supported equipment.
e. Install anchor bolts according to anchor-bolt manufacturer's written instructions.

4. Install roof-mounting units on equipment supports specified in Division 07.
5. Vibration Isolation: Mount condensing units on rubber pads with a minimum deflection of 1/4 inch (6.35 mm). Vibration isolation devices and installation requirements are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   OR
   Vibration Isolation: Mount condensing units on restrained spring isolators with a minimum deflection specified by the Owner. Vibration isolation devices and installation requirements are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
6. Maintain manufacturer's recommended clearances for service and maintenance.
7. Loose Components: Install electrical components, devices, and accessories that are not factory mounted.

B. Connections
1. Piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
2. Install piping adjacent to machine to allow service and maintenance.
3. Connect precharged refrigerant tubing to unit's quick-connect fittings. Install tubing so it does not interfere with access to unit. Install furnished accessories.
4. Connect refrigerant piping to air-cooled condensing units; maintain required access to unit. Install furnished field-mounted accessories. Refrigerant piping and specialties are specified in Division 23 Section "Refrigerant Piping".
5. Connect refrigerant and condenser-water piping to water-cooled condensing units. Maintain clear tube removal space. Refrigerant piping and specialties are specified in Division 23 Section "Refrigerant Piping" and condenser-water piping and specialties are specified in Division 22 Section(s) "Domestic Water Piping" OR Division 23 Section(s) "Hydronic Piping", **as directed**.

C. Field Quality Control
1. Perform the following field tests and inspections and prepare test reports:
   a. Perform electrical test and visual and mechanical inspection.
   b. Leak Test: After installation, charge systems with refrigerant and oil and test for leaks. Repair leaks, replace lost refrigerant and oil, and retest until no leaks exist.
   c. Operational Test: After electrical circuitry has been energized, start units to confirm proper operation, product capability, and compliance with requirements.
   d. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
   e. Verify proper airflow over coils.
2. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.
3. Remove and replace malfunctioning condensing units and retest as specified above.

D. Startup Service
1. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
   a. Inspect for physical damage to unit casing.
   b. Verify that access doors move freely and are weathertight.
   c. Clean units and inspect for construction debris.
   d. Verify that all bolts and screws are tight.
   e. Adjust vibration isolation and flexible connections.
   f. Verify that controls are connected and operational.
2. Lubricate bearings on fans.
3. Verify that fan wheel is rotating in the correct direction and is not vibrating or binding.
4. Adjust fan belts to proper alignment and tension.

5. Start unit according to manufacturer's written instructions and complete manufacturer's startup checklist.
6. Measure and record airflow over coils.
7. Verify proper operation of condenser capacity control device.
8. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.
9. After startup and performance test, lubricate bearings and adjust belt tension, **as directed**.

E. Demonstration
1. Train Owner's maintenance personnel to adjust, operate, and maintain condensing units.

END OF SECTION 23 01 60 00

SECTION 23 05 13 00 - COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for common motor requirements for HVAC equipment. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the products manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section includes general requirements for single-phase and polyphase, general-purpose, horizontal, small and medium, squirrel-cage induction motors for use on ac power systems up to 600 V and installed at equipment manufacturer's factory or shipped separately by equipment manufacturer for field installation.

C. Coordination
1. Coordinate features of motors, installed units, and accessory devices to be compatible with the following:
   a. Motor controllers.
   b. Torque, speed, and horsepower requirements of the load.
   c. Ratings and characteristics of supply circuit and required control sequence.
   d. Ambient and environmental conditions of installation location.

1.2 PRODUCTS

A. General Motor Requirements
1. Comply with requirements in this Section except when stricter requirements are specified in HVAC equipment schedules or Sections.
2. Comply with NEMA MG 1 unless otherwise indicated.
3. Comply with IEEE 841 for severe-duty motors.

B. Motor Characteristics
1. Duty: Continuous duty at ambient temperature of 40 deg C and at altitude of 3300 feet (1000 m) above sea level.
2. Capacity and Torque Characteristics: Sufficient to start, accelerate, and operate connected loads at designated speeds, at installed altitude and environment, with indicated operating sequence, and without exceeding nameplate ratings or considering service factor.

C. Polyphase Motors
1. Description: NEMA MG 1, Design B, medium induction motor.
2. Efficiency: Energy efficient, as defined in NEMA MG 1.
3. Service Factor: 1.15.
4. Multispeed Motors: Variable torque.
   a. For motors with 2:1 speed ratio, consequent pole, single winding.
   b. For motors with other than 2:1 speed ratio, separate winding for each speed.
5. Multispeed Motors: Separate winding for each speed.
6. Rotor: Random-wound, squirrel cage.
7. Bearings: Regreasable, shielded, antifriction ball bearings suitable for radial and thrust loading.
8. Temperature Rise: Match insulation rating.
9. Insulation: Class F.
10. Code Letter Designation:
    a. Motors 15 HP and Larger: NEMA starting Code F or Code G.

b. Motors Smaller than 15 HP: Manufacturer's standard starting characteristic.

11. Enclosure Material: Cast iron for motor frame sizes 324T and larger; rolled steel for motor frame sizes smaller than 324T.

D. Polyphase Motors With Additional Requirements

1. Motors Used with Reduced-Voltage and Multispeed Controllers: Match wiring connection requirements for controller with required motor leads. Provide terminals in motor terminal box, suited to control method.
2. Motors Used with Variable Frequency Controllers: Ratings, characteristics, and features coordinated with and approved by controller manufacturer.
   a. Windings: Copper magnet wire with moisture-resistant insulation varnish, designed and tested to resist transient spikes, high frequencies, and short time rise pulses produced by pulse-width modulated inverters.
   b. Energy- and Premium-Efficient Motors: Class B temperature rise; Class F insulation.
   c. Inverter-Duty Motors: Class F temperature rise; Class H insulation.
   d. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.
3. Severe-Duty Motors: Comply with IEEE 841, with 1.15 minimum service factor.

E. Single-Phase Motors

1. Motors larger than 1/20 hp shall be one of the following, to suit starting torque and requirements of specific motor application:
   a. Permanent-split capacitor.
   b. Split phase.
   c. Capacitor start, inductor run.
   d. Capacitor start, capacitor run.
2. Multispeed Motors: Variable-torque, permanent-split-capacitor type.
3. Bearings: Prelubricated, antifriction ball bearings or sleeve bearings suitable for radial and thrust loading.
4. Motors 1/20 HP and Smaller: Shaded-pole type.
5. Thermal Protection: Internal protection to automatically open power supply circuit to motor when winding temperature exceeds a safe value calibrated to temperature rating of motor insulation. Thermal-protection device shall automatically reset when motor temperature returns to normal range.

1.3 EXECUTION (Not Applicable)

END OF SECTION 23 05 13 00

SECTION 23 05 16 00 - EXPANSION FITTINGS AND LOOPS FOR PLUMBING PIPING

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for expansion fittings and loops for plumbing piping. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the products manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Flexible-hose packless expansion joints.
b. Metal-bellows packless expansion joints.
c. Rubber packless expansion joints.
d. Grooved-joint expansion joints.
e. Pipe loops and swing connections.
f. Alignment guides and anchors.

C. Performance Requirements
1. Compatibility: Products shall be suitable for piping service fluids, materials, working pressures, and temperatures.
2. Capability: Products to absorb 200 percent of maximum axial movement between anchors.

D. Submittals
1. Product Data: For each type of product indicated.
2. Delegated-Design Submittal: For each anchor and alignment guide indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
a. Design Calculations: Calculate requirements for thermal expansion of piping systems and for selecting and designing expansion joints, loops, and swing connections.
b. Anchor Details: Detail fabrication of each anchor indicated. Show dimensions and methods of assembly and attachment to building structure.
c. Alignment Guide Details: Detail field assembly and attachment to building structure.
d. Schedule: Indicate type, manufacturer's number, size, material, pressure rating, end connections, and location for each expansion joint.
3. Welding certificates.
4. Product Certificates: For each type of expansion joint, from manufacturer.
5. Maintenance Data: For expansion joints to include in maintenance manuals.

E. Quality Assurance
1. Welding Qualifications: Qualify procedures and personnel according to the following:
a. AWS D1.1/D1.1M, "Structural Welding Code - Steel."
b. ASME Boiler and Pressure Vessel Code: Section IX.

1.2 PRODUCTS

A. Packless Expansion Joints
1. Flexible-Hose Packless Expansion Joints:
a. Description: Manufactured assembly with inlet and outlet elbow fittings and two flexible-metal-hose legs joined by long-radius, 180-degree return bend or center section of flexible hose.
b. Flexible Hose: Corrugated-metal inner hoses and braided outer sheaths.

c. Expansion Joints for Copper Tubing NPS 2 (DN 50) and Smaller: Copper-alloy fittings with solder-joint end connections.
   1) Bronze hoses and single-braid bronze sheaths with 450 psig at 70 deg F (3100 kPa at 21 deg C) and 340 psig at 450 deg F (2340 kPa at 232 deg C) ratings.
   2) Bronze hoses and double-braid bronze sheaths with 700 psig at 70 deg F (4830 kPa at 21 deg C) and 500 psig at 450 deg F (3450 kPa at 232 deg C) ratings.

d. Expansion Joints for Copper Tubing NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Copper-alloy fittings with threaded end connections.
   1) Stainless-steel hoses and single-braid, stainless-steel sheaths with 300 psig at 70 deg F (2070 kPa at 21 deg C) and 225 psig at 450 deg F (1550 kPa at 232 deg C) ratings.
   2) Stainless-steel hoses and double-braid, stainless-steel sheaths with 420 psig at 70 deg F (2890 kPa at 21 deg C) and 315 psig at 450 deg F (2170 kPa at 232 deg C) ratings.

e. Expansion Joints for Steel Piping NPS 2 (DN 50) and Smaller: Stainless-steel fittings with threaded end connections.
   1) Stainless-steel hoses and single-braid, stainless-steel sheaths with 450 psig at 70 deg F (3100 kPa at 21 deg C) and 325 psig at 600 deg F (2250 kPa at 315 deg C) ratings.
   2) Stainless-steel hoses and double-braid, stainless-steel sheaths with 700 psig at 70 deg F (4830 kPa at 21 deg C) and 515 psig at 600 deg F (3550 kPa at 315 deg C) ratings.

f. Expansion Joints for Steel Piping NPS 2-1/2 to NPS 6 (DN 65 to DN 150): Stainless-steel fittings with flanged end connections.
   1) Stainless-steel hoses and single-braid, stainless-steel sheaths with 200 psig at 70 deg F (1380 kPa at 21 deg C) and 145 psig at 600 deg F (1000 kPa at 315 deg C) ratings.
   2) Stainless-steel hoses and double-braid, stainless-steel sheaths with 275 psig at 70 deg F (1900 kPa at 21 deg C) and 200 psig at 600 deg F (1380 kPa at 315 deg C) ratings.

g. Expansion Joints for Steel Piping NPS 8 to NPS 12 (DN 200 to DN 300): Stainless-steel fittings with flanged end connections.
   1) Stainless-steel hoses and single-braid, stainless-steel sheaths with 125 psig at 70 deg F (860 kPa at 21 deg C) and 90 psig at 600 deg F (625 kPa at 315 deg C) ratings.
   2) Stainless-steel hoses and double-braid, stainless-steel sheaths with 165 psig at 70 deg F (1130 kPa at 21 deg C) and 120 psig at 600 deg F (830 kPa at 315 deg C) ratings.

2. Metal-Bellows Packless Expansion Joints:
   a. Standards: ASTM F 1120 and EJMA's "Standards of the Expansion Joint Manufacturers Association, Inc."
   b. Type: Circular, corrugated bellows with external tie rods.
   c. Minimum Pressure Rating: 150 psig (1035 kPa) **OR** 175 psig (1200 kPa), **as directed**, unless otherwise indicated.
   d. Configuration: Single joint **OR** Single joint with base and double joint with base, **as directed**, class(es) unless otherwise indicated.
   e. Expansion Joints for Copper Tubing: Single **OR** Multi, **as directed**,-ply phosphor-bronze bellows, copper pipe ends, and brass shrouds.
      1) End Connections for Copper Tubing NPS 2 (DN 50) and Smaller: Solder joint or threaded.
      2) End Connections for Copper Tubing NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Solder joint or threaded.
      3) End Connections for Copper Tubing NPS 5 (DN 125) and Larger: Flanged.
3. Rubber Packless Expansion Joints:

a. Standards: ASTM F 1123 and FSA's "Technical Handbook: Non-Metallic Expansion Joints and Flexible Pipe Connectors."
b. Material: Fabric-reinforced rubber complying with FSA-NMEJ-703.
c. Arch Type: Single **OR** Multiple, **as directed**, arches with external control rods, **as directed**.
d. Spherical Type: Single **OR** Multiple, **as directed** spheres with external control rods, **as directed**.
e. Minimum Pressure Rating for NPS 1-1/2 to NPS 4 (DN 40 to DN 100): 150 psig (1035 kPa) at 220 deg F (104 deg C).
f. Minimum Pressure Rating for NPS 5 and NPS 6 (DN 125 and DN 150): 140 psig (966 kPa) at 200 deg F (93 deg C).
g. Minimum Pressure Rating for NPS 8 to NPS 12 (DN 200 to DN 300): 140 psig (966 kPa) at 180 deg F (82 deg C).
h. Material for Fluids Containing Acids, Alkalies, or Chemicals: BR **OR** CSM **OR** EPDM, **as directed**.
i. Material for Fluids Containing Gas, Hydrocarbons, or Oil: Buna-N **OR** CR, **as directed**.
j. Material for Water: BR **OR** Buna-N **OR** CR **OR** CSM **OR** EPDM **OR** NR, **as directed**.
k. End Connections: Full-faced, integral steel flanges with steel retaining rings.

B. Grooved-Joint Expansion Joints
1. Description: Factory-assembled expansion joint made of several grooved-end pipe nipples, couplings, and grooved joints.
2. Standard: AWWA C606, for grooved joints.
3. Nipples: Galvanized, **as directed**, ASTM A 53/A 53M, Schedule 40, Type E or S, steel pipe with grooved ends.
4. Couplings: Five **OR** Seven **OR** 10 **OR** 12, **as directed**, flexible type for steel-pipe dimensions. Include ferrous housing sections, Buna-N gasket suitable for diluted acid, alkaline fluids, and cold and hot water **OR** EPDM gasket suitable for cold and hot water, **as directed**, and bolts and nuts.

C. Alignment Guides And Anchors
1. Alignment Guides:
a. Description: Steel, factory-fabricated alignment guide, with bolted two-section outer cylinder and base for attaching to structure; with two-section guiding spider for bolting to pipe.
2. Anchor Materials:
a. Steel Shapes and Plates: ASTM A 36/A 36M.
b. Bolts and Nuts: ASME B18.10 or ASTM A 183, steel hex head.
c. Washers: ASTM F 844, steel, plain, flat washers.
d. Mechanical Fasteners: Insert-wedge-type stud with expansion plug anchor for use in hardened portland cement concrete, with tension and shear capacities appropriate for application.
1) Stud: Threaded, zinc-coated carbon steel.
2) Expansion Plug: Zinc-coated steel.
3) Washer and Nut: Zinc-coated steel.
e. Chemical Fasteners: Insert-type-stud, bonding-system anchor for use with hardened portland cement concrete, with tension and shear capacities appropriate for application.
1) Bonding Material: ASTM C 881/C 881M, Type IV, Grade 3, two-component epoxy resin suitable for surface temperature of hardened concrete where fastener is to be installed.
2) Stud: ASTM A 307, zinc-coated carbon steel with continuous thread on stud unless otherwise indicated.
3) Washer and Nut: Zinc-coated steel.

1.3 EXECUTION

A. Expansion-Joint Installation
1. Install expansion joints of sizes matching sizes of piping in which they are installed.
2. Install metal-bellows expansion joints according to EJMA's "Standards of the Expansion Joint Manufacturers Association, Inc."
3. Install rubber packless expansion joints according to FSA-NMEJ-702.
4. Install grooved-joint expansion joints to grooved-end steel piping

B. Pipe Loop And Swing Connection Installation
1. Install pipe loops cold-sprung in tension or compression as required to partly absorb tension or compression produced during anticipated change in temperature.
2. Connect risers and branch connections to mains with at least five pipe fittings including tee in main.
3. Connect risers and branch connections to terminal units with at least four pipe fittings including tee in riser.
4. Connect mains and branch connections to terminal units with at least four pipe fittings including tee in main.

C. Alignment-Guide And Anchor Installation
1. Install alignment guides to guide expansion and to avoid end-loading and torsional stress.
2. Install one **OR** two, **as directed**, guide(s) on each side of pipe expansion fittings and loops. Install guides nearest to expansion joint not more than four pipe diameters from expansion joint.
3. Attach guides to pipe and secure guides to building structure.
4. Install anchors at locations to prevent stresses from exceeding those permitted by ASME B31.9 and to prevent transfer of loading and stresses to connected equipment.
5. Anchor Attachments:
   a. Anchor Attachment to Black-Steel Pipe: Attach by welding. Comply with ASME B31.9 and ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."
   b. Anchor Attachment to Galvanized-Steel Pipe: Attach with pipe hangers. Use MSS SP-69, Type 42, riser clamp welded to anchor.
   c. Anchor Attachment to Copper Tubing: Attach with pipe hangers. Use MSS SP-69, Type 24, U-bolts bolted to anchor.
6. Fabricate and install steel anchors by welding steel shapes, plates, and bars. Comply with ASME B31.9 and AWS D1.1/D1.1M.
   a. Anchor Attachment to Steel Structural Members: Attach by welding.
   b. Anchor Attachment to Concrete Structural Members: Attach by fasteners. Follow fastener manufacturer's written instructions.
7. Use grout to form flat bearing surfaces for guides and anchors attached to concrete.

END OF SECTION 23 05 16 00

SECTION 23 05 16 00a - EXPANSION FITTINGS AND LOOPS FOR HVAC PIPING

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for expansion fittings and loops for HVAC piping. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the products manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Flexible, ball-joint, packed expansion joints.
b. Slip-joint packed expansion joints.
c. Expansion-compensator packless expansion joints.
d. Flexible-hose packless expansion joints.
e. Metal-bellows packless expansion joints.
f. Rubber packless expansion joints.
g. Grooved-joint expansion joints.
h. Pipe loops and swing connections.
i. Alignment guides and anchors.

C. Performance Requirements
1. Compatibility: Products shall be suitable for piping service fluids, materials, working pressures, and temperatures.
2. Capability: Products to absorb 200 percent of maximum axial movement between anchors.

D. Submittals
1. Product Data: For each type of product indicated.
2. Delegated-Design Submittal: For each anchor and alignment guide indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
a. Design Calculations: Calculate requirements for thermal expansion of piping systems and for selecting and designing expansion joints, loops, and swing connections.
b. Anchor Details: Detail fabrication of each anchor indicated. Show dimensions and methods of assembly and attachment to building structure.
c. Alignment Guide Details: Detail field assembly and attachment to building structure.
d. Schedule: Indicate type, manufacturer's number, size, material, pressure rating, end connections, and location for each expansion joint.
3. Welding certificates.
4. Product Certificates: For each type of expansion joint, from manufacturer.
5. Maintenance Data: For expansion joints to include in maintenance manuals.

E. Quality Assurance
1. Welding Qualifications: Qualify procedures and personnel according to the following:
a. AWS D1.1/D1.1M, "Structural Welding Code - Steel."
b. ASME Boiler and Pressure Vessel Code: Section IX.

1.2 PRODUCTS

A. Packed Expansion Joints
1. Flexible, Ball-Joint, Packed Expansion Joints:

a. Standards: ASME Boiler and Pressure Vessel Code: Section II, "Materials"; and ASME B31.9, "Building Services Piping," for materials and design of pressure-containing parts and bolting.
b. Material: Carbon-steel assembly with asbestos-free composition packing.
c. Design: For 360-degree rotation and angular deflection.
d. Minimum Pressure Rating: 250 psig at 400 deg F (1725 kPa at 204 deg C).
e. Angular Deflection for NPS 6 (DN 150) and Smaller: 30 degree minimum.
f. Angular Deflection for NPS 8 (DN 200) and Larger: 15 degree minimum.
g. End Connections for NPS 2 (DN 50) and Smaller: Threaded.
h. End Connections for NPS 2-1/2 (DN 65) and Larger: Flanged.

2. Slip-Joint Packed Expansion Joints:
a. Standard: ASTM F 1007.
b. Material: Carbon steel with asbestos-free PTFE packing.
c. Design: With internal guide and injection device for repacking under pressure. Include drip connection if used for steam piping.
d. Configuration: Single joint **OR** Single joint with base and double joint with base, **as directed**, class(es) unless otherwise indicated.
e. End Connections: Flanged or weld ends to match piping system.

B. Packless Expansion Joints
1. Metal, Expansion-Compensator Packless Expansion Joints:
a. Minimum Pressure Rating: 150 psig (1035 kPa) **OR** 175 psig (1200 kPa), **as directed**, unless otherwise indicated.
b. Configuration for Copper Tubing: Two-ply, phosphor-bronze bellows with copper pipe ends.
1) End Connections for Copper Tubing NPS 2 (DN 50) and Smaller: Solder joint or threaded.
2) End Connections for Copper Tubing NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Threaded.
c. Configuration for Steel Piping: Two-ply, stainless-steel bellows; steel-pipe end connections; and carbon-steel shroud.
1) End Connections for Steel Pipe NPS 2 (DN 50) and Smaller: Threaded.
2) End Connections for Steel Pipe NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Flanged **OR** Weld, **as directed**.

2. Rubber, Expansion-Compensator Packless Expansion Joints:
a. Material: Twin reinforced-rubber spheres with external restraining cables.
b. Minimum Pressure Rating: 150 psig at 170 deg F (1035 kPa at 77 deg C) unless otherwise indicated.
c. End Connections for NPS 2 (DN 50) and Smaller: Threaded.

3. Flexible-Hose Packless Expansion Joints:
a. Description: Manufactured assembly with inlet and outlet elbow fittings and two flexible-metal-hose legs joined by long-radius, 180-degree return bend or center section of flexible hose.
b. Flexible Hose: Corrugated-metal inner hoses and braided outer sheaths.
c. Expansion Joints for Copper Tubing NPS 2 (DN 50) and Smaller: Copper-alloy fittings with solder-joint end connections.
1) Bronze hoses and single-braid bronze sheaths with 450 psig at 70 deg F (3100 kPa at 21 deg C) and 340 psig at 450 deg F (2340 kPa at 232 deg C) ratings.
2) Bronze hoses and double-braid bronze sheaths with 700 psig at 70 deg F (4830 kPa at 21 deg C) and 500 psig at 450 deg F (3450 kPa at 232 deg C) ratings.
d. Expansion Joints for Copper Tubing NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Copper-alloy fittings with threaded end connections.
1) Stainless-steel hoses and single-braid, stainless-steel sheaths with 300 psig at 70 deg F (2070 kPa at 21 deg C) and 225 psig at 450 deg F (1550 kPa at 232 deg C) ratings.

2) Stainless-steel hoses and double-braid, stainless-steel sheaths with 420 psig at 70 deg F (2890 kPa at 21 deg C) and 315 psig at 450 deg F (2170 kPa at 232 deg C) ratings.

e. Expansion Joints for Steel Piping NPS 2 (DN 50) and Smaller: Carbon-steel fittings with threaded end connections.
   1) Stainless-steel hoses and single-braid, stainless-steel sheaths with 450 psig at 70 deg F (3100 kPa at 21 deg C) and 325 psig at 600 deg F (2250 kPa at 315 deg C) ratings.
   2) Stainless-steel hoses and double-braid, stainless-steel sheaths with 700 psig at 70 deg F (4830 kPa at 21 deg C) and 515 psig at 600 deg F (3550 kPa at 315 deg C) ratings.

f. Expansion Joints for Steel Piping NPS 2-1/2 to NPS 6 (DN 65 to DN 150): Carbon-steel fittings with flanged **OR** weld, **as directed**, end connections.
   1) Stainless-steel hoses and single-braid, stainless-steel sheaths with 200 psig at 70 deg F (1380 kPa at 21 deg C) and 145 psig at 600 deg F (1000 kPa at 315 deg C) ratings.
   2) Stainless-steel hoses and double-braid, stainless-steel sheaths with 275 psig at 70 deg F (1900 kPa at 21 deg C) and 200 psig at 600 deg F (1380 kPa at 315 deg C) ratings.

g. Expansion Joints for Steel Piping NPS 8 to NPS 12 (DN 200 to DN 300): Carbon-steel fittings with flanged **OR** weld, **as directed**, end connections.
   1) Stainless-steel hoses and single-braid, stainless-steel sheaths with 125 psig at 70 deg F (860 kPa at 21 deg C) and 90 psig at 600 deg F (625 kPa at 315 deg C) ratings.
   2) Stainless-steel hoses and double-braid, stainless-steel sheaths with 165 psig at 70 deg F (1130 kPa at 21 deg C) and 120 psig at 600 deg F (830 kPa at 315 deg C) ratings.

h. Expansion Joints for Steel Piping NPS 14 (DN 350) and Larger: Carbon-steel fittings with flanged **OR** weld, **as directed**, end connections.
   1) Stainless-steel hoses and double-braid, stainless-steel sheaths with 165 psig at 70 deg F (1130 kPa at 21 deg C) and 120 psig at 600 deg F (830 kPa at 315 deg C) ratings.

4. Metal-Bellows Packless Expansion Joints:
   a. Standards: ASTM F 1120 and EJMA's "Standards of the Expansion Joint Manufacturers Association, Inc."
   b. Type: Circular, corrugated bellows with external tie rods.
   c. Minimum Pressure Rating: 150 psig (1035 kPa) **OR** 175 psig (1200 kPa), **as directed**, unless otherwise indicated.
   d. Configuration: Single joint **OR** Single joint with base and double joint with base, **as directed**, class(es) unless otherwise indicated.
   e. Expansion Joints for Copper Tubing: Single **OR** Multi, **as directed**,-ply phosphor-bronze bellows, copper pipe ends, and brass shrouds.
      1) End Connections for Copper Tubing NPS 2 (DN 50) and Smaller: Solder joint or threaded.
      2) End Connections for Copper Tubing NPS 2-1/2 to NPS 4 (DN 65 to DN 100): Solder joint or threaded.
      3) End Connections for Copper Tubing NPS 5 (DN 125) and Larger: Flanged.
   f. Expansion Joints for Steel Piping: Single **OR** Multi, **as directed**,-ply stainless-steel bellows, steel pipe ends, and carbon-steel shroud.
      1) End Connections for Steel Pipe NPS 2 (DN 50) and Smaller: Threaded.
      2) End Connections for Steel Pipe NPS 2-1/2 (DN 65) and Larger: Flanged **OR** Weld, **as directed**.
5. Rubber Packless Expansion Joints:
   a. Standards: ASTM F 1123 and FSA's "Technical Handbook: Non-Metallic Expansion Joints and Flexible Pipe Connectors."
   b. Material: Fabric-reinforced rubber complying with FSA-NMEJ-703.

c. Arch Type: Single **OR** Multiple, **as directed**, arches with external control rods, **as directed**.
d. Spherical Type: Single **OR** Multiple, **as directed**, spheres with external control rods, **as directed**.
e. Minimum Pressure Rating for NPS 1-1/2 to NPS 4 (DN 40 to DN 100): 150 psig (1035 kPa) at 220 deg F (104 deg C).
f. Minimum Pressure Rating for NPS 5 and NPS 6 (DN 125 and DN 150): 140 psig (966 kPa) at 200 deg F (93 deg C).
g. Minimum Pressure Rating for NPS 8 to NPS 12 (DN 200 to DN 300): 140 psig (966 kPa) at 180 deg F (82 deg C).
h. Material for Fluids Containing Acids, Alkalies, or Chemicals: BR **OR** CSM **OR** EPDM, **as directed**.
i. Material for Fluids Containing Gas, Hydrocarbons, or Oil: Buna-N **OR** CR, **as directed**.
j. Material for Water: BR **OR** Buna-N **OR** CR **OR** CSM **OR** EPDM **OR** NR, **as directed**.
k. End Connections: Full-faced, integral steel flanges with steel retaining rings.

C. Grooved-Joint Expansion Joints
1. Description: Factory-assembled expansion joint made of several grooved-end pipe nipples, couplings, and grooved joints.
2. Standard: AWWA C606, for grooved joints.
3. Nipples: Galvanized, **as directed**, ASTM A 53/A 53M, Schedule 40, Type E or S, steel pipe with grooved ends.
4. Couplings: Five **OR** Seven **OR** 10 **OR** 12, **as directed**, flexible type for steel-pipe dimensions. Include ferrous housing sections, Buna-N gasket suitable for diluted acid, alkaline fluids, and cold and hot water **OR** EPDM gasket suitable for cold and hot water, **as directed**, and bolts and nuts.

D. Alignment Guides And Anchors
1. Alignment Guides:
a. Description: Steel, factory-fabricated alignment guide, with bolted two-section outer cylinder and base for attaching to structure; with two-section guiding spider for bolting to pipe.
2. Anchor Materials:
a. Steel Shapes and Plates: ASTM A 36/A 36M.
b. Bolts and Nuts: ASME B18.10 or ASTM A 183, steel hex head.
c. Washers: ASTM F 844, steel, plain, flat washers.
d. Mechanical Fasteners: Insert-wedge-type stud with expansion plug anchor for use in hardened portland cement concrete, with tension and shear capacities appropriate for application.
1) Stud: Threaded, zinc-coated carbon steel.
2) Expansion Plug: Zinc-coated steel.
3) Washer and Nut: Zinc-coated steel.
e. Chemical Fasteners: Insert-type-stud, bonding-system anchor for use with hardened portland cement concrete, with tension and shear capacities appropriate for application.
1) Bonding Material: ASTM C 881/C 881M, Type IV, Grade 3, two-component epoxy resin suitable for surface temperature of hardened concrete where fastener is to be installed.
2) Stud: ASTM A 307, zinc-coated carbon steel with continuous thread on stud unless otherwise indicated.
3) Washer and Nut: Zinc-coated steel.

1.3 EXECUTION

A. Expansion-Joint Installation
1. Install expansion joints of sizes matching sizes of piping in which they are installed.

2. Install packed-type expansion joints with packing suitable for fluid service.
3. Install metal-bellows expansion joints according to EJMA's "Standards of the Expansion Joint Manufacturers Association, Inc."
4. Install rubber packless expansion joints according to FSA-NMEJ-702.
5. Install grooved-joint expansion joints to grooved-end steel piping

B. Pipe Loop And Swing Connection Installation
1. Install pipe loops cold-sprung in tension or compression as required to partly absorb tension or compression produced during anticipated change in temperature.
2. Connect risers and branch connections to mains with at least five pipe fittings including tee in main.
3. Connect risers and branch connections to terminal units with at least four pipe fittings including tee in riser.
4. Connect mains and branch connections to terminal units with at least four pipe fittings including tee in main.

C. Alignment-Guide And Anchor Installation
1. Install alignment guides to guide expansion and to avoid end-loading and torsional stress.
2. Install one **OR** two, **as directed**, guide(s) on each side of pipe expansion fittings and loops. Install guides nearest to expansion joint not more than four pipe diameters from expansion joint.
3. Attach guides to pipe and secure guides to building structure.
4. Install anchors at locations to prevent stresses from exceeding those permitted by ASME B31.9 and to prevent transfer of loading and stresses to connected equipment.
5. Anchor Attachments:
   a. Anchor Attachment to Steel Pipe: Attach by welding. Comply with ASME B31.9 and ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."
   b. Anchor Attachment to Copper Tubing: Attach with pipe hangers. Use MSS SP-69, Type 24, U-bolts bolted to anchor.
6. Fabricate and install steel anchors by welding steel shapes, plates, and bars. Comply with ASME B31.9 and AWS D1.1/D1.1M.
   a. Anchor Attachment to Steel Structural Members: Attach by welding.
   b. Anchor Attachment to Concrete Structural Members: Attach by fasteners. Follow fastener manufacturer's written instructions.
7. Use grout to form flat bearing surfaces for guides and anchors attached to concrete.

END OF SECTION 23 05 16 00a

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Task	Specification	Specification Description
23 05 19 00	22 05 23 00	Piped Utilities Basic Materials And Methods
23 05 19 00	07 63 00 00	Common Work Results for Fire Suppression
23 05 19 00	07 63 00 00a	Common Work Results for Plumbing
23 05 19 00	07 63 00 00b	Common Work Results for HVAC
23 05 19 00	21 05 19 00a	Meters and Gages for Plumbing Piping
23 05 19 00	21 05 19 00b	Meters and Gages for HVAC Piping
23 05 23 00	01 22 16 00	No Specification Required
23 05 23 00	22 05 23 00	Piped Utilities Basic Materials And Methods
23 05 23 00	21 05 19 00	Water Distribution
23 05 23 00	22 05 23 00a	General-Duty Valves for Plumbing Piping
23 05 23 00	22 05 23 00b	General-Duty Valves for HVAC Piping
23 05 23 00	22 05 76 00a	Storm Drainage Piping Specialties
23 05 23 00	22 11 16 00c	Hydronic Piping
23 05 23 00	22 11 16 00e	Refrigerant Piping
23 05 23 00	22 11 23 39a	Hydronic Pumps
23 05 23 00	22 11 16 00f	General-Service Compressed-Air Piping

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SECTION 23 05 29 00 - STEAM DISTRIBUTION

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for steam distribution. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes underground piping outside the building for distribution of steam and condensate.

C. Performance Requirements
1. Provide components and installation capable of producing steam piping systems with the following minimum working-pressure ratings:
   a. Steam Piping: 15 psig (104 kPa) **OR** 125 psig (860 kPa), **as directed**.
   b. Condensate Piping: 100 psig (690 kPa).

D. Submittals
1. Product Data:
2. Shop Drawings:
3. Welding certificates.
4. Source quality-control test reports.
5. Field quality-control test reports.

E. Quality Assurance
1. Welding: Qualify procedures and personnel according to ASME Boiler and Pressure Vessel Code: Section IX.
2. ASME Compliance: Comply with ASME B31.1, "Power Piping" **OR** ASME B31.9, "Building Services Piping," **as directed**, for materials, products, and installation.
3. ASME Compliance: Safety valves and pressure vessels shall bear appropriate ASME labels.

F. Project Conditions
1. Existing Utilities: Do not interrupt utilities serving facilities occupied by the Owner or others unless permitted under the following conditions and then only after arranging to provide temporary utility services according to requirements indicated:
   a. Notify the Owner no fewer than two days in advance of proposed utility interruptions.
   b. Do not proceed with utility interruptions without written permission.

1.2 PRODUCTS

A. Piping Materials
1. Refer to Article 1.3 "Piping Application" for applications of pipes, tubes, fittings, and joining methods.
2. Refer to Division 33 Section "Common Work Results For Utilities" for commonly used joining materials.

B. Steel Pipes And Fittings
1. Steel Pipe: ASTM A 53/A 53M, Type E, Grade A, Standard Weight; with plain ends.
2. Nipples: ASTM A 733, Standard Weight, seamless, carbon-steel pipe complying with ASTM A 53/A 53M.

3. Malleable-Iron, Threaded Fittings: ASME B16.3, Classes 150 and 300, with threads according to ASME B1.20.1.
4. Cast-Iron, Threaded Fittings: ASME B16.4, Classes 125 and 250, standard pattern, with threads according to ASME B1.20.1.
5. Steel Welding Fittings: ASME B16.9 and ASTM A 234/A 234M, seamless or welded.

C. Conduit Piping
1. Description: Factory-fabricated and -assembled, airtight and watertight, drainable, pressure-tested piping with conduit, inner pipe supports, and insulated carrier piping. Fabricate so insulation can be dried in place by forcing dry air through conduit.
2. Carrier Pipe: Steel pipe complying with ASTM A 53/A 53M, Type E, Grade A with beveled **OR** socket, **as directed**, ends for welded joints.
3. Carrier Pipe Insulation:
   a. Mineral-Wool Pipe Insulation: ASTM C 547, Type I, molded.
      1) Apparent Thermal Conductivity (k-Value): 0.31 at 200 deg F (0.044 at 93 deg C) mean temperature.
      2) Density: Maximum 10 lb/cu. ft. (160 kg/cu. m) average.
      3) Compressive Strength: 10 psig (69 kPa) minimum at 5 percent deformation.
      4) Bands: ASTM A 666, Type 304, stainless steel, 3/4 inch (19 mm) wide, 0.020 inch (0.5 mm) thick.
   b. Calcium Silicate Pipe Insulation: ASTM C 533, Type I; preformed, incombustible, inorganic, with non-asbestos fibrous reinforcement.
      1) Thermal Conductivity (k-Value): 0.60 at 500 deg F (0.087 at 260 deg C).
      2) Dry Density: 15 lb/cu. ft. (240 kg/cu. m) maximum.
      3) Compressive Strength: 60 psig (414 kPa) minimum at 5 percent deformation.
      4) Bands: ASTM A 666, Type 304, stainless steel, 3/4 inch (19 mm) wide, 0.020 inch (0.5 mm) thick.
   c. Polyisocyanurate Foam Pipe Insulation: ASTM C 591, preformed, rigid, cellular.
      1) Thermal Conductivity (k-Value): 0.14 at 75 deg F (0.020 at 24 deg C).
      2) Service Temperature: Minus 250 to plus 400 deg F (Minus 156 to plus 204 deg C).
      3) Moisture Absorption: ASTM D 2842, maximum 0.054 percent by volume.
      4) Minimum 90 percent closed cell.
      5) Dry Density: 2 lb/cu. ft. (32 kg/cu. m) maximum.
      6) Compressive Strength: 35 psig (242 kPa) minimum at 5 percent deformation.
      7) Water-Vapor Transmission: 1.26 perm inches (1.83 ng/Pa x s x m) according to ASTM E 96.
   d. Polyurethane Foam Pipe Insulation: ASTM C 591, preformed, rigid, cellular.
      1) Thermal Conductivity (k-Value): 0.13 at 75 deg F (0.019 at 24 deg C).
      2) Service Temperature: Minus 250 to plus 200 deg F (Minus 156 to plus 93 deg C).
      3) Moisture Absorption: ASTM D 2842, maximum 0.054 percent by volume.
      4) Minimum 90 percent closed cell.
      5) Dry Density: 2 lb/cu. ft. (32 kg/cu. m) maximum.
      6) Compressive Strength: 35 psig (242 kPa) minimum at 5 percent deformation.
      7) Water-Vapor Transmission: 1.26 perm inches (1.83 ng/Pa x s x m) according to ASTM E 96.
4. Minimum Clearance:
   a. Between Carrier Pipe Insulation and Conduit: 1 inch (25 mm).
   b. Between Insulation of Multiple Carrier Pipes: 3/16 inch (4.75 mm).
   c. Between Bottom of Carrier Pipe Insulation and Conduit: 1 inch (25 mm).
   d. Between Bottom of Bare, Carrier Pipe and Casing: 1-3/8 inches (35 mm).
5. Conduit: Spiral wound, steel. Finish conduit with 2 coats of fusion-bonded epoxy, minimum 20 mils (0.50 mm) thick. Cover with polyurethane foam insulation with a high-density polyethylene jacket; thickness indicated in Part 1.3 "Piping Application" Article, **as directed**.
6. Conduit: Spiral wound, bare steel. Cover with polyurethane foam insulation with a high-density polyethylene jacket; thickness indicated in Part 1.3 "Piping Application" Article.

7. Carrier Piping Supports within Conduit: Corrugated galvanized steel with a maximum spacing of 10 feet (3 m).
8. Fittings: Factory-fabricated and -insulated elbows and tees. Elbows may be bent pipe equal to carrier pipe. Tees shall be factory fabricated and insulated, and shall be compatible with the carrier pipe.
9. Expansion Offsets and Loops: Size casing to contain piping expansion.
10. Conduit accessories include the following:
    a. Water Shed: Terminal end protector for carrier pipes entering building through floor, 3 inches (75 mm) deep and 2 inches (50 mm) larger than casing; terminate casing 20 inches (500 mm) above the floor level.
    b. Guides and Anchors: Steel plate welded to carrier pipes and to casing, complete with vent and drainage openings inside casing.
    c. End Seals: Steel plate welded to carrier pipes and to casing, complete with drain and vent openings on vertical centerline.
    d. Gland Seals: Packed stuffing box and gland follower mounted on steel plate, welded to end of casing, permitting axial movement of carrier piping, with drain and vent connections on vertical centerline.
    e. Joint Kit: Half-shell, pourable or split insulation and shrink-wrap sleeve.
11. Source Quality Control: Factory test the conduit to 15 psig (105 kPa) for a minimum of 2 minutes with no change in pressure. Factory test the carrier pipe to 150 percent of the operating pressure of system. Furnish test certificates.

D. Cased Piping
1. Description: Factory-fabricated piping with carrier pipe, insulation, and casing.
2. Carrier Pipe: Steel pipe complying with ASTM A 53/A 53M, Type E, Grade A with beveled **OR** socket, **as directed**, ends for welded joints.
3. Carrier Pipe Insulation:
    a. Polyurethane Foam Pipe Insulation: ASTM C 591, preformed, rigid, cellular.
        1) Thermal Conductivity (k-Value): 0.13 at 75 deg F (0.019 at 24 deg C).
        2) Service Temperature: Minus 250 to plus 200 deg F (Minus 156 to plus 93 deg C).
        3) Moisture Absorption: ASTM D 2842, maximum 0.054 percent by volume.
        4) Minimum 90 percent closed cell.
        5) Dry Density: 2 lb/cu. ft. (32 kg/cu. m) maximum.
        6) Compressive Strength: 35 psig (242 kPa) minimum at 5 percent deformation.
        7) Water-Vapor Transmission: 1.26 perm inches (1.83 ng/Pa x s x m) according to ASTM E 96.
4. Casing: High-density polyethylene **OR** Filament-wound, fiberglass-reinforced polyester resin **OR** PVC, **as directed**.
5. Casing accessories include the following:
    a. Joint Kit: Half-shell, pourable or split insulation, casing sleeve, and shrink-wrap sleeve.
    b. Expansion Blanket: Elastomeric foam, formed to fit over piping.
    c. End Seals: Shrink wrap the casing material to seal watertight around casing and carrier pipe.
6. Source Quality Control: Factory test the carrier pipe to 150 percent of the operating pressure of system. Furnish test certificates.

E. Loose-Fill Insulation
1. Granular, Loose-Fill Insulation: Inorganic, nontoxic, nonflammable, sodium potassium aluminum silicate with calcium carbonate filler. Include chemical treatment that renders insulation hydrophobic.
    a. Thermal Conductivity (k-Value): 0.60 at 175 deg F (0.087 at 79 deg C) and 0.65 at 300 deg F (0.094 at 149 deg C).
    b. Application Temperature Range: 35 to 800 deg F (2 to 426 deg C).
    c. Dry Density: 40 to 42 lb/cu. ft. (640 to 672 kg/cu. m).
    d. Strength: 12,000 lb/sq. ft. (58 600 kg/sq. m).

2. Powder, Loose-Fill Insulation: Inert, nontoxic, nonflammable, calcium carbonate particles. Include chemical treatment that renders insulation hydrophobic.
   a. Thermal Conductivity (k-Value): ASTM C 177, 0.58 at 100 deg F (0.084 at 37 deg C) and 0.68 at 300 deg F (0.098 at 149 deg C).
   b. Application Temperature Range: Minus 273 to plus 480 deg F (Minus 169 to plus 250 deg C).
   c. Dry Density: Approximately 60 lb/cu. ft. (960 kg/cu. m).
   d. Strength: 12,000 lb/sq. ft. (58 600 kg/sq. m).

1.3 EXECUTION

A. Earthwork: Refer to Division 31 Section "Earth Moving" for excavating, trenching, and backfilling.

B. Piping Application
1. Steam Piping: Schedule 40 **OR** Schedule 80, **as directed**, steel pipe with cast-iron, threaded fittings and threaded **OR** steel fittings and welded **OR** ductile-iron, grooved-end fittings and mechanical, **as directed**, joints; granular **OR** powder, **as directed**, loose-fill insulation.
2. Steam Piping: Conduit piping with mineral-wool **OR** calcium silicate **OR** polyisocyanurate **OR** polyurethane, **as directed**, carrier-pipe insulation and with coated, **unless directed otherwise to be** coated and insulated, conduit.
   a. Insulation Thickness: 1 inch (25 mm) **OR** 2 inches (50 mm), **as directed**.
3. Condensate Piping: Schedule 40 **OR** Schedule 80, **as directed**, steel pipe with cast-iron, threaded fittings and threaded **OR** steel welding fittings and welded **OR** ductile-iron, grooved-end fittings and mechanical, **as directed**, joints; granular **OR** powder, **as directed**, loose-fill insulation.
4. Condensate Piping: Conduit piping with mineral-wool **OR** calcium silicate **OR** polyisocyanurate **OR** polyurethane, **as directed**, carrier-pipe insulation and with coated **OR** coated and insulated, **as directed**, conduit.
   a. Insulation Thickness: 1 inch (25 mm) **OR** 2 inches (50 mm), **as directed**.
5. Condensate Piping: Cased piping with polyurethane carrier-pipe insulation.

C. Piping Installation
1. General Locations and Arrangements: Drawings indicate general location and arrangement of piping. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated, unless deviations to layout are approved.
2. Remove any standing water in the bottom of trench.
3. Bed the pipe on a minimum 6-inch (150-mm) layer of granular fill material with a minimum 6-inch (150-mm) clearance between the pipes.
4. Do not insulate piping or backfill piping trench until field quality-control testing has been completed and results approved.
5. Install piping at uniform grade of 0.2 percent downward in direction of flow or as indicated.
6. Install condensate piping at uniform grade of 0.4 percent downward in direction of flow.
7. Install components with pressure rating equal to or greater than system operating pressure.
8. Install piping free of sags and bends.
9. Install fittings for changes in direction and branch connections.
10. Refer to Division 23 Section "Common Work Results For Hvac" for sleeves and mechanical sleeve seals through exterior building walls.
11. Secure anchors with concrete thrust blocks. Concrete is specified in Division 03 Section "Cast-in-place Concrete".
12. Connect to steam and condensate piping where it passes through the building wall. Steam and condensate piping inside the building is specified in Division 23 Section "Steam And Condensate Heating Piping".

D. Loose-Fill Insulation Installation
1. Do not disturb the bottom of trench, or compact and stabilize it to ensure proper support.
2. Remove any standing water in the bottom of trench.
3. Form insulation trench by excavation or by installing drywall side forms to establish the required height and width of the insulation.
4. Support piping with proper pitch, separation, and clearance to backfill or side forms using temporary supporting devices that can be removed after back filling with insulation.
5. Place insulation and backfill after field quality-control testing has been completed and results approved.
6. Apply bitumastic coating to carbon-steel anchors and guides. Pour concrete thrust blocks and anchors. Refer to Division 03 Section "Cast-in-place Concrete" for concrete and reinforcement.
7. Wrap piping at expansion loops and offsets with mineral-wool insulation of thickness appropriate for calculated expansion amount.
8. Pour loose-fill insulation to required dimension agitating insulation to eliminate voids around piping.
9. Remove temporary hangers and supports.
10. Cover loose-fill insulation with polyethylene sheet a minimum of 4 mils (0.10 mm) thick, and empty loose-fill insulation bags on top.
11. Manually backfill 6 inches (150 mm) of clean backfill. If mechanical compaction is required manually backfill to 12 inches (300 mm) before using mechanical-compaction equipment.

E. Joint Construction
1. Refer to Division 33 Section "Common Work Results For Utilities" for basic piping joint construction.
2. Keyed-Coupling Joints: Cut- or roll-groove pipes. Assemble joints with keyed couplings, gaskets, lubricant, and bolts.
3. Conduit and Cased Piping Joints: Assemble sections and finish joints with pourable or split insulation, exterior jacket sleeve, and apply shrink-wrap seals as required by manufacturer's written installation instructions.

F. Identification: Install continuous plastic underground warning tapes during back filling of trenches for underground steam and condensate distribution piping. Locate 6 to 8 inches (150 to 200 mm) below finished grade, directly over piping. Refer to Division 31 Section "Earth Moving" for warning-tape materials and devices and their installation.

G. Field Quality Control
1. Prepare steam and condensate piping for testing according to ASME B31.1 and ASME B31.9 and as follows:
   a. Leave joints, including welds, uninsulated and exposed for examination during test.
   b. Isolate equipment. Do not subject equipment to test pressure.
   c. Install relief valve set at pressure no more than one-third higher than test pressure.
   d. Fill system with temperature water. Where there is risk of freezing, air or a safe, compatible liquid may be used.
   e. Use vents installed at high points to release trapped air while filling system. Use drip legs installed at low points for complete removal of liquid.
2. Test steam and condensate piping as follows:
   a. Subject steam and condensate piping to hydrostatic test pressure that is not less than 1.5 times the design pressure.
   b. After hydrostatic test pressure has been applied for 10 minutes, examine joints for leakage. Remake leaking joints using new materials and repeat hydrostatic test until no leaks exist.
3. Test conduit as follows:
   a. Seal vents and drains and subject conduit to 15 psig (105 kPa) for 4 hours with no loss of pressure. Repair leaks and retest as required.
4. Prepare a written report of testing.

END OF SECTION 23 05 29 00

SECTION 23 05 29 00a - HANGERS AND SUPPORTS FOR PLUMBING PIPING AND EQUIPMENT

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for hangers and supports for plumbing piping and equipment. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the products manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Metal pipe hangers and supports.
b. Trapeze pipe hangers.
c. Fiberglass pipe hangers.
d. Metal framing systems.
e. Fiberglass strut systems.
f. Thermal-hanger shield inserts.
g. Fastener systems.
h. Pipe stands.
i. Pipe positioning systems.
j. Equipment supports.

C. Definitions
1. MSS: Manufacturers Standardization Society of The Valve and Fittings Industry Inc.

D. Performance Requirements
1. Delegated Design: Design trapeze pipe hangers and equipment supports, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
2. Structural Performance: Hangers and supports for plumbing piping and equipment shall withstand the effects of gravity loads and stresses within limits and under conditions indicated according to ASCE/SEI 7.
a. Design supports for multiple pipes, including pipe stands, capable of supporting combined weight of supported systems, system contents, and test water.
b. Design equipment supports capable of supporting combined operating weight of supported equipment and connected systems and components.
c. Design seismic-restraint hangers and supports for piping and equipment and obtain approval from authorities having jurisdiction.

E. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings: Signed and sealed by a qualified professional engineer. Show fabrication and installation details and include calculations for the following; include Product Data for components:
a. Trapeze pipe hangers.
b. Metal framing systems.
c. Fiberglass strut systems.
d. Pipe stands.
e. Equipment supports.
3. Delegated-Design Submittal: For trapeze hangers indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
a. Detail fabrication and assembly of trapeze hangers.

b. Design Calculations: Calculate requirements for designing trapeze hangers.

4. Welding certificates.

F. Quality Assurance

1. Structural Steel Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
2. Pipe Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.

1.2 PRODUCTS

A. Metal Pipe Hangers And Supports

1. Carbon-Steel Pipe Hangers and Supports:
   a. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.
   b. Galvanized Metallic Coatings: Pregalvanized or hot dipped.
   c. Nonmetallic Coatings: Plastic coating, jacket, or liner.
   d. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion to support bearing surface of piping.
   e. Hanger Rods: Continuous-thread rod, nuts, and washer made of carbon steel **OR** stainless steel, **as directed**.
2. Stainless-Steel Pipe Hangers and Supports:
   a. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.
   b. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion to support bearing surface of piping.
   c. Hanger Rods: Continuous-thread rod, nuts, and washer made of stainless steel.
3. Copper Pipe Hangers:
   a. Description: MSS SP-58, Types 1 through 58, copper-coated-steel, factory-fabricated components.
   b. Hanger Rods: Continuous-thread rod, nuts, and washer made of copper-coated steel **OR** stainless steel, **as directed**.

B. Trapeze Pipe Hangers

1. Description: MSS SP-69, Type 59, shop- or field-fabricated pipe-support assembly made from structural carbon-steel shapes with MSS SP-58 carbon-steel hanger rods, nuts, saddles, and U-bolts.

C. Fiberglass Pipe Hangers

1. Clevis-Type, Fiberglass Pipe Hangers:
   a. Description: Similar to MSS SP-58, Type 1, steel pipe hanger except hanger is made of fiberglass or fiberglass-reinforced resin.
   b. Hanger Rods: Continuous-thread rod, washer, and nuts made of fiberglass, polyurethane or stainless steel.
2. Strap-Type, Fiberglass Pipe Hangers:
   a. Description: Similar to MSS SP-58, Type 9 or Type 10, steel pipe hanger except hanger is made of fiberglass-reinforced resin.
   b. Hanger Rod and Fittings: Continuous-thread rod, washer, and nuts made of stainless steel.

D. Metal Framing Systems

1. MFMA Manufacturer Metal Framing Systems:
   a. Description: Shop- or field-fabricated pipe-support assembly for supporting multiple parallel pipes.
   b. Standard: MFMA-4.

c. Channels: Continuous slotted steel channel with inturned lips.
d. Channel Nuts: Formed or stamped steel nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.
e. Hanger Rods: Continuous-thread rod, nuts, and washer made of carbon steel **OR** stainless steel, **as directed**.
f. Metallic Coating: Electroplated zinc **OR** Hot-dipped galvanized **OR** Mill galvanized **OR** In-line, hot galvanized **OR** Mechanically-deposited zinc, **as directed**.
OR
Paint Coating: Vinyl **OR** Vinyl alkyd **OR** Epoxy **OR** Polyester **OR** Acrylic **OR** Amine **OR** Alkyd, **as directed**.
OR
Plastic Coating: PVC **OR** Polyurethane **OR** Epoxy **OR** Polyester, **as directed**.
OR
Combination Coating: <**Insert coating materials in order of application**>.

2. Non-MFMA Manufacturer Metal Framing Systems:
a. Description: Shop- or field-fabricated pipe-support assembly made of steel channels, accessories, fittings, and other components for supporting multiple parallel pipes.
b. Standard: Comply with MFMA-4.
c. Channels: Continuous slotted steel channel with inturned lips.
d. Channel Nuts: Formed or stamped steel nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.
e. Hanger Rods: Continuous-thread rod, nuts, and washer made of carbon steel **OR** stainless steel, **as directed**.
f. Coating: Zinc **OR** Paint **OR** PVC, **as directed**.

E. Fiberglass Strut Systems
1. Description: Shop- or field-fabricated pipe-support assembly similar to MFMA-4 for supporting multiple parallel pipes.
a. Channels: Continuous slotted fiberglass or other plastic channel with inturned lips.
b. Channel Nuts: Fiberglass nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.
c. Hanger Rods: Continuous-thread rod, nuts, and washer made of fiberglass **OR** stainless steel, **as directed**.

F. Thermal-Hanger Shield Inserts
1. Insulation-Insert Material for Cold Piping: ASTM C 552, Type II cellular glass with 100-psig (688-kPa) or ASTM C 591, Type VI, Grade 1 polyisocyanurate with 125-psig (862-kPa) minimum compressive strength and vapor barrier.
2. Insulation-Insert Material for Hot Piping: Water-repellent treated, ASTM C 533, Type I calcium silicate with 100-psig (688-kPa), ASTM C 552, Type II cellular glass with 100-psig (688-kPa) or ASTM C 591, Type VI, Grade 1 polyisocyanurate with 125-psig (862-kPa) minimum compressive strength.
3. For Trapeze or Clamped Systems: Insert and shield shall cover entire circumference of pipe.
4. For Clevis or Band Hangers: Insert and shield shall cover lower 180 degrees of pipe.
5. Insert Length: Extend 2 inches (50 mm) beyond sheet metal shield for piping operating below ambient air temperature.

G. Fastener Systems
1. Powder-Actuated Fasteners: Threaded-steel stud, for use in hardened portland cement concrete with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.
2. Mechanical-Expansion Anchors: Insert-wedge-type, zinc-coated **OR** stainless-, **as directed**, steel anchors, for use in hardened portland cement concrete; with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

H. Pipe Stands

1. General Requirements for Pipe Stands: Shop- or field-fabricated assemblies made of manufactured corrosion-resistant components to support roof-mounted piping.
2. Compact Pipe Stand: One-piece plastic unit with integral-rod roller, pipe clamps, or V-shaped cradle to support pipe, for roof installation without membrane penetration.
3. Low-Type, Single-Pipe Stand: One-piece plastic **OR** stainless-steel, **as directed**, base unit with plastic roller, for roof installation without membrane penetration.
4. High-Type, Single-Pipe Stand:
   a. Description: Assembly of base, vertical and horizontal members, and pipe support, for roof installation without membrane penetration.
   b. Base: Plastic **OR** Stainless steel, **as directed**.
   c. Vertical Members: Two or more cadmium-plated-steel or stainless-steel, continuous-thread rods.
   d. Horizontal Member: Cadmium-plated-steel or stainless-steel rod with plastic or stainless-steel, roller-type pipe support.
5. High-Type, Multiple-Pipe Stand:
   a. Description: Assembly of bases, vertical and horizontal members, and pipe supports, for roof installation without membrane penetration.
   b. Bases: One or more; plastic.
   c. Vertical Members: Two or more protective-coated-steel channels.
   d. Horizontal Member: Protective-coated-steel channel.
   e. Pipe Supports: Galvanized-steel, clevis-type pipe hangers.
6. Curb-Mounting-Type Pipe Stands: Shop- or field-fabricated pipe supports made from structural-steel shapes, continuous-thread rods, and rollers, for mounting on permanent stationary roof curb.

I. Pipe Positioning Systems
1. Description: IAPMO PS 42, positioning system of metal brackets, clips, and straps for positioning piping in pipe spaces; for plumbing fixtures in commercial applications.

J. Equipment Supports
1. Description: Welded, shop- or field-fabricated equipment support made from structural carbon-steel shapes.

K. Miscellaneous Materials
1. Structural Steel: ASTM A 36/A 36M, carbon-steel plates, shapes, and bars; black and galvanized.
2. Grout: ASTM C 1107, factory-mixed and -packaged, dry, hydraulic-cement, nonshrink and nonmetallic grout; suitable for interior and exterior applications.
   a. Properties: Nonstaining, noncorrosive, and nongaseous.
   b. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.

1.3 EXECUTION

A. Hanger And Support Installation
1. Metal Pipe-Hanger Installation: Comply with MSS SP-69 and MSS SP-89. Install hangers, supports, clamps, and attachments as required to properly support piping from the building structure.
2. Metal Trapeze Pipe-Hanger Installation: Comply with MSS SP-69 and MSS SP-89. Arrange for grouping of parallel runs of horizontal piping, and support together on field-fabricated trapeze pipe hangers.
   a. Pipes of Various Sizes: Support together and space trapezes for smallest pipe size or install intermediate supports for smaller diameter pipes as specified for individual pipe hangers.

b. Field fabricate from ASTM A 36/A 36M, carbon-steel shapes selected for loads being supported. Weld steel according to AWS D1.1/D1.1M.

3. Fiberglass Pipe-Hanger Installation: Comply with applicable portions of MSS SP-69 and MSS SP-89. Install hangers and attachments as required to properly support piping from building structure.
4. Metal Framing System Installation: Arrange for grouping of parallel runs of piping, and support together on field-assembled metal framing systems.
5. Fiberglass Strut System Installation: Arrange for grouping of parallel runs of piping, and support together on field-assembled fiberglass struts.
6. Thermal-Hanger Shield Installation: Install in pipe hanger or shield for insulated piping.
7. Fastener System Installation:
   a. Install powder-actuated fasteners for use in lightweight concrete or concrete slabs less than 4 inches (100 mm) thick in concrete after concrete is placed and completely cured. Use operators that are licensed by powder-actuated tool manufacturer. Install fasteners according to powder-actuated tool manufacturer's operating manual.
   b. Install mechanical-expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.
8. Pipe Stand Installation:
   a. Pipe Stand Types except Curb-Mounted Type: Assemble components and mount on smooth roof surface. Do not penetrate roof membrane.
   b. Curb-Mounted-Type Pipe Stands: Assemble components or fabricate pipe stand and mount on permanent, stationary roof curb. See Division 7 Section "Roof Accessories" for curbs.
9. Pipe Positioning-System Installation: Install support devices to make rigid supply and waste piping connections to each plumbing fixture. See Division 15 plumbing fixture Sections for requirements for pipe positioning systems for plumbing fixtures.
10. Install hangers and supports complete with necessary attachments, inserts, bolts, rods, nuts, washers, and other accessories.
11. Equipment Support Installation: Fabricate from welded-structural-steel shapes.
12. Install hangers and supports to allow controlled thermal and seismic movement of piping systems, to permit freedom of movement between pipe anchors, and to facilitate action of expansion joints, expansion loops, expansion bends, and similar units.
13. Install lateral bracing with pipe hangers and supports to prevent swaying.
14. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads, including valves, flanges, and strainers, NPS 2-1/2 (DN 65) and larger and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms and install reinforcing bars through openings at top of inserts.
15. Load Distribution: Install hangers and supports so that piping live and dead loads and stresses from movement will not be transmitted to connected equipment.
16. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and to not exceed maximum pipe deflections allowed by ASME B31.9 for building services piping.
17. Insulated Piping:
    a. Attach clamps and spacers to piping.
       1) Piping Operating above Ambient Air Temperature: Clamp may project through insulation.
       2) Piping Operating below Ambient Air Temperature: Use thermal-hanger shield insert with clamp sized to match OD of insert.
       3) Do not exceed pipe stress limits allowed by ASME B31.9 for building services piping.
    b. Install MSS SP-58, Type 39, protection saddles if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation.
       1) Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 (DN 100) and larger if pipe is installed on rollers.
    c. Install MSS SP-58, Type 40, protective shields on cold piping with vapor barrier. Shields shall span an arc of 180 degrees.

1) Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 (DN 100) and larger if pipe is installed on rollers.

d. Shield Dimensions for Pipe: Not less than the following:
   1) NPS 1/4 to NPS 3-1/2 (DN 8 to DN 90): 12 inches (305 mm) long and 0.048 inch (1.22 mm) thick.
   2) NPS 4 (DN 100): 12 inches (305 mm) long and 0.06 inch (1.52 mm) thick.
   3) NPS 5 and NPS 6 (DN 125 and DN 150): 18 inches (457 mm) long and 0.06 inch (1.52 mm) thick.
   4) NPS 8 to NPS 14 (DN 200 to DN 350): 24 inches (610 mm) long and 0.075 inch (1.91 mm) thick.
   5) NPS 16 to NPS 24 (DN 400 to DN 600): 24 inches (610 mm) long and 0.105 inch (2.67 mm) thick.

e. Pipes NPS 8 (DN 200) and Larger: Include wood or reinforced calcium-silicate-insulation inserts of length at least as long as protective shield.

f. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.

B. Equipment Supports
1. Fabricate structural-steel stands to suspend equipment from structure overhead or to support equipment above floor.
2. Grouting: Place grout under supports for equipment and make bearing surface smooth.
3. Provide lateral bracing, to prevent swaying, for equipment supports.

C. Metal Fabrications
1. Cut, drill, and fit miscellaneous metal fabrications for trapeze pipe hangers and equipment supports.
2. Fit exposed connections together to form hairline joints. Field weld connections that cannot be shop welded because of shipping size limitations.
3. Field Welding: Comply with AWS D1.1/D1.1M procedures for shielded, metal arc welding; appearance and quality of welds; and methods used in correcting welding work; and with the following:
   a. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
   b. Obtain fusion without undercut or overlap.
   c. Remove welding flux immediately.
   d. Finish welds at exposed connections so no roughness shows after finishing and so contours of welded surfaces match adjacent contours.

D. Adjusting
1. Hanger Adjustments: Adjust hangers to distribute loads equally on attachments and to achieve indicated slope of pipe.
2. Trim excess length of continuous-thread hanger and support rods to 1-1/2 inches (40 mm).

E. Painting
1. Touchup: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.
   a. Apply paint by brush or spray to provide a minimum dry film thickness of 2.0 mils (0.05 mm).

   OR

   Touchup: Cleaning and touchup painting of field welds, bolted connections, and abraded areas of shop paint on miscellaneous metal are specified in Division 9 painting Sections **OR** Section "High-Performance Coatings", **as directed**.
2. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

F. Hanger And Support Schedule
1. Specific hanger and support requirements are in Sections specifying piping systems and equipment.
2. Comply with MSS SP-69 for pipe-hanger selections and applications that are not specified in piping system Sections.
3. Use hangers and supports with galvanized metallic coatings for piping and equipment that will not have field-applied finish.
4. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.
5. Use carbon-steel pipe hangers and supports**,** metal trapeze pipe hangers and metal framing systems and attachments for general service applications.
6. Use stainless-steel pipe hangers and fiberglass pipe hangers and fiberglass strut systems and stainless-steel or corrosion-resistant attachments for hostile environment applications.
7. Use copper-plated pipe hangers and copper or stainless-steel attachments for copper piping and tubing.
8. Use padded hangers for piping that is subject to scratching.
9. Use thermal-hanger shield inserts for insulated piping and tubing.
10. Horizontal-Piping Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
    a. Adjustable, Steel Clevis Hangers (MSS Type 1): For suspension of noninsulated or insulated, stationary pipes NPS 1/2 to NPS 30 (DN 15 to DN 750).
    b. Yoke-Type Pipe Clamps (MSS Type 2): For suspension of up to 1050 deg F (566 deg C), pipes NPS 4 to NPS 24 (DN 100 to DN 600), requiring up to 4 inches (100 mm) of insulation.
    c. Carbon- or Alloy-Steel, Double-Bolt Pipe Clamps (MSS Type 3): For suspension of pipes NPS 3/4 to NPS 36 (DN 20 to DN 900), requiring clamp flexibility and up to 4 inches (100 mm) of insulation.
    d. Steel Pipe Clamps (MSS Type 4): For suspension of cold and hot pipes NPS 1/2 to NPS 24 (DN 15 to DN 600) if little or no insulation is required.
    e. Pipe Hangers (MSS Type 5): For suspension of pipes NPS 1/2 to NPS 4 (DN 15 to DN 100), to allow off-center closure for hanger installation before pipe erection.
    f. Adjustable, Swivel Split- or Solid-Ring Hangers (MSS Type 6): For suspension of noninsulated, stationary pipes NPS 3/4 to NPS 8 (DN 20 to DN 200).
    g. Adjustable, Steel Band Hangers (MSS Type 7): For suspension of noninsulated, stationary pipes NPS 1/2 to NPS 8 (DN 15 to DN 200).
    h. Adjustable Band Hangers (MSS Type 9): For suspension of noninsulated, stationary pipes NPS 1/2 to NPS 8 (DN 15 to DN 200).
    i. Adjustable, Swivel-Ring Band Hangers (MSS Type 10): For suspension of noninsulated, stationary pipes NPS 1/2 to NPS 8 (DN 15 to DN 200).
    j. Split Pipe Ring with or without Turnbuckle Hangers (MSS Type 11): For suspension of noninsulated, stationary pipes NPS 3/8 to NPS 8 (DN 10 to DN 200).
    k. Extension Hinged or Two-Bolt Split Pipe Clamps (MSS Type 12): For suspension of noninsulated, stationary pipes NPS 3/8 to NPS 3 (DN 10 to DN 80).
    l. U-Bolts (MSS Type 24): For support of heavy pipes NPS 1/2 to NPS 30 (DN 15 to DN 750).
    m. Clips (MSS Type 26): For support of insulated pipes not subject to expansion or contraction.
    n. Pipe Saddle Supports (MSS Type 36): For support of pipes NPS 4 to NPS 36 (DN 100 to DN 900), with steel-pipe base stanchion support and cast-iron floor flange or carbon-steel plate.
    o. Pipe Stanchion Saddles (MSS Type 37): For support of pipes NPS 4 to NPS 36 (DN 100 to DN 900), with steel-pipe base stanchion support and cast-iron floor flange or carbon-steel plate, and with U-bolt to retain pipe.
    p. Adjustable Pipe Saddle Supports (MSS Type 38): For stanchion-type support for pipes NPS 2-1/2 to NPS 36 (DN 65 to DN 900) if vertical adjustment is required, with steel-pipe base stanchion support and cast-iron floor flange.

q. Single-Pipe Rolls (MSS Type 41): For suspension of pipes NPS 1 to NPS 30 (DN 25 to DN 750), from two rods if longitudinal movement caused by expansion and contraction might occur.
r. Adjustable Roller Hangers (MSS Type 43): For suspension of pipes NPS 2-1/2 to NPS 24 (DN 65 to DN 600), from single rod if horizontal movement caused by expansion and contraction might occur.
s. Complete Pipe Rolls (MSS Type 44): For support of pipes NPS 2 to NPS 42 (DN 50 to DN 1050) if longitudinal movement caused by expansion and contraction might occur but vertical adjustment is not necessary.
t. Pipe Roll and Plate Units (MSS Type 45): For support of pipes NPS 2 to NPS 24 (DN 50 to DN 600) if small horizontal movement caused by expansion and contraction might occur and vertical adjustment is not necessary.
u. Adjustable Pipe Roll and Base Units (MSS Type 46): For support of pipes NPS 2 to NPS 30 (DN 50 to DN 750) if vertical and lateral adjustment during installation might be required in addition to expansion and contraction.

11. Vertical-Piping Clamps: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
    a. Extension Pipe or Riser Clamps (MSS Type 8): For support of pipe risers NPS 3/4 to NPS 24 (DN 24 to DN 600).
    b. Carbon- or Alloy-Steel Riser Clamps (MSS Type 42): For support of pipe risers NPS 3/4 to NPS 24 (DN 20 to DN 600) if longer ends are required for riser clamps.
12. Hanger-Rod Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
    a. Steel Turnbuckles (MSS Type 13): For adjustment up to 6 inches (150 mm) for heavy loads.
    b. Steel Clevises (MSS Type 14): For 120 to 450 deg F (49 to 232 deg C) piping installations.
    c. Swivel Turnbuckles (MSS Type 15): For use with MSS Type 11, split pipe rings.
    d. Malleable-Iron Sockets (MSS Type 16): For attaching hanger rods to various types of building attachments.
    e. Steel Weldless Eye Nuts (MSS Type 17): For 120 to 450 deg F (49 to 232 deg C) piping installations.
13. Building Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
    a. Steel or Malleable Concrete Inserts (MSS Type 18): For upper attachment to suspend pipe hangers from concrete ceiling.
    b. Top-Beam C-Clamps (MSS Type 19): For use under roof installations with bar-joist construction, to attach to top flange of structural shape.
    c. Side-Beam or Channel Clamps (MSS Type 20): For attaching to bottom flange of beams, channels, or angles.
    d. Center-Beam Clamps (MSS Type 21): For attaching to center of bottom flange of beams.
    e. Welded Beam Attachments (MSS Type 22): For attaching to bottom of beams if loads are considerable and rod sizes are large.
    f. C-Clamps (MSS Type 23): For structural shapes.
    g. Top-Beam Clamps (MSS Type 25): For top of beams if hanger rod is required tangent to flange edge.
    h. Side-Beam Clamps (MSS Type 27): For bottom of steel I-beams.
    i. Steel-Beam Clamps with Eye Nuts (MSS Type 28): For attaching to bottom of steel I-beams for heavy loads.
    j. Linked-Steel Clamps with Eye Nuts (MSS Type 29): For attaching to bottom of steel I-beams for heavy loads, with link extensions.
    k. Malleable-Beam Clamps with Extension Pieces (MSS Type 30): For attaching to structural steel.
    l. Welded-Steel Brackets: For support of pipes from below or for suspending from above by using clip and rod. Use one of the following for indicated loads:

1) Light (MSS Type 31): 750 lb (340 kg).
2) Medium (MSS Type 32): 1500 lb (680 kg).
3) Heavy (MSS Type 33): 3000 lb (1360 kg).

m. Side-Beam Brackets (MSS Type 34): For sides of steel or wooden beams.
n. Plate Lugs (MSS Type 57): For attaching to steel beams if flexibility at beam is required.
o. Horizontal Travelers (MSS Type 58): For supporting piping systems subject to linear horizontal movement where headroom is limited.

14. Saddles and Shields: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
    a. Steel-Pipe-Covering Protection Saddles (MSS Type 39): To fill interior voids with insulation that matches adjoining insulation.
    b. Protection Shields (MSS Type 40): Of length recommended in writing by manufacturer to prevent crushing insulation.
    c. Thermal-Hanger Shield Inserts: For supporting insulated pipe.
15. Spring Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
    a. Restraint-Control Devices (MSS Type 47): Where indicated to control piping movement.
    b. Spring Cushions (MSS Type 48): For light loads if vertical movement does not exceed 1-1/4 inches (32 mm).
    c. Spring-Cushion Roll Hangers (MSS Type 49): For equipping Type 41, roll hanger with springs.
    d. Spring Sway Braces (MSS Type 50): To retard sway, shock, vibration, or thermal expansion in piping systems.
    e. Variable-Spring Hangers (MSS Type 51): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from hanger.
    f. Variable-Spring Base Supports (MSS Type 52): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from base support.
    g. Variable-Spring Trapeze Hangers (MSS Type 53): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from trapeze support.
    h. Constant Supports: For critical piping stress and if necessary to avoid transfer of stress from one support to another support, critical terminal, or connected equipment. Include auxiliary stops for erection, hydrostatic test, and load-adjustment capability. These supports include the following types:
        1) Horizontal (MSS Type 54): Mounted horizontally.
        2) Vertical (MSS Type 55): Mounted vertically.
        3) Trapeze (MSS Type 56): Two vertical-type supports and one trapeze member.
16. Comply with MSS SP-69 for trapeze pipe-hanger selections and applications that are not specified in piping system Sections.
17. Comply with MFMA-103 for metal framing system selections and applications that are not specified in piping system Sections.
18. Use powder-actuated fasteners or mechanical-expansion anchors instead of building attachments where required in concrete construction.
19. Use pipe positioning systems in pipe spaces behind plumbing fixtures to support supply and waste piping for plumbing fixtures.

END OF SECTION 23 05 29 00a

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SECTION 23 05 29 00b - HANGERS AND SUPPORTS FOR HVAC PIPING AND EQUIPMENT

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for hangers and supports for HVAC piping and equipment. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the products manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Metal pipe hangers and supports.
b. Trapeze pipe hangers.
c. Fiberglass pipe hangers.
d. Metal framing systems.
e. Fiberglass strut systems.
f. Thermal-hanger shield inserts.
g. Fastener systems.
h. Pipe stands.
i. Equipment supports.

C. Definitions
1. MSS: Manufacturers Standardization Society of The Valve and Fittings Industry Inc.

D. Performance Requirements
1. Delegated Design: Design trapeze pipe hangers and equipment supports, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
2. Structural Performance: Hangers and supports for HVAC piping and equipment shall withstand the effects of gravity loads and stresses within limits and under conditions indicated according to ASCE/SEI 7.
a. Design supports for multiple pipes, including pipe stands, capable of supporting combined weight of supported systems, system contents, and test water.
b. Design equipment supports capable of supporting combined operating weight of supported equipment and connected systems and components.
c. Design seismic-restraint hangers and supports for piping and equipment and obtain approval from authorities having jurisdiction.

E. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings: Signed and sealed by a qualified professional engineer. Show fabrication and installation details and include calculations for the following; include Product Data for components:
a. Trapeze pipe hangers.
b. Metal framing systems.
c. Fiberglass strut systems.
d. Pipe stands.
e. Equipment supports.
3. Delegated-Design Submittal: For trapeze hangers indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
a. Detail fabrication and assembly of trapeze hangers.
b. Design Calculations: Calculate requirements for designing trapeze hangers.

4. Welding certificates.

F. Quality Assurance
1. Structural Steel Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
2. Pipe Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.

1.2 PRODUCTS

A. Metal Pipe Hangers And Supports
1. Carbon-Steel Pipe Hangers and Supports:
a. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.
b. Galvanized Metallic Coatings: Pregalvanized or hot dipped.
c. Nonmetallic Coatings: Plastic coating, jacket, or liner.
d. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion to support bearing surface of piping.
e. Hanger Rods: Continuous-thread rod, nuts, and washer made of carbon steel **OR** stainless steel, **as directed**.
2. Stainless-Steel Pipe Hangers and Supports:
a. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.
b. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion to support bearing surface of piping.
c. Hanger Rods: Continuous-thread rod, nuts, and washer made of stainless steel.
3. Copper Pipe Hangers:
a. Description: MSS SP-58, Types 1 through 58, copper-coated-steel, factory-fabricated components.
b. Hanger Rods: Continuous-thread rod, nuts, and washer made of copper-coated steel **OR** stainless steel, **as directed**.

B. Trapeze Pipe Hangers
1. Description: MSS SP-69, Type 59, shop- or field-fabricated pipe-support assembly made from structural carbon-steel shapes with MSS SP-58 carbon-steel hanger rods, nuts, saddles, and U-bolts.

C. Fiberglass Pipe Hangers
1. Clevis-Type, Fiberglass Pipe Hangers:
a. Description: Similar to MSS SP-58, Type 1, steel pipe hanger except hanger is made of fiberglass or fiberglass-reinforced resin.
b. Hanger Rods: Continuous-thread rod, washer, and nuts made of fiberglass, polyurethane or stainless steel.
2. Strap-Type, Fiberglass Pipe Hangers:
a. Description: Similar to MSS SP-58, Type 9 or Type 10, steel pipe hanger except hanger is made of fiberglass-reinforced resin.
b. Hanger Rod and Fittings: Continuous-thread rod, washer, and nuts made of stainless steel.

D. Metal Framing Systems
1. MFMA Manufacturer Metal Framing Systems:
a. Description: Shop- or field-fabricated pipe-support assembly for supporting multiple parallel pipes.
b. Standard: MFMA-4.
c. Channels: Continuous slotted steel channel with inturned lips.

d. Channel Nuts: Formed or stamped steel nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.
e. Hanger Rods: Continuous-thread rod, nuts, and washer made of carbon steel **OR** stainless steel, **as directed**.
f. Metallic Coating: Electroplated zinc **OR** Hot-dipped galvanized **OR** Mill galvanized **OR** In-line, hot galvanized **OR** Mechanically-deposited zinc, **as directed**.
OR
Paint Coating: Vinyl **OR** Vinyl alkyd **OR** Epoxy **OR** Polyester **OR** Acrylic **OR** Amine **OR** Alkyd, **as directed**.
OR
Plastic Coating: PVC **OR** Polyurethane **OR** Epoxy **OR** Polyester, **as directed**.
OR
Combination Coating: as directed by the Owner.

2. Non-MFMA Manufacturer Metal Framing Systems:
a. Description: Shop- or field-fabricated pipe-support assembly made of steel channels, accessories, fittings, and other components for supporting multiple parallel pipes.
b. Standard: Comply with MFMA-4.
c. Channels: Continuous slotted steel channel with inturned lips.
d. Channel Nuts: Formed or stamped steel nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.
e. Hanger Rods: Continuous-thread rod, nuts, and washer made of carbon steel **OR** stainless steel, **as directed**.
f. Coating: Zinc **OR** Paint **OR** PVC, **as directed**.

E. Fiberglass Strut Systems
1. Description: Shop- or field-fabricated pipe-support assembly similar to MFMA-4 for supporting multiple parallel pipes.
a. Channels: Continuous slotted fiberglass or other plastic channel with inturned lips.
b. Channel Nuts: Fiberglass nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.
c. Hanger Rods: Continuous-thread rod, nuts, and washer made of fiberglass **OR** stainless steel, **as directed**.

F. Thermal-Hanger Shield Inserts
1. Insulation-Insert Material for Cold Piping: ASTM C 552, Type II cellular glass with 100-psig (688-kPa) or ASTM C 591, Type VI, Grade 1 polyisocyanurate with 125-psig (862-kPa) minimum compressive strength and vapor barrier.
2. Insulation-Insert Material for Hot Piping: Water-repellent treated, ASTM C 533, Type I calcium silicate with 100-psig (688-kPa), ASTM C 552, Type II cellular glass with 100-psig (688-kPa) or ASTM C 591, Type VI, Grade 1 polyisocyanurate with 125-psig (862-kPa) minimum compressive strength.
3. For Trapeze or Clamped Systems: Insert and shield shall cover entire circumference of pipe.
4. For Clevis or Band Hangers: Insert and shield shall cover lower 180 degrees of pipe.
5. Insert Length: Extend 2 inches (50 mm) beyond sheet metal shield for piping operating below ambient air temperature.

G. Fastener Systems
1. Powder-Actuated Fasteners: Threaded-steel stud, for use in hardened portland cement concrete with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.
2. Mechanical-Expansion Anchors: Insert-wedge-type, zinc-coated **OR** stainless-, **as directed**, steel anchors, for use in hardened portland cement concrete; with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

H. Pipe Stands

1. General Requirements for Pipe Stands: Shop- or field-fabricated assemblies made of manufactured corrosion-resistant components to support roof-mounted piping.
2. Compact Pipe Stand: One-piece plastic unit with integral-rod roller, pipe clamps, or V-shaped cradle to support pipe, for roof installation without membrane penetration.
3. Low-Type, Single-Pipe Stand: One-piece plastic **OR** stainless-steel, **as directed**, base unit with plastic roller, for roof installation without membrane penetration.
4. High-Type, Single-Pipe Stand:
   a. Description: Assembly of base, vertical and horizontal members, and pipe support, for roof installation without membrane penetration.
   b. Base: Plastic **OR** Stainless steel, **as directed**.
   c. Vertical Members: Two or more cadmium-plated-steel or stainless-steel, continuous-thread rods.
   d. Horizontal Member: Cadmium-plated-steel or stainless-steel rod with plastic or stainless-steel, roller-type pipe support.
5. High-Type, Multiple-Pipe Stand:
   a. Description: Assembly of bases, vertical and horizontal members, and pipe supports, for roof installation without membrane penetration.
   b. Bases: One or more; plastic.
   c. Vertical Members: Two or more protective-coated-steel channels.
   d. Horizontal Member: Protective-coated-steel channel.
   e. Pipe Supports: Galvanized-steel, clevis-type pipe hangers.
6. Curb-Mounted-Type Pipe Stands: Shop- or field-fabricated pipe supports made from structural-steel shapes, continuous-thread rods, and rollers, for mounting on permanent stationary roof curb.

I. Equipment Supports
1. Description: Welded, shop- or field-fabricated equipment support made from structural carbon-steel shapes.

J. Miscellaneous Materials
1. Structural Steel: ASTM A 36/A 36M, carbon-steel plates, shapes, and bars; black and galvanized.
2. Grout: ASTM C 1107, factory-mixed and -packaged, dry, hydraulic-cement, nonshrink and nonmetallic grout; suitable for interior and exterior applications.
   a. Properties: Nonstaining, noncorrosive, and nongaseous.
   b. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.

1.3 EXECUTION

A. Hanger And Support Installation
1. Metal Pipe-Hanger Installation: Comply with MSS SP-69 and MSS SP-89. Install hangers, supports, clamps, and attachments as required to properly support piping from the building structure.
2. Metal Trapeze Pipe-Hanger Installation: Comply with MSS SP-69 and MSS SP-89. Arrange for grouping of parallel runs of horizontal piping, and support together on field-fabricated trapeze pipe hangers.
   a. Pipes of Various Sizes: Support together and space trapezes for smallest pipe size or install intermediate supports for smaller diameter pipes as specified for individual pipe hangers.
   b. Field fabricate from ASTM A 36/A 36M, carbon-steel shapes selected for loads being supported. Weld steel according to AWS D1.1/D1.1M.
3. Fiberglass Pipe-Hanger Installation: Comply with applicable portions of MSS SP-69 and MSS SP-89. Install hangers and attachments as required to properly support piping from building structure.

4. Metal Framing System Installation: Arrange for grouping of parallel runs of piping, and support together on field-assembled metal framing systems.
5. Fiberglass Strut System Installation: Arrange for grouping of parallel runs of piping, and support together on field-assembled fiberglass struts.
6. Thermal-Hanger Shield Installation: Install in pipe hanger or shield for insulated piping.
7. Fastener System Installation:
   a. Install powder-actuated fasteners for use in lightweight concrete or concrete slabs less than 4 inches (100 mm) thick in concrete after concrete is placed and completely cured. Use operators that are licensed by powder-actuated tool manufacturer. Install fasteners according to powder-actuated tool manufacturer's operating manual.
   b. Install mechanical-expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.
8. Pipe Stand Installation:
   a. Pipe Stand Types except Curb-Mounted Type: Assemble components and mount on smooth roof surface. Do not penetrate roof membrane.
   b. Curb-Mounted-Type Pipe Stands: Assemble components or fabricate pipe stand and mount on permanent, stationary roof curb. See Division 07 Section "Roof Accessories" for curbs.
9. Install hangers and supports complete with necessary attachments, inserts, bolts, rods, nuts, washers, and other accessories.
10. Equipment Support Installation: Fabricate from welded-structural-steel shapes.
11. Install hangers and supports to allow controlled thermal and seismic movement of piping systems, to permit freedom of movement between pipe anchors, and to facilitate action of expansion joints, expansion loops, expansion bends, and similar units.
12. Install lateral bracing with pipe hangers and supports to prevent swaying.
13. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads, including valves, flanges, and strainers, NPS 2-1/2 (DN 65) and larger and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms and install reinforcing bars through openings at top of inserts.
14. Load Distribution: Install hangers and supports so that piping live and dead loads and stresses from movement will not be transmitted to connected equipment.
15. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and to not exceed maximum pipe deflections allowed by ASME B31.9 for building services piping.
16. Insulated Piping:
   a. Attach clamps and spacers to piping.
      1) Piping Operating above Ambient Air Temperature: Clamp may project through insulation.
      2) Piping Operating below Ambient Air Temperature: Use thermal-hanger shield insert with clamp sized to match OD of insert.
      3) Do not exceed pipe stress limits allowed by ASME B31.9 for building services piping.
   b. Install MSS SP-58, Type 39, protection saddles if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation.
      1) Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 (DN 100) and larger if pipe is installed on rollers.
   c. Install MSS SP-58, Type 40, protective shields on cold piping with vapor barrier. Shields shall span an arc of 180 degrees.
      1) Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 (DN 100) and larger if pipe is installed on rollers.
   d. Shield Dimensions for Pipe: Not less than the following:
      1) NPS 1/4 to NPS 3-1/2 (DN 8 to DN 90): 12 inches (305 mm) long and 0.048 inch (1.22 mm) thick.
      2) NPS 4 (DN 100): 12 inches (305 mm) long and 0.06 inch (1.52 mm) thick.
      3) NPS 5 and NPS 6 (DN 125 and DN 150): 18 inches (457 mm) long and 0.06 inch (1.52 mm) thick.

4) NPS 8 to NPS 14 (DN 200 to DN 350): 24 inches (610 mm) long and 0.075 inch (1.91 mm) thick.
5) NPS 16 to NPS 24 (DN 400 to DN 600): 24 inches (610 mm) long and 0.105 inch (2.67 mm) thick.

e. Pipes NPS 8 (DN 200) and Larger: Include wood or reinforced calcium-silicate-insulation inserts of length at least as long as protective shield.

f. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.

B. Equipment Supports

1. Fabricate structural-steel stands to suspend equipment from structure overhead or to support equipment above floor.
2. Grouting: Place grout under supports for equipment and make bearing surface smooth.
3. Provide lateral bracing, to prevent swaying, for equipment supports.

C. Metal Fabrications

1. Cut, drill, and fit miscellaneous metal fabrications for trapeze pipe hangers and equipment supports.
2. Fit exposed connections together to form hairline joints. Field weld connections that cannot be shop welded because of shipping size limitations.
3. Field Welding: Comply with AWS D1.1/D1.1M procedures for shielded, metal arc welding; appearance and quality of welds; and methods used in correcting welding work; and with the following:
   a. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
   b. Obtain fusion without undercut or overlap.
   c. Remove welding flux immediately.
   d. Finish welds at exposed connections so no roughness shows after finishing and so contours of welded surfaces match adjacent contours.

D. Adjusting

1. Hanger Adjustments: Adjust hangers to distribute loads equally on attachments and to achieve indicated slope of pipe.
2. Trim excess length of continuous-thread hanger and support rods to 1-1/2 inches (40 mm).

E. Painting

1. Touchup: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.
   a. Apply paint by brush or spray to provide a minimum dry film thickness of 2.0 mils (0.05 mm).

   OR

   Touchup: Cleaning and touchup painting of field welds, bolted connections, and abraded areas of shop paint on miscellaneous metal are specified in Division 07 OR Division 09 Section(s) "High-performance Coatings", **as directed**.
2. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

F. Hanger And Support Schedule

1. Specific hanger and support requirements are in Sections specifying piping systems and equipment.
2. Comply with MSS SP-69 for pipe-hanger selections and applications that are not specified in piping system Sections.
3. Use hangers and supports with galvanized metallic coatings for piping and equipment that will not have field-applied finish.

4. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.
5. Use carbon-steel pipe hangers and supports, metal trapeze pipe hangers and metal framing systems and attachments for general service applications.
6. Use stainless-steel pipe hangers and fiberglass pipe hangers and fiberglass strut systems and stainless-steel or corrosion-resistant attachments for hostile environment applications.
7. Use copper-plated pipe hangers and copper or stainless-steel attachments for copper piping and tubing.
8. Use padded hangers for piping that is subject to scratching.
9. Use thermal-hanger shield inserts for insulated piping and tubing.
10. Horizontal-Piping Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
    a. Adjustable, Steel Clevis Hangers (MSS Type 1): For suspension of noninsulated or insulated, stationary pipes NPS 1/2 to NPS 30 (DN 15 to DN 750).
    b. Yoke-Type Pipe Clamps (MSS Type 2): For suspension of up to 1050 deg F (566 deg C),pipes NPS 4 to NPS 24 (DN 100 to DN 600), requiring up to 4 inches (100 mm) of insulation.
    c. Carbon- or Alloy-Steel, Double-Bolt Pipe Clamps (MSS Type 3): For suspension of pipes NPS 3/4 to NPS 36 (DN 20 to DN 900), requiring clamp flexibility and up to 4 inches (100 mm) of insulation.
    d. Steel Pipe Clamps (MSS Type 4): For suspension of cold and hot pipes NPS 1/2 to NPS 24 (DN 15 to DN 600) if little or no insulation is required.
    e. Pipe Hangers (MSS Type 5): For suspension of pipes NPS 1/2 to NPS 4 (DN 15 to DN 100), to allow off-center closure for hanger installation before pipe erection.
    f. Adjustable, Swivel Split- or Solid-Ring Hangers (MSS Type 6): For suspension of noninsulated, stationary pipes NPS 3/4 to NPS 8 (DN 20 to DN 200).
    g. Adjustable, Steel Band Hangers (MSS Type 7): For suspension of noninsulated, stationary pipes NPS 1/2 to NPS 8 (DN 15 to DN 200).
    h. Adjustable Band Hangers (MSS Type 9): For suspension of noninsulated, stationary pipes NPS 1/2 to NPS 8 (DN 15 to DN 200).
    i. Adjustable, Swivel-Ring Band Hangers (MSS Type 10): For suspension of noninsulated, stationary pipes NPS 1/2 to NPS 8 (DN 15 to DN 200).
    j. Split Pipe Ring with or without Turnbuckle Hangers (MSS Type 11): For suspension of noninsulated, stationary pipes NPS 3/8 to NPS 8 (DN 10 to DN 200).
    k. Extension Hinged or Two-Bolt Split Pipe Clamps (MSS Type 12): For suspension of noninsulated, stationary pipes NPS 3/8 to NPS 3 (DN 10 to DN 80).
    l. U-Bolts (MSS Type 24): For support of heavy pipes NPS 1/2 to NPS 30 (DN 15 to DN 750).
    m. Clips (MSS Type 26): For support of insulated pipes not subject to expansion or contraction.
    n. Pipe Saddle Supports (MSS Type 36): For support of pipes NPS 4 to NPS 36 (DN 100 to DN 900), with steel-pipe base stanchion support and cast-iron floor flange or carbon-steel plate.
    o. Pipe Stanchion Saddles (MSS Type 37): For support of pipes NPS 4 to NPS 36 (DN 100 to DN 900), with steel-pipe base stanchion support and cast-iron floor flange or carbon-steel plate, and with U-bolt to retain pipe.
    p. Adjustable Pipe Saddle Supports (MSS Type 38): For stanchion-type support for pipes NPS 2-1/2 to NPS 36 (DN 65 to DN 900) if vertical adjustment is required, with steel-pipe base stanchion support and cast-iron floor flange.
    q. Single-Pipe Rolls (MSS Type 41): For suspension of pipes NPS 1 to NPS 30 (DN 25 to DN 750), from two rods if longitudinal movement caused by expansion and contraction might occur.
    r. Adjustable Roller Hangers (MSS Type 43): For suspension of pipes NPS 2-1/2 to NPS 24 (DN 65 to DN 600), from single rod if horizontal movement caused by expansion and contraction might occur.

s. Complete Pipe Rolls (MSS Type 44): For support of pipes NPS 2 to NPS 42 (DN 50 to DN 1050) if longitudinal movement caused by expansion and contraction might occur but vertical adjustment is not necessary.
t. Pipe Roll and Plate Units (MSS Type 45): For support of pipes NPS 2 to NPS 24 (DN 50 to DN 600) if small horizontal movement caused by expansion and contraction might occur and vertical adjustment is not necessary.
u. Adjustable Pipe Roll and Base Units (MSS Type 46): For support of pipes NPS 2 to NPS 30 (DN 50 to DN 750) if vertical and lateral adjustment during installation might be required in addition to expansion and contraction.

11. Vertical-Piping Clamps: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
    a. Extension Pipe or Riser Clamps (MSS Type 8): For support of pipe risers NPS 3/4 to NPS 24 (DN 24 to DN 600).
    b. Carbon- or Alloy-Steel Riser Clamps (MSS Type 42): For support of pipe risers NPS 3/4 to NPS 24 (DN 20 to DN 600) if longer ends are required for riser clamps.
12. Hanger-Rod Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
    a. Steel Turnbuckles (MSS Type 13): For adjustment up to 6 inches (150 mm) for heavy loads.
    b. Steel Clevises (MSS Type 14): For 120 to 450 deg F (49 to 232 deg C) piping installations.
    c. Swivel Turnbuckles (MSS Type 15): For use with MSS Type 11, split pipe rings.
    d. Malleable-Iron Sockets (MSS Type 16): For attaching hanger rods to various types of building attachments.
    e. Steel Weldless Eye Nuts (MSS Type 17): For 120 to 450 deg F (49 to 232 deg C) piping installations.
13. Building Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
    a. Steel or Malleable Concrete Inserts (MSS Type 18): For upper attachment to suspend pipe hangers from concrete ceiling.
    b. Top-Beam C-Clamps (MSS Type 19): For use under roof installations with bar-joist construction, to attach to top flange of structural shape.
    c. Side-Beam or Channel Clamps (MSS Type 20): For attaching to bottom flange of beams, channels, or angles.
    d. Center-Beam Clamps (MSS Type 21): For attaching to center of bottom flange of beams.
    e. Welded Beam Attachments (MSS Type 22): For attaching to bottom of beams if loads are considerable and rod sizes are large.
    f. C-Clamps (MSS Type 23): For structural shapes.
    g. Top-Beam Clamps (MSS Type 25): For top of beams if hanger rod is required tangent to flange edge.
    h. Side-Beam Clamps (MSS Type 27): For bottom of steel I-beams.
    i. Steel-Beam Clamps with Eye Nuts (MSS Type 28): For attaching to bottom of steel I-beams for heavy loads.
    j. Linked-Steel Clamps with Eye Nuts (MSS Type 29): For attaching to bottom of steel I-beams for heavy loads, with link extensions.
    k. Malleable-Beam Clamps with Extension Pieces (MSS Type 30): For attaching to structural steel.
    l. Welded-Steel Brackets: For support of pipes from below or for suspending from above by using clip and rod. Use one of the following for indicated loads:
        1) Light (MSS Type 31): 750 lb (340 kg).
        2) Medium (MSS Type 32): 1500 lb (680 kg).
        3) Heavy (MSS Type 33): 3000 lb (1360 kg).
    m. Side-Beam Brackets (MSS Type 34): For sides of steel or wooden beams.
    n. Plate Lugs (MSS Type 57): For attaching to steel beams if flexibility at beam is required.
    o. Horizontal Travelers (MSS Type 58): For supporting piping systems subject to linear horizontal movement where headroom is limited.

14. Saddles and Shields: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
    a. Steel-Pipe-Covering Protection Saddles (MSS Type 39): To fill interior voids with insulation that matches adjoining insulation.
    b. Protection Shields (MSS Type 40): Of length recommended in writing by manufacturer to prevent crushing insulation.
    c. Thermal-Hanger Shield Inserts: For supporting insulated pipe.
15. Spring Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
    a. Restraint-Control Devices (MSS Type 47): Where indicated to control piping movement.
    b. Spring Cushions (MSS Type 48): For light loads if vertical movement does not exceed 1-1/4 inches (32 mm).
    c. Spring-Cushion Roll Hangers (MSS Type 49): For equipping Type 41, roll hanger with springs.
    d. Spring Sway Braces (MSS Type 50): To retard sway, shock, vibration, or thermal expansion in piping systems.
    e. Variable-Spring Hangers (MSS Type 51): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from hanger.
    f. Variable-Spring Base Supports (MSS Type 52): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from base support.
    g. Variable-Spring Trapeze Hangers (MSS Type 53): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from trapeze support.
    h. Constant Supports: For critical piping stress and if necessary to avoid transfer of stress from one support to another support, critical terminal, or connected equipment. Include auxiliary stops for erection, hydrostatic test, and load-adjustment capability. These supports include the following types:
        1) Horizontal (MSS Type 54): Mounted horizontally.
        2) Vertical (MSS Type 55): Mounted vertically.
        3) Trapeze (MSS Type 56): Two vertical-type supports and one trapeze member.
16. Comply with MSS SP-69 for trapeze pipe-hanger selections and applications that are not specified in piping system Sections.
17. Comply with MFMA-103 for metal framing system selections and applications that are not specified in piping system Sections.
18. Use powder-actuated fasteners or mechanical-expansion anchors instead of building attachments where required in concrete construction.

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Task	Specification	Specification Description
23 05 29 00	22 05 23 00	Piped Utilities Basic Materials And Methods
23 05 29 00	07 63 00 00	Common Work Results for Fire Suppression
23 05 29 00	07 63 00 00a	Common Work Results for Plumbing
23 05 29 00	07 63 00 00b	Common Work Results for HVAC

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SECTION 23 05 48 00 - VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of vibration and seismic controls for HVAC piping and equipment. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the products manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following:
a. Isolation pads.
b. Isolation mounts.
c. Restrained elastomeric isolation mounts.
d. Freestanding and Restrained spring isolators.
e. Housed spring mounts.
f. Elastomeric hangers.
g. Spring hangers.
h. Spring hangers with vertical-limit stops.
i. Pipe riser resilient supports.
j. Resilient pipe guides.
k. Freestanding and Restrained air-mounting system.
l. Restrained vibration isolation roof-curb rails.
m. Seismic snubbers.
n. Restraining braces and cables.
o. Steel and Inertia, vibration isolation equipment bases.

C. Definitions
1. IBC: International Building Code.
2. ICC-ES: ICC-Evaluation Service.
3. OSHPD: Office of Statewide Health Planning and Development for the State of California.

D. Performance Requirements
1. Wind-Restraint Loading:
a. Basic Wind Speed: As required to meet Project requirements.
b. Building Classification Category: I **OR** II **OR** III **OR** IV, **as directed**.
c. Minimum 10 lb/sq. ft. (48.8 kg/sq. m) multiplied by the maximum area of the HVAC component projected on a vertical plane that is normal to the wind direction, and 45 degrees either side of normal.
2. Seismic-Restraint Loading:
a. Site Class as Defined in the IBC: A **OR** B **OR** C **OR** D **OR** E **OR** F, **as directed**.
b. Assigned Seismic Use Group or Building Category as Defined in the IBC: I **OR** II **OR** III, **as directed**.
1) Component Importance Factor: 1.0 **OR** 1.5, **as directed**.
2) Component Response Modification Factor: 1.5 **OR** 2.5 **OR** 3.5 **OR** 5.0, **as directed**.
3) Component Amplification Factor: 1.0 **OR** 2.5, **as directed**.
c. Design Spectral Response Acceleration at Short Periods (0.2 Second): Percentage as directed.
d. Design Spectral Response Acceleration at 1-Second Period: Percentage as directed.

E. Submittals
1. Product Data: For each product indicated.

2. Delegated-Design Submittal: For vibration isolation and seismic-restraint calculations and details indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
3. Welding certificates.
4. Qualification Data: For professional engineer.
5. Field quality-control test reports.

F. Quality Assurance
1. Comply with seismic-restraint requirements in the IBC unless requirements in this Section are more stringent.
2. Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
3. Seismic-restraint devices shall have horizontal and vertical load testing and analysis and shall bear anchorage preapproval OPA number from OSHPD, preapproval by ICC-ES, or preapproval by another agency acceptable to authorities having jurisdiction, showing maximum seismic-restraint ratings. Ratings based on independent testing are preferred to ratings based on calculations. If preapproved ratings are not available, submittals based on independent testing are preferred. Calculations (including combining shear and tensile loads) to support seismic-restraint designs must be signed and sealed by a qualified professional engineer.

1.2 PRODUCTS

A. Vibration Isolators
1. Pads: Arranged in single or multiple layers of sufficient stiffness for uniform loading over pad area, molded with a nonslip pattern and galvanized-steel baseplates, and factory cut to sizes that match requirements of supported equipment.
   a. Resilient Material: Oil- and water-resistant neoprene **OR** rubber **OR** hermetically sealed compressed fiberglass, **as directed**.
2. Mounts: Double-deflection type, with molded, oil-resistant rubber, hermetically sealed compressed fiberglass, or neoprene isolator elements with factory-drilled, encapsulated top plate for bolting to equipment and with baseplate for bolting to structure. Color-code or otherwise identify to indicate capacity range.
   a. Materials: Cast-ductile-iron or welded steel housing containing two separate and opposing, oil-resistant rubber or neoprene elements that prevent central threaded element and attachment hardware from contacting the housing during normal operation.
   b. Neoprene: Shock-absorbing materials compounded according to the standard for bridge-bearing neoprene as defined by AASHTO.
3. Restrained Mounts: All-directional mountings with seismic restraint.
   a. Materials: Cast-ductile-iron or welded steel housing containing two separate and opposing, oil-resistant rubber or neoprene elements that prevent central threaded element and attachment hardware from contacting the housing during normal operation.
   b. Neoprene: Shock-absorbing materials compounded according to the standard for bridge-bearing neoprene as defined by AASHTO.
4. Spring Isolators: Freestanding, laterally stable, open-spring isolators.
   a. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
   b. Minimum Additional Travel: 50 percent of the required deflection at rated load.
   c. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
   d. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
   e. Baseplates: Factory drilled for bolting to structure and bonded to 1/4-inch- (6-mm-) thick, rubber isolator pad attached to baseplate underside. Baseplates shall limit floor load to 500 psig (3447 kPa).

f. Top Plate and Adjustment Bolt: Threaded top plate with adjustment bolt and cap screw to fasten and level equipment.

5. Restrained Spring Isolators: Freestanding, steel, open-spring isolators with seismic or limit-stop restraint.
   a. Housing: Steel with resilient vertical-limit stops to prevent spring extension due to weight being removed; factory-drilled baseplate bonded to 1/4-inch- (6-mm-) thick, neoprene or rubber isolator pad attached to baseplate underside; and adjustable equipment mounting and leveling bolt that acts as blocking during installation.
   b. Restraint: Seismic or limit stop as required for equipment and authorities having jurisdiction.
   c. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
   d. Minimum Additional Travel: 50 percent of the required deflection at rated load.
   e. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
   f. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
6. Housed Spring Mounts: Housed spring isolator with integral seismic snubbers.
   a. Housing: Ductile-iron or steel housing to provide all-directional seismic restraint.
   b. Base: Factory drilled for bolting to structure.
   c. Snubbers: Vertically adjustable to allow a maximum of 1/4-inch (6-mm) travel up or down before contacting a resilient collar.
7. Elastomeric Hangers: Single or double-deflection type, fitted with molded, oil-resistant elastomeric isolator elements bonded to steel housings with threaded connections for hanger rods. Color-code or otherwise identify to indicate capacity range.
8. Spring Hangers: Combination coil-spring and elastomeric-insert hanger with spring and insert in compression.
   a. Frame: Steel, fabricated for connection to threaded hanger rods and to allow for a maximum of 30 degrees of angular hanger-rod misalignment without binding or reducing isolation efficiency.
   b. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
   c. Minimum Additional Travel: 50 percent of the required deflection at rated load.
   d. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
   e. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
   f. Elastomeric Element: Molded, oil-resistant rubber or neoprene. Steel-washer-reinforced cup to support spring and bushing projecting through bottom of frame.
   g. Self-centering hanger rod cap to ensure concentricity between hanger rod and support spring coil.
9. Spring Hangers with Vertical-Limit Stop: Combination coil-spring and elastomeric-insert hanger with spring and insert in compression and with a vertical-limit stop.
   a. Frame: Steel, fabricated for connection to threaded hanger rods and to allow for a maximum of 30 degrees of angular hanger-rod misalignment without binding or reducing isolation efficiency.
   b. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
   c. Minimum Additional Travel: 50 percent of the required deflection at rated load.
   d. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
   e. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
   f. Elastomeric Element: Molded, oil-resistant rubber or neoprene.
   g. Adjustable Vertical Stop: Steel washer with neoprene washer "up-stop" on lower threaded rod.
   h. Self-centering hanger rod cap to ensure concentricity between hanger rod and support spring coil.

10. Pipe Riser Resilient Support: All-directional, acoustical pipe anchor consisting of 2 steel tubes separated by a minimum of 1/2-inch- (13-mm-) thick neoprene. Include steel and neoprene vertical-limit stops arranged to prevent vertical travel in both directions. Design support for a maximum load on the isolation material of 500 psig (3.45 MPa) and for equal resistance in all directions.
11. Resilient Pipe Guides: Telescopic arrangement of 2 steel tubes or post and sleeve arrangement separated by a minimum of 1/2-inch- (13-mm-) thick neoprene. Where clearances are not readily visible, a factory-set guide height with a shear pin to allow vertical motion due to pipe expansion and contraction shall be fitted. Shear pin shall be removable and reinsertable to allow for selection of pipe movement. Guides shall be capable of motion to meet location requirements.

B. Air-Mounting Systems
1. Air Mounts: Freestanding, single or multiple, compressed-air bellows.
   a. Assembly: Upper and lower steel sections connected by a replaceable, flexible, nylon-reinforced neoprene bellows.
   b. Maximum Natural Frequency: 3 Hz.
   c. Operating Pressure Range: 25 to 100 psig (172 to 690 kPa).
   d. Burst Pressure: At least three times manufacturer's published maximum operating pressure.
   e. Leveling Valves: Minimum of 3 required to maintain leveling within plus or minus 1/8 inch (3 mm).
2. Restrained Air Mounts: Housed compressed-air bellows.
   a. Assembly: Upper and lower steel sections connected by a replaceable, flexible, nylon-reinforced neoprene bellows and spring, with angle-iron frame having vertical-limit stops and channel-section top with leveling adjustment and attachment screws.
   b. Maximum Natural Frequency: 3 Hz.
   c. Operating Pressure Range: 25 to 100 psig (172 to 690 kPa).
   d. Burst Pressure: At least three times manufacturer's published maximum operating pressure.
   e. Leveling Valves: Minimum of 3 required to maintain leveling within plus or minus 1/8 inch (3 mm).

C. Restrained Vibration Isolation Roof-Curb Rails
1. General Requirements for Restrained Vibration Isolation Roof-Curb Rails: Factory-assembled, fully enclosed, insulated, air- and watertight curb rail designed to resiliently support equipment and to withstand seismic and wind, **as directed**, forces.
2. Lower Support Assembly: Formed sheet-metal section containing adjustable and removable steel springs that support upper frame. Upper frame shall provide continuous support for equipment and shall be captive to resiliently resist seismic and wind, **as directed**, forces. Lower support assembly shall have a means for attaching to building structure and a wood nailer for attaching roof materials, and shall be insulated with a minimum of 2 inches (50 mm) of rigid, glass-fiber insulation on inside of assembly.
3. Spring Isolators: Adjustable, restrained spring isolators shall be mounted on 1/4-inch- (6-mm-) thick, elastomeric vibration isolation pads and shall have access ports, for level adjustment, with removable waterproof covers at all isolator locations. Isolators shall be located so they are accessible for adjustment at any time during the life of the installation without interfering with the integrity of the roof.
   a. Restrained Spring Isolators: Freestanding, steel, open-spring isolators with seismic or wind, **as directed**, restraint.
      1) Housing: Steel with resilient vertical-limit stops and adjustable equipment mounting and leveling bolt.
      2) Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
      3) Minimum Additional Travel: 50 percent of the required deflection at rated load.

4) Lateral Stiffness: More than 80 percent of rated vertical stiffness.
5) Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

b. Pads: Arranged in single or multiple layers of sufficient stiffness for uniform loading over pad area, molded with a nonslip pattern and galvanized-steel baseplates, and factory cut to sizes that match requirements of supported equipment.
1) Resilient Material: Oil- and water-resistant standard neoprene **OR** natural rubber **OR** hermetically sealed compressed fiberglass, **as directed**.

4. Snubber Bushings: All-directional, elastomeric snubber bushings at least 1/4 inch (6 mm) thick.
5. Water Seal: Galvanized sheet metal with EPDM seals at corners, attached to upper support frame, extending down past wood nailer of lower support assembly, and counterflashed over roof materials.

D. Vibration Isolation Equipment Bases
1. Steel Base: Factory-fabricated, welded, structural-steel bases and rails.
a. Design Requirements: Lowest possible mounting height with not less than 1-inch (25-mm) clearance above the floor. Include equipment anchor bolts and auxiliary motor slide bases or rails.
1) Include supports for suction and discharge elbows for pumps.
b. Structural Steel: Steel shapes, plates, and bars complying with ASTM A 36/A 36M. Bases shall have shape to accommodate supported equipment.
c. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.
2. Inertia Base: Factory-fabricated, welded, structural-steel bases and rails ready for placement of cast-in-place concrete.
a. Design Requirements: Lowest possible mounting height with not less than 1-inch (25-mm) clearance above the floor. Include equipment anchor bolts and auxiliary motor slide bases or rails.
1) Include supports for suction and discharge elbows for pumps.
b. Structural Steel: Steel shapes, plates, and bars complying with ASTM A 36/A 36M. Bases shall have shape to accommodate supported equipment.
c. Support Brackets: Factory-welded steel brackets on frame for outrigger isolation mountings and to provide for anchor bolts and equipment support.
d. Fabrication: Fabricate steel templates to hold equipment anchor-bolt sleeves and anchors in place during placement of concrete. Obtain anchor-bolt templates from supported equipment manufacturer.

E. Seismic-Restraint Devices
1. General Requirements for Restraint Components: Rated strengths, features, and applications shall be as defined in reports by an evaluation service member of ICC-ES **OR** OSHPD **OR** an agency acceptable to authorities having jurisdiction, **as directed**.
a. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least four times the maximum seismic forces to which they will be subjected.
2. Snubbers: Factory fabricated using welded structural-steel shapes and plates, anchor bolts, and replaceable resilient isolation washers and bushings.
a. Anchor bolts for attaching to concrete shall be seismic-rated, drill-in, and stud-wedge or female-wedge type.
b. Resilient Isolation Washers and Bushings: Oil- and water-resistant neoprene.
c. Maximum 1/4-inch (6-mm) air gap, and minimum 1/4-inch- (6-mm-) thick resilient cushion.
3. Channel Support System: MFMA-3, shop- or field-fabricated support assembly made of slotted steel channels with accessories for attachment to braced component at one end and to building structure at the other end and other matching components and with corrosion-resistant coating; and rated in tension, compression, and torsion forces.

4. Restraint Cables: ASTM A 603 galvanized-steel **OR** ASTM A 492 stainless-steel, **as directed**, cables with end connections made of steel assemblies with thimbles, brackets, swivel, and bolts designed for restraining cable service; and with a minimum of two clamping bolts for cable engagement.
5. Hanger Rod Stiffener: Steel tube or steel slotted-support-system sleeve with internally bolted connections **OR** Reinforcing steel angle clamped, **as directed**, to hanger rod.
6. Bushings for Floor-Mounted Equipment Anchor Bolts: Neoprene bushings designed for rigid equipment mountings, and matched to type and size of anchor bolts and studs.
7. Bushing Assemblies for Wall-Mounted Equipment Anchorage: Assemblies of neoprene elements and steel sleeves designed for rigid equipment mountings, and matched to type and size of attachment devices used.
8. Resilient Isolation Washers and Bushings: One-piece, molded, oil- and water-resistant neoprene, with a flat washer face.
9. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type in zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488. Minimum length of eight times diameter.
10. Adhesive Anchor Bolts: Drilled-in and capsule anchor system containing polyvinyl or urethane methacrylate-based resin and accelerator, or injected polymer or hybrid mortar adhesive. Provide anchor bolts and hardware with zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

F. Factory Finishes
1. Finish
a. Manufacturer's standard prime-coat finish ready for field painting.
OR
Manufacturer's standard paint applied to factory-assembled and -tested equipment before shipping.
1) Powder coating on springs and housings.
2) All hardware shall be galvanized. Hot-dip galvanize metal components for exterior use.
3) Baked enamel or powder coat for metal components on isolators for interior use.
4) Color-code or otherwise mark vibration isolation and seismic-control and wind-control, **as directed**, devices to indicate capacity range.

1.3 EXECUTION

A. Applications
1. Multiple Pipe Supports: Secure pipes to trapeze member with clamps approved for application by an evaluation service member of ICC-ES **OR** OSHPD **OR** an agency acceptable to authorities having jurisdiction, **as directed**.
2. Hanger Rod Stiffeners: Install hanger rod stiffeners where indicated or scheduled on Drawings to receive them and where required to prevent buckling of hanger rods due to seismic forces.
3. Strength of Support and Seismic-Restraint Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static and seismic loads within specified loading limits.

B. Vibration-Control And Seismic-Restraint Device Installation
1. Comply with requirements in Division 07 Section "Roof Accessories" for installation of roof curbs, equipment supports, and roof penetrations.
2. Equipment Restraints:

a. Install seismic snubbers on HVAC equipment mounted on vibration isolators. Locate snubbers as close as possible to vibration isolators and bolt to equipment base and supporting structure.
b. Install resilient bolt isolation washers on equipment anchor bolts where clearance between anchor and adjacent surface exceeds 0.125 inch (3.2 mm).
c. Install seismic-restraint devices using methods approved by an evaluation service member of ICC-ES **OR** OSHPD **OR** an agency acceptable to authorities having jurisdiction, **as directed**, providing required submittals for component.

3. Piping Restraints:
   a. Comply with requirements in MSS SP-127.
   b. Space lateral supports a maximum of 40 feet (12 m) o.c., and longitudinal supports a maximum of 80 feet (24 m) o.c.
   c. Brace a change of direction longer than 12 feet (3.7 m).
4. Install cables so they do not bend across edges of adjacent equipment or building structure.
5. Install seismic-restraint devices using methods approved by an evaluation service member of ICC-ES **OR** OSHPD **OR** an agency acceptable to authorities having jurisdiction, **as directed**, providing required submittals for component.
6. Install bushing assemblies for anchor bolts for floor-mounted equipment, arranged to provide resilient media between anchor bolt and mounting hole in concrete base.
7. Install bushing assemblies for mounting bolts for wall-mounted equipment, arranged to provide resilient media where equipment or equipment-mounting channels are attached to wall.
8. Attachment to Structure: If specific attachment is not indicated, anchor bracing to structure at flanges of beams, at upper truss chords of bar joists, or at concrete members.
9. Drilled-in Anchors:
   a. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling. Notify the structural engineer if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
   b. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
   c. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
   d. Adhesive Anchors: Clean holes to remove loose material and drilling dust prior to installation of adhesive. Place adhesive in holes proceeding from the bottom of the hole and progressing toward the surface in such a manner as to avoid introduction of air pockets in the adhesive.
   e. Set anchors to manufacturer's recommended torque, using a torque wrench.
   f. Install zinc-coated steel anchors for interior and stainless-steel anchors for exterior applications.

C. Accommodation Of Differential Seismic Motion
1. Install flexible connections in piping where they cross seismic joints, where adjacent sections or branches are supported by different structural elements, and where the connections terminate with connection to equipment that is anchored to a different structural element from the one supporting the connections as they approach equipment. Comply with requirements in Division 23 Section "Hydronic Piping" for piping flexible connections.

D. Field Quality Control
1. Perform tests and inspections.
2. Tests and Inspections:
   a. Provide evidence of recent calibration of test equipment by a testing agency acceptable to authorities having jurisdiction.

b. Schedule test with the Owner before connecting anchorage device to restrained component (unless postconnection testing has been approved), and with at least seven days' advance notice.
c. Obtain approval before transmitting test loads to structure. Provide temporary load-spreading members.
d. Test at least four of each type and size of installed anchors and fasteners selected.
e. Test to 90 percent of rated proof load of device.
f. Measure isolator restraint clearance.
g. Measure isolator deflection.
h. Verify snubber minimum clearances.
i. Air-Mounting System Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
j. Air-Mounting System Operational Test: Test the compressed-air leveling system.
k. Test and adjust air-mounting system controls and safeties.
l. If a device fails test, modify all installations of same type and retest until satisfactory results are achieved.

3. Remove and replace malfunctioning units and retest as specified above.
4. Prepare test and inspection reports.

E. Adjusting
1. Adjust isolators after piping system is at operating weight.
2. Adjust limit stops on restrained spring isolators to mount equipment at normal operating height. After equipment installation is complete, adjust limit stops so they are out of contact during normal operation.
3. Adjust air-spring leveling mechanism.
4. Adjust active height of spring isolators.
5. Adjust restraints to permit free movement of equipment within normal mode of operation.

F. Demonstration
1. Engage a factory-authorized service representative to train the Owner's maintenance personnel to adjust, operate, and maintain air-mounting systems.

END OF SECTION 23 05 48 00

Task	Specification	Specification Description
23 05 48 00	01 22 16 00	No Specification Required
23 05 48 00	22 05 23 00	Piped Utilities Basic Materials And Methods
23 05 48 00	21 05 48 00	Vibration And Seismic Controls For Fire-Suppression Piping And Equipment
23 05 48 00	22 05 48 00	Vibration And Seismic Controls For Plumbing Piping And Equipment
23 05 48 00	22 11 16 00c	Hydronic Piping
23 05 48 00	22 11 16 00d	Steam And Condensate Piping
23 05 48 00	22 11 16 00e	Refrigerant Piping
23 05 48 00	22 11 16 00f	General-Service Compressed-Air Piping

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SECTION 23 05 53 00 - IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for identification for HVAC piping and equipment. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the products manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Equipment labels.
b. Warning signs and labels.
c. Pipe labels.
d. Duct labels.
e. Stencils.
f. Valve tags.
g. Warning tags.

C. Submittals
1. Product Data: For each type of product indicated.

1.2 PRODUCTS

A. Equipment Labels
1. Metal Labels for Equipment:
a. Material and Thickness: Brass, 0.032-inch (0.8-mm) **OR** Stainless steel, 0.025-inch (0.64-mm) **OR** Aluminum, 0.032-inch (0.8-mm) **OR** anodized aluminum, 0.032-inch (0.8-mm), **as directed**, minimum thickness, and having predrilled or stamped holes for attachment hardware.
b. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch (64 by 19 mm).
c. Minimum Letter Size: 1/4 inch (6.4 mm) for name of units if viewing distance is less than 24 inches (600 mm), 1/2 inch (13 mm) for viewing distances up to 72 inches (1830 mm), and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
d. Fasteners: Stainless-steel rivets **OR** self-tapping screws, **as directed**.
e. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.
2. Plastic Labels for Equipment:
a. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/16 inch (1.6 mm) **OR** 1/8 inch (3.2 mm), **as directed**, thick, and having predrilled holes for attachment hardware.
b. Letter Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
c. Background Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
d. Maximum Temperature: Able to withstand temperatures up to 160 deg F (71 deg C).
e. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch (64 by 19 mm).
f. Minimum Letter Size: 1/4 inch (6.4 mm) for name of units if viewing distance is less than 24 inches (600 mm), 1/2 inch (13 mm) for viewing distances up to 72 inches (1830 mm), and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
g. Fasteners: Stainless-steel rivets **OR** self-tapping screws, **as directed**.

h. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

3. Label Content: Include equipment's Drawing designation or unique equipment number, Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Specification Section number and title where equipment is specified.
4. Equipment Label Schedule: For each item of equipment to be labeled, on 8-1/2-by-11-inch (A4) bond paper. Tabulate equipment identification number and identify Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Specification Section number and title where equipment is specified. Equipment schedule shall be included in operation and maintenance data.

B. Warning Signs And Labels
1. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/16 inch (1.6 mm) **OR** 1/8 inch (3.2 mm), **as directed**, thick, and having predrilled holes for attachment hardware.
2. Letter Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
3. Background Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
4. Maximum Temperature: Able to withstand temperatures up to 160 deg F (71 deg C).
5. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch (64 by 19 mm).
6. Minimum Letter Size: 1/4 inch (6.4 mm) for name of units if viewing distance is less than 24 inches (600 mm), 1/2 inch (13 mm) for viewing distances up to 72 inches (1830 mm), and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
7. Fasteners: Stainless-steel rivets **OR** self-tapping screws, **as directed**.
8. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.
9. Label Content: Include caution and warning information, plus emergency notification instructions.

C. Pipe Labels
1. General Requirements for Manufactured Pipe Labels: Preprinted, color-coded, with lettering indicating service, and showing flow direction.
2. Pretensioned Pipe Labels: Precoiled, semirigid plastic formed to partially cover **OR** cover full, **as directed**, circumference of pipe and to attach to pipe without fasteners or adhesive.
3. Self-Adhesive Pipe Labels: Printed plastic with contact-type, permanent-adhesive backing.
4. Pipe Label Contents: Include identification of piping service using same designations or abbreviations as used on Drawings, pipe size, and an arrow indicating flow direction.
   a. Flow-Direction Arrows: Integral with piping system service lettering to accommodate both directions, or as separate unit on each pipe label to indicate flow direction.
   b. Lettering Size: At least 1-1/2 inches (38 mm) high.

D. Duct Labels
1. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/16 inch (1.6 mm) **OR** 1/8 inch (3.2 mm), **as directed**, thick, and having predrilled holes for attachment hardware.
2. Letter Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
3. Background Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
4. Maximum Temperature: Able to withstand temperatures up to 160 deg F (71 deg C).
5. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch (64 by 19 mm).
6. Minimum Letter Size: 1/4 inch (6.4 mm) for name of units if viewing distance is less than 24 inches (600 mm), 1/2 inch (13 mm) for viewing distances up to 72 inches (1830 mm), and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
7. Fasteners: Stainless-steel rivets **OR** self-tapping screws, **as directed**.
8. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

9. Duct Label Contents: Include identification of duct service using same designations or abbreviations as used on Drawings, duct size, and an arrow indicating flow direction.
   a. Flow-Direction Arrows: Integral with duct system service lettering to accommodate both directions, or as separate unit on each duct label to indicate flow direction.
   b. Lettering Size: At least 1-1/2 inches (38 mm) high.

E. Stencils
1. Stencils: Prepared with letter sizes according to ASME A13.1 for piping; minimum letter height of 1-1/4 inches (32 mm) for ducts; and minimum letter height of 3/4 inch (19 mm) for access panel and door labels, equipment labels, and similar operational instructions.
   a. Stencil Material: Aluminum **OR** Brass **OR** Fiberboard, **as directed**.
   b. Stencil Paint: Exterior, gloss, alkyd enamel **OR** acrylic enamel, **as directed**, black unless otherwise indicated. Paint may be in pressurized spray-can form.
   c. Identification Paint: Exterior, alkyd enamel **OR** acrylic enamel, **as directed**, in colors according to ASME A13.1 unless otherwise indicated.

F. Valve Tags
1. Valve Tags: Stamped or engraved with 1/4-inch (6.4-mm) letters for piping system abbreviation and 1/2-inch (13-mm) numbers.
   a. Tag Material: Brass, 0.032-inch (0.8-mm) **OR** Stainless steel, 0.025-inch (0.64-mm) **OR** Aluminum, 0.032-inch (0.8-mm) **OR** anodized aluminum, 0.032-inch (0.8-mm), **as directed**, minimum thickness, and having predrilled or stamped holes for attachment hardware.
   b. Fasteners: Brass wire-link chain **OR** beaded chain **OR** S-hook, **as directed**.
2. Valve Schedules: For each piping system, on 8-1/2-by-11-inch (A4) bond paper. Tabulate valve number, piping system, system abbreviation (as shown on valve tag), location of valve (room or space), normal-operating position (open, closed, or modulating), and variations for identification. Mark valves for emergency shutoff and similar special uses.
   a. Valve-tag schedule shall be included in operation and maintenance data.

G. Warning Tags
1. Warning Tags: Preprinted or partially preprinted, accident-prevention tags, of plasticized card stock with matte finish suitable for writing.
   a. Size: 3 by 5-1/4 inches (75 by 133 mm) minimum **OR** Approximately 4 by 7 inches (100 by 178 mm), **as directed**.
   b. Fasteners: Brass grommet and wire **OR** Reinforced grommet and wire or string, **as directed**.
   c. Nomenclature: Large-size primary caption such as "DANGER," "CAUTION," or "DO NOT OPERATE."
   d. Color: Yellow background with black lettering.

1.3 EXECUTION

A. Preparation
1. Clean piping and equipment surfaces of substances that could impair bond of identification devices, including dirt, oil, grease, release agents, and incompatible primers, paints, and encapsulants.

B. Equipment Label Installation
1. Install or permanently fasten labels on each major item of mechanical equipment.
2. Locate equipment labels where accessible and visible.

C. Pipe Label Installation
1. Piping Color-Coding: Painting of piping is specified in Division 09 Section(s) "Interior Painting" OR "High-performance Coatings", **as directed**.

2. Stenciled Pipe Label Option: Stenciled labels may be provided instead of manufactured pipe labels, at Installer's option. Install stenciled pipe labels with painted, color-coded bands or rectangles **OR** complying with ASME A13.1**, as directed**, on each piping system.
   a. Identification Paint: Use for contrasting background.
   b. Stencil Paint: Use for pipe marking.
3. Locate pipe labels where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:
   a. Near each valve and control device.
   b. Near each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
   c. Near penetrations through walls, floors, ceilings, and inaccessible enclosures.
   d. At access doors, manholes, and similar access points that permit view of concealed piping.
   e. Near major equipment items and other points of origination and termination.
   f. Spaced at maximum intervals of 50 feet (15 m) along each run. Reduce intervals to 25 feet (7.6 m) in areas of congested piping and equipment.
   g. On piping above removable acoustical ceilings. Omit intermediately spaced labels.
4. Pipe Label Color Schedule:
   a. Chilled-Water Piping:
      1) Background Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
      2) Letter Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
   b. Condenser-Water Piping:
      1) Background Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
      2) Letter Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **asa directed**.
   c. Heating Water Piping:
      1) Background Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
      2) Letter Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
   d. Refrigerant Piping:
      1) Background Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
      2) Letter Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
   e. Low-Pressure Steam Piping:
      1) Background Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
      2) Letter Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
   f. High-Pressure Steam Piping:
      1) Background Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
      2) Letter Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
   g. Steam Condensate Piping:
      1) Background Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.
      2) Letter Color: Black **OR** Blue **OR** Red **OR** White **OR** Yellow, **as directed**.

D. Duct Label Installation
1. Install plastic-laminated **OR** self-adhesive, **as directed**, duct labels with permanent adhesive on air ducts in the following color codes:
   a. Blue: For cold-air supply ducts.
   b. Yellow: For hot-air supply ducts.
   c. Green: For exhaust-, outside-, relief-, return-, and mixed-air ducts.
   d. ASME A13.1 Colors and Designs: For hazardous material exhaust.
2. Stenciled Duct Label Option: Stenciled labels, showing service and flow direction, may be provided instead of plastic-laminated duct labels, at Installer's option, if lettering larger than 1 inch (25 mm) high is needed for proper identification because of distance from normal location of required identification.
3. Locate labels near points where ducts enter into concealed spaces and at maximum intervals of 50 feet (15 m) in each space where ducts are exposed or concealed by removable ceiling system.

E. Valve-Tag Installation
1. Install tags on valves and control devices in piping systems, except check valves; valves within factory-fabricated equipment units; shutoff valves; faucets; convenience and lawn-watering hose connections; and HVAC terminal devices and similar roughing-in connections of end-use fixtures and units. List tagged valves in a valve schedule.
2. Valve-Tag Application Schedule: Tag valves according to size, shape, and color scheme and with captions similar to those indicated in the following subparagraphs:
   a. Valve-Tag Size and Shape:
      1) Chilled Water: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, round **OR** square, **as directed**.
      2) Condenser Water: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, round **OR** square, **as directed**.
      3) Refrigerant: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, round **OR** square, **as directed**.
      4) Hot Water: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, round **OR** square, **as directed**.
      5) Gas: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, round **OR** square, **as directed**.
      6) Low-Pressure Steam: 1-1/2 inches (38 mm)2 inches (50 mm), **as directed**, round **OR** square, **as directed**.
      7) High-Pressure Steam: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, round **OR** square, **as directed**.
      8) Steam Condensate: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, round **OR** square, **as directed**.
   b. Valve-Tag Color:
      1) Chilled Water: Natural **OR** Green, **as directed.**
      2) Condenser Water: Natural **OR** Green, **as directed.**
      3) Refrigerant: Natural **OR** Green, **as directed**.
      4) Hot Water: Natural **OR** Green, **as directed**.
      5) Gas: Natural **OR** Yellow, **as directed**.
      6) Low-Pressure Steam: Natural **OR** Yellow, **as directed**.
      7) High-Pressure Steam: Natural **OR** Green, **as directed**.
      8) Steam Condensate: Natural **OR** Green, **as directed**.
   c. Letter Color:
      1) Chilled Water: Black **OR** White, **as directed**.
      2) Condenser Water: Black **OR** White, **as directed**.
      3) Refrigerant: Black **OR** White, **as directed**.
      4) Hot Water: Black **OR** White, **as directed**.
      5) Gas: Black **OR** White, **as directed**.
      6) Low-Pressure Steam: Black **OR** White, **as directed**.
      7) High-Pressure Steam: Black **OR** White, **as directed**.
      8) Steam Condensate: Black **OR** White, **as directed**.

F. Warning-Tag Installation
1. Write required message on, and attach warning tags to, equipment and other items where required.

END OF SECTION 23 05 53 00

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Task	Specification	Specification Description
23 05 53 00	22 05 53 00	Identification for Plumbing Piping and Equipment
23 05 53 00	23 01 10 00	Sequence Of Operation
23 05 93 00	01 71 23 16	Cutting and Patching
23 05 93 00	02 41 16 13	Selective Demolition
23 05 93 00	23 01 10 00	Sequence Of Operation
23 05 93 00	23 01 10 00a	Testing, Adjusting, And Balancing

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SECTION 23 07 13 00 - HVAC INSULATION

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for HVAC insulation. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the products manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Insulation Materials:
1) Calcium silicate.
2) Cellular glass.
3) Flexible elastomeric.
4) Mineral fiber.
5) Phenolic.
6) Polyisocyanurate.
7) Polyolefin.
8) Polystyrene.
b. Fire-rated insulation systems.
c. Insulating cements.
d. Adhesives.
e. Mastics.
f. Lagging adhesives.
g. Sealants.
h. Factory-applied jackets.
i. Field-applied fabric-reinforcing mesh.
j. Field-applied cloths.
k. Field-applied jackets.
l. Tapes.
m. Securements.
n. Corner angles.

C. Submittals
1. Product Data: For each type of product indicated.
2. LEED Submittal:
a. Product Data for Credit EQ 4.1: For adhesives and sealants, including printed statement of VOC content.
3. Shop Drawings:
a. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
b. Detail attachment and covering of heat tracing inside insulation.
c. Detail insulation application at pipe expansion joints for each type of insulation.
d. Detail insulation application at elbows, fittings, flanges, valves, and specialties for each type of insulation.
e. Detail removable insulation at piping specialties, equipment connections, and access panels.
f. Detail application of field-applied jackets.
g. Detail application at linkages of control devices.
h. Detail field application for each equipment type.
4. Field quality-control reports.

D. Quality Assurance
1. Fire-Test-Response Characteristics: Insulation and related materials shall have fire-test-response characteristics indicated, as determined by testing identical products per ASTM E 84, by a testing and inspecting agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing and inspecting agency.
   a. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
   b. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

E. Delivery, Storage, And Handling
1. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

1.2 PRODUCTS

A. Insulation Materials
1. Comply with requirements in Part 1.3 schedule articles for where insulating materials shall be applied.
2. Products shall not contain asbestos, lead, mercury, or mercury compounds.
3. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.
4. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.
5. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.
6. Calcium Silicate:
   a. Preformed Pipe Sections: Flat-, curved-, and grooved-block sections of noncombustible, inorganic, hydrous calcium silicate with a non-asbestos fibrous reinforcement. Comply with ASTM C 533, Type I.
   b. Flat-, curved-, and grooved-block sections of noncombustible, inorganic, hydrous calcium silicate with a non-asbestos fibrous reinforcement. Comply with ASTM C 533, Type I.
   c. Prefabricated Fitting Covers: Comply with ASTM C 450 and ASTM C 585 for dimensions used in preforming insulation to cover valves, elbows, tees, and flanges.
7. Cellular Glass: Inorganic, incombustible, foamed or cellulated glass with annealed, rigid, hermetically sealed cells. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
   a. Block Insulation: ASTM C 552, Type I.
   b. Special-Shaped Insulation: ASTM C 552, Type III.
   c. Board Insulation: ASTM C 552, Type IV.
   d. Preformed Pipe Insulation without Jacket: Comply with ASTM C 552, Type II, Class 1.
   e. Preformed Pipe Insulation with Factory-Applied ASJ **OR** ASJ-SSL, **as directed**: Comply with ASTM C 552, Type II, Class 2.
   f. Factory fabricate shapes according to ASTM C 450 and ASTM C 585.
8. Flexible Elastomeric: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534, Type I for tubular materials and Type II for sheet materials.
9. Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 553, Type II and ASTM C 1290, Type I **OR** II with factory-applied vinyl jacket **OR** III with factory-applied FSK jacket **OR** III with factory-applied FSP jacket, **as directed**. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
10. High-Temperature, Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 553, Type V, without factory-applied jacket.

11. Mineral-Fiber Board Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 612, Type IA or Type IB. For duct and plenum applications, provide insulation without factory-applied jacket **OR** with factory-applied ASJ **OR** with factory-applied FSK jacket, **as directed**. For equipment applications, provide insulation without factory-applied jacket **OR** with factory-applied ASJ **OR** with factory-applied FSK jacket, **as directed**. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
12. High-Temperature, Mineral-Fiber Board Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 612, Type III, without factory-applied jacket.
13. Mineral-Fiber, Preformed Pipe Insulation:
    a. Type I, 850 deg F (454 deg C) Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type I, Grade A, without factory-applied jacket **OR** with factory-applied ASJ **OR** with factory-applied ASJ-SSL, **as directed**. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
    b. Type II, 1200 deg F (649 deg C) Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type II, Grade A, without factory-applied jacket **OR** with factory-applied ASJ **OR** with factory-applied ASJ-SSL, **as directed**. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
14. Mineral-Fiber, Pipe Insulation Wicking System: Preformed pipe insulation complying with ASTM C 547, Type I, Grade A, with absorbent cloth factory applied to the entire inside surface of preformed pipe insulation and extended through the longitudinal joint to outside surface of insulation under insulation jacket. Factory apply a white, polymer, vapor-retarder jacket with self-sealing adhesive tape seam and evaporation holes running continuously along the longitudinal seam, exposing the absorbent cloth.
15. Mineral-Fiber, Pipe and Tank Insulation: Mineral or glass fibers bonded with a thermosetting resin. Semirigid board material with factory-applied ASJ **OR** FSK jacket, **as directed**, complying with ASTM C 1393, Type II or Type IIIA Category 2, or with properties similar to ASTM C 612, Type IB. Nominal density is 2.5 lb/cu. ft. (40 kg/cu. m) or more. Thermal conductivity (k-value) at 100 deg F (55 deg C) is 0.29 Btu x in./h x sq. ft. x deg F (0.042 W/m x K) or less. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.
16. Phenolic:
    a. Preformed pipe insulation of rigid, expanded, closed-cell structure. Comply with ASTM C 1126, Type III, Grade 1.
    b. Block insulation of rigid, expanded, closed-cell structure. Comply with ASTM C 1126, Type II, Grade 1.
    c. Factory fabricate shapes according to ASTM C 450 and ASTM C 585.
    d. Factory-Applied Jacket: Requirements are specified in "Factory-Applied Jackets" Article.
        1) Preformed Pipe Insulation: None **OR** ASJ, **as directed**.
        2) Board for Duct and Plenum Applications: None **OR** ASJ, **as directed**.
        3) Board for Equipment Applications: None **OR** ASJ, **as directed**.
17. Polyisocyanurate: Unfaced, preformed, rigid cellular polyisocyanurate material intended for use as thermal insulation.
    a. Comply with ASTM C 591, Type I or Type IV, except thermal conductivity (k-value) shall not exceed 0.19 Btu x in./h x sq. ft. x deg F (0.027 W/m x K) at 75 deg F (24 deg C) after 180 days of aging.
    b. Flame-spread index shall be 25 or less and smoke-developed index shall be 50 or less for thickness up to 1-1/2 inches (38 mm) as tested by ASTM E 84.
    c. Fabricate shapes according to ASTM C 450 and ASTM C 585.
    d. Factory-Applied Jacket: Requirements are specified in "Factory-Applied Jackets" Article.
        1) Pipe Applications: None **OR** ASJ **OR** ASJ-SSL **OR** PVDC **OR** PVDC-SSL, **as directed**.
        2) Equipment Applications: None **OR** ASJ **OR** ASJ-SSL **OR** PVDC **OR** PVDC-SSL, **as directed**.
18. Polyolefin: Unicellular, polyethylene thermal plastic insulation. Comply with ASTM C 534 or ASTM C 1427, Type I, Grade 1 for tubular materials and Type II, Grade 1 for sheet materials.
19. Polystyrene: Rigid, extruded cellular polystyrene intended for use as thermal insulation. Comply with ASTM C 578, Type IV or Type XIII, except thermal conductivity (k-value) shall not exceed

0.26 Btu x in./h x sq. ft. x deg F (0.038 W/m x K) after 180 days of aging. Fabricate shapes according to ASTM C 450 and ASTM C 585.

B. Fire-Rated Insulation Systems
1. Fire-Rated Board: Structural-grade, press-molded, xonolite calcium silicate, fireproofing board suitable for operating temperatures up to 1700 deg F (927 deg C). Comply with ASTM C 656, Type II, Grade 6. tested and certified to provide a 1-hour **OR** 2-hour, **as directed**, fire rating by a NRTL acceptable to authority having jurisdiction.
2. Fire-Rated Blanket: High-temperature, flexible, blanket insulation with FSK jacket that is tested and certified to provide a 1-hour **OR** 2-hour, **as directed**, fire rating by a NRTL acceptable to authority having jurisdiction.

C. Insulating Cements
1. Mineral-Fiber Insulating Cement: Comply with ASTM C 195.
2. Expanded or Exfoliated Vermiculite Insulating Cement: Comply with ASTM C 196.
3. Mineral-Fiber, Hydraulic-Setting Insulating and Finishing Cement: Comply with ASTM C 449/C 449M.

D. Adhesives
1. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated, unless otherwise indicated.
2. Calcium Silicate Adhesive: Fibrous, sodium-silicate-based adhesive with a service temperature range of 50 to 800 deg F (10 to 427 deg C).
   a. For indoor applications, use adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
3. Cellular-Glass, Phenolic, Polyisocyanurate, and Polystyrene Adhesive: Solvent-based resin adhesive, with a service temperature range of minus 75 to plus 300 deg F (minus 59 to plus 149 deg C).
   a. For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
4. Flexible Elastomeric and Polyolefin Adhesive: Comply with MIL-A-24179A, Type II, Class I.
   a. For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
5. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.
   a. For indoor applications, use adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
6. Polystyrene Adhesive: Solvent- or water-based, synthetic resin adhesive with a service temperature range of minus 20 to plus 140 deg F (29 to plus 60 deg C).
7. ASJ Adhesive, and FSK and PVDC Jacket Adhesive: Comply with MIL-A-3316C, Class 2, Grade A for bonding insulation jacket lap seams and joints.
   a. For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
8. PVC Jacket Adhesive: Compatible with PVC jacket.
   a. For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

E. Mastics
1. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-C-19565C, Type II.
   a. For indoor applications, use mastics that have an approved VOC content or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. Vapor-Barrier Mastic: Water based; suitable for indoor and outdoor use on below ambient services.
   a. Water-Vapor Permeance: ASTM E 96, Procedure B, 0.013 perm (0.009 metric perm) at 43-mil (1.09-mm) dry film thickness.

b. Service Temperature Range: Minus 20 to plus 180 deg F (Minus 29 to plus 82 deg C).
c. Solids Content: ASTM D 1644, 59 percent by volume and 71 percent by weight.
d. Color: White.

3. Vapor-Barrier Mastic: Solvent based; suitable for indoor use on below ambient services.
   a. Water-Vapor Permeance: ASTM F 1249, 0.05 perm (0.03 metric perm) at 35-mil (0.9-mm) dry film thickness.
   b. Service Temperature Range: 0 to 180 deg F (Minus 18 to plus 82 deg C).
   c. Solids Content: ASTM D 1644, 44 percent by volume and 62 percent by weight.
   d. Color: White.
4. Vapor-Barrier Mastic: Solvent based; suitable for outdoor use on below ambient services.
   a. Water-Vapor Permeance: ASTM F 1249, 0.05 perm (0.033 metric perm) at 30-mil (0.8-mm) dry film thickness.
   b. Service Temperature Range: Minus 50 to plus 220 deg F (Minus 46 to plus 104 deg C).
   c. Solids Content: ASTM D 1644, 33 percent by volume and 46 percent by weight.
   d. Color: White.
5. Breather Mastic: Water based; suitable for indoor and outdoor use on above ambient services.
   a. Water-Vapor Permeance: ASTM F 1249, 3 perms (2 metric perms) at 0.0625-inch (1.6-mm) dry film thickness.
   b. Service Temperature Range: Minus 20 to plus 200 deg F (Minus 29 to plus 93 deg C).
   c. Solids Content: 63 percent by volume and 73 percent by weight.
   d. Color: White.

F. Lagging Adhesives
1. Description: Comply with MIL-A-3316C Class I, Grade A and shall be compatible with insulation materials, jackets, and substrates.
   a. For indoor applications, use lagging adhesives that have an approved VOC content when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
   b. Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over duct, equipment, and pipe insulation.
   c. Service Temperature Range: Minus 50 to plus 180 deg F (Minus 46 to plus 82 deg C).
   d. Color: White.

G. Sealants
1. Joint Sealants:
   a. Materials shall be compatible with insulation materials, jackets, and substrates.
   b. Permanently flexible, elastomeric sealant.
   c. Service Temperature Range: Minus 100 to plus 300 deg F (Minus 73 to plus 149 deg C).
   d. Color: White or gray.
   e. For indoor applications, use sealants that have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. FSK and Metal Jacket Flashing Sealants:
   a. Materials shall be compatible with insulation materials, jackets, and substrates.
   b. Fire- and water-resistant, flexible, elastomeric sealant.
   c. Service Temperature Range: Minus 40 to plus 250 deg F (Minus 40 to plus 121 deg C).
   d. Color: Aluminum.
   e. For indoor applications, use sealants that have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
3. ASJ Flashing Sealants, and Vinyl, PVDC, and PVC Jacket Flashing Sealants:
   a. Materials shall be compatible with insulation materials, jackets, and substrates.
   b. Fire- and water-resistant, flexible, elastomeric sealant.
   c. Service Temperature Range: Minus 40 to plus 250 deg F (Minus 40 to plus 121 deg C).
   d. Color: White.
   e. For indoor applications, use sealants that have a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

H. Factory-Applied Jackets

1. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:
   a. ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C 1136, Type I.
   b. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C 1136, Type I.
   c. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C 1136, Type II.
   d. FSP Jacket: Aluminum-foil, fiberglass-reinforced scrim with polyethylene backing; complying with ASTM C 1136, Type II.
   e. PVDC Jacket for Indoor Applications: 4-mil- (0.10-mm-) thick, white PVDC biaxially oriented barrier film with a permeance at 0.02 perms (0.013 metric perms) when tested according to ASTM E 96 and with a flame-spread index of 5 and a smoke-developed index of 20 when tested according to ASTM E 84.
   f. PVDC Jacket for Outdoor Applications: 6-mil- (0.15-mm-) thick, white PVDC biaxially oriented barrier film with a permeance at 0.01 perms (0.007 metric perms) when tested according to ASTM E 96 and with a flame-spread index of 5 and a smoke-developed index of 25 when tested according to ASTM E 84.
   g. PVDC-SSL Jacket: PVDC jacket with a self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip.

I. Vinyl Jacket: White vinyl with a permeance of 1.3 perms (0.86 metric perms) when tested according to ASTM E 96, Procedure A, and complying with NFPA 90A and NFPA 90B.

J. Field-Applied Fabric-Reinforcing Mesh
1. Woven Glass-Fiber Fabric for Pipe Insulation: Approximately 2 oz./sq. yd. (68 g/sq. m) with a thread count of 10 strands by 10 strands/sq. inch (4 strands by 4 strands/sq. mm) for covering pipe and pipe fittings.
2. Woven Glass-Fiber Fabric for Duct and Equipment Insulation: Approximately 6 oz./sq. yd. (203 g/sq. m) with a thread count of 5 strands by 5 strands/sq. inch (2 strands by 2 strands/sq. mm) for covering equipment.
3. Woven Polyester Fabric: Approximately 1 oz./sq. yd. (34 g/sq. m) with a thread count of 10 strands by 10 strands/sq. inch (4 strands by 4 strands/sq. mm), in a Leno weave, for duct, equipment, and pipe.

K. Field-Applied Cloths
1. Woven Glass-Fiber Fabric: Comply with MIL-C-20079H, Type I, plain weave, and presized a minimum of 8 oz./sq. yd. (271 g/sq. m).

L. Field-Applied Jackets
1. Field-applied jackets shall comply with ASTM C 921, Type I, unless otherwise indicated.
2. FSK Jacket: Aluminum-foil-face, fiberglass-reinforced scrim with kraft-paper backing.
3. PVC Jacket: High-impact-resistant, UV-resistant PVC complying with ASTM D 1784, Class 16354-C; thickness as scheduled; roll stock ready for shop or field cutting and forming. Thickness is indicated in field-applied jacket schedules.
   a. Adhesive: As recommended by jacket material manufacturer.
   b. Color: White **OR** Color-code jackets based on system. Color as selected by the Owner, **as directed**.
   c. Factory-fabricated fitting covers to match jacket if available; otherwise, field fabricate.
      1) Shapes: 45- and 90-degree, short- and long-radius elbows, tees, valves, flanges, unions, reducers, end caps, soil-pipe hubs, traps, mechanical joints, and P-trap and supply covers for lavatories.
   d. Factory-fabricated tank heads and tank side panels.
4. Metal Jacket:

a. Aluminum Jacket: Comply with ASTM B 209 (ASTM B 209M), Alloy 3003, 3005, 3105 or 5005, Temper H-14.
   1) Sheet and roll stock ready for shop or field sizing **OR** Factory cut and rolled to size, **as directed**.
   2) Finish and thickness are indicated in field-applied jacket schedules.
   3) Moisture Barrier for Indoor Applications: 1-mil- (0.025-mm-) thick, heat-bonded polyethylene and kraft paper **OR** 3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper **OR** 2.5-mil- (0.063-mm-) thick Polysurlyn, **as directed**.
   4) Moisture Barrier for Outdoor Applications: 3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper **OR** 2.5-mil- (0.063-mm-) thick Polysurlyn, **as directed**.
   5) Factory-Fabricated Fitting Covers:
      a) Same material, finish, and thickness as jacket.
      b) Preformed 2-piece or gore, 45- and 90-degree, short- and long-radius elbows.
      c) Tee covers.
      d) Flange and union covers.
      e) End caps.
      f) Beveled collars.
      g) Valve covers.
      h) Field fabricate fitting covers only if factory-fabricated fitting covers are not available.

b. Stainless-Steel Jacket: ASTM A 167 or ASTM A 240/A 240M.
   1) Sheet and roll stock ready for shop or field sizing **OR** Factory cut and rolled to size, **as directed**.
   2) Material, finish, and thickness are indicated in field-applied jacket schedules.
   3) Moisture Barrier for Indoor Applications: 1-mil- (0.025-mm-) thick, heat-bonded polyethylene and kraft paper **OR** 3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper **OR** 2.5-mil- (0.063-mm-) thick Polysurlyn, **as directed**.
   4) Moisture Barrier for Outdoor Applications: 3-mil- (0.075-mm-) thick, heat-bonded polyethylene and kraft paper **OR** 2.5-mil- (0.063-mm-) thick Polysurlyn, **as directed**.
   5) Factory-Fabricated Fitting Covers:
      a) Same material, finish, and thickness as jacket.
      b) Preformed 2-piece or gore, 45- and 90-degree, short- and long-radius elbows.
      c) Tee covers.
      d) Flange and union covers.
      e) End caps.
      f) Beveled collars.
      g) Valve covers.
      h) Field fabricate fitting covers only if factory-fabricated fitting covers are not available.

5. Underground Direct-Buried Jacket: 125-mil- (3.2-mm-) thick vapor barrier and waterproofing membrane consisting of a rubberized bituminous resin reinforced with a woven-glass fiber or polyester scrim and laminated aluminum foil.
6. Self-Adhesive Outdoor Jacket: 60-mil- (1.5-mm-) thick, laminated vapor barrier and waterproofing membrane for installation over insulation located aboveground outdoors; consisting of a rubberized bituminous resin on a crosslaminated polyethylene film covered with white **OR** stucco-embossed, **as directed**, aluminum-foil facing.
7. PVDC Jacket for Indoor Applications: 4-mil- (0.10-mm-) thick, white PVDC biaxially oriented barrier film with a permeance at 0.02 perms (0.013 metric perms) when tested according to ASTM E 96 and with a flame-spread index of 5 and a smoke-developed index of 20 when tested according to ASTM E 84.
8. PVDC Jacket for Outdoor Applications: 6-mil- (0.15-mm-) thick, white PVDC biaxially oriented barrier film with a permeance at 0.01 perms (0.007 metric perms) when tested according to ASTM E 96 and with a flame-spread index of 5 and a smoke-developed index of 25 when tested according to ASTM E 84.
9. PVDC-SSL Jacket: PVDC jacket with a self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip.

M. Tapes
1. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C 1136.
   a. Width: 3 inches (75 mm).
   b. Thickness: 11.5 mils (0.29 mm).
   c. Adhesion: 90 ounces force/inch (1.0 N/mm) in width.
   d. Elongation: 2 percent.
   e. Tensile Strength: 40 lbf/inch (7.2 N/mm) in width.
   f. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.
2. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C 1136.
   a. Width: 3 inches (75 mm).
   b. Thickness: 6.5 mils (0.16 mm).
   c. Adhesion: 90 ounces force/inch (1.0 N/mm) in width.
   d. Elongation: 2 percent.
   e. Tensile Strength: 40 lbf/inch (7.2 N/mm) in width.
   f. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.
3. PVC Tape: White vapor-retarder tape matching field-applied PVC jacket with acrylic adhesive. Suitable for indoor and outdoor applications.
   a. Width: 2 inches (50 mm).
   b. Thickness: 6 mils (0.15 mm).
   c. Adhesion: 64 ounces force/inch (0.7 N/mm) in width.
   d. Elongation: 500 percent.
   e. Tensile Strength: 18 lbf/inch (3.3 N/mm) in width.
4. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.
   a. Width: 2 inches (50 mm).
   b. Thickness: 3.7 mils (0.093 mm).
   c. Adhesion: 100 ounces force/inch (1.1 N/mm) in width.
   d. Elongation: 5 percent.
   e. Tensile Strength: 34 lbf/inch (6.2 N/mm) in width.
5. PVDC Tape for Indoor Applications: White vapor-retarder PVDC tape with acrylic adhesive.
   a. Width: 3 inches (75 mm).
   b. Film Thickness: 4 mils (0.10 mm).
   c. Adhesive Thickness: 1.5 mils (0.04 mm).
   d. Elongation at Break: 145 percent.
   e. Tensile Strength: 55 lbf/inch (10.1 N/mm) in width.
6. PVDC Tape for Outdoor Applications: White vapor-retarder PVDC tape with acrylic adhesive.
   a. Width: 3 inches (75 mm).
   b. Film Thickness: 6 mils (0.15 mm).
   c. Adhesive Thickness: 1.5 mils (0.04 mm).
   d. Elongation at Break: 145 percent.
   e. Tensile Strength: 55 lbf/inch (10.1 N/mm) in width.

N. Securements
1. Bands:
   a. Stainless Steel: ASTM A 167 or ASTM A 240/A 240M, Type 304 **OR** Type 316, **as directed**; 0.015 inch (0.38 mm) thick, 1/2 inch (13 mm) **OR** 3/4 inch (19 mm), **as directed**, wide with wing seal **OR** closed seal, **as directed**.
   b. Aluminum: ASTM B 209 (ASTM B 209M), Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch (0.51 mm) thick, 1/2 inch (13 mm) **OR** 3/4 inch (19 mm), **as directed**, wide with wing seal **OR** closed seal, **as directed**.
   c. Springs: Twin spring set constructed of stainless steel with ends flat and slotted to accept metal bands. Spring size determined by manufacturer for application.
2. Insulation Pins and Hangers:

a. Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.106-inch- (2.6-mm-) **OR** 0.135-inch- (3.5-mm-), **as directed**, diameter shank, length to suit depth of insulation indicated.

b. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.106-inch- (2.6-mm-) **OR** 0.135-inch- (3.5-mm-), **as directed**, diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch (38-mm) galvanized carbon-steel washer.

c. Metal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

1) Baseplate: Perforated, galvanized carbon-steel sheet, 0.030 inch (0.76 mm) thick by 2 inches (50 mm) square.

2) Spindle: Copper- or zinc-coated, low carbon steel **OR** Aluminum **OR** Stainless steel, **as directed**, fully annealed, 0.106-inch- (2.6-mm-) diameter shank, length to suit depth of insulation indicated.

3) Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

d. Nonmetal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate fastened to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

1) Baseplate: Perforated, nylon sheet, 0.030 inch (0.76 mm) thick by 1-1/2 inches (38 mm) in diameter.

2) Spindle: Nylon, 0.106-inch- (2.6-mm-) diameter shank, length to suit depth of insulation indicated, up to 2-1/2 inches (63 mm).

3) Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

e. Self-Sticking-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

1) Baseplate: Galvanized carbon-steel sheet, 0.030 inch (0.76 mm) thick by 2 inches (50 mm) square.

2) Spindle: Copper- or zinc-coated, low carbon steel **OR** Aluminum **OR** Stainless steel, **as directed**, fully annealed, 0.106-inch- (2.6-mm-) diameter shank, length to suit depth of insulation indicated.

3) Adhesive-backed base with a peel-off protective cover.

f. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- (0.41-mm-) thick, galvanized-steel **OR** aluminum **OR** stainless-steel, **as directed**, sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches (38 mm) in diameter.

1) Protect ends with capped self-locking washers incorporating a spring steel insert to ensure permanent retention of cap in exposed locations.

g. Nonmetal Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- (0.41-mm-) thick nylon sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches (38 mm) in diameter.

3. Staples: Outward-clinching insulation staples, nominal 3/4-inch- (19-mm-) wide, stainless steel or Monel.

4. Wire: 0.080-inch (2.0-mm) nickel-copper alloy **OR** 0.062-inch (1.6-mm) soft-annealed, stainless steel **OR** 0.062-inch (1.6-mm) soft-annealed, galvanized steel, **as directed**.

O. Corner Angles

1. PVC Corner Angles: 30 mils (0.8 mm) thick, minimum 1 by 1 inch (25 by 25 mm), PVC according to ASTM D 1784, Class 16354-C. White or color-coded to match adjacent surface.

2. Aluminum Corner Angles: 0.040 inch (1.0 mm) thick, minimum 1 by 1 inch (25 by 25 mm), aluminum according to ASTM B 209 (ASTM B 209M), Alloy 3003, 3005, 3105 or 5005; Temper H-14.
3. Stainless-Steel Corner Angles: 0.024 inch (0.61 mm) thick, minimum 1 by 1 inch (25 by 25 mm), stainless steel according to ASTM A 167 or ASTM A 240/A 240M, Type 304 **OR** Type 316, **as directed**.

1.3 EXECUTION

A. Preparation
1. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.
   OR
   Surface Preparation: Clean and prepare surfaces to be insulated. Before insulating, apply a corrosion coating to insulated surfaces as follows:
   a. Stainless Steel: Coat 300 series stainless steel with an epoxy primer 5 mils (0.127 mm) thick and an epoxy finish 5 mils (0.127 mm) thick if operating in a temperature range between 140 and 300 deg F (60 and 149 deg C). Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
   b. Carbon Steel: Coat carbon steel operating at a service temperature between 32 and 300 deg F (0 and 149 deg C) with an epoxy coating. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
2. Coordinate insulation installation with the trade installing heat tracing. Comply with requirements for heat tracing that apply to insulation.
3. Mix insulating cements with clean potable water; if insulating cements are to be in contact with stainless-steel surfaces, use demineralized water.

B. General Installation Requirements
1. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of equipment, ducts and fittings, and piping including fittings, valves, and specialties.
2. Install insulation materials, forms, vapor barriers or retarders, jackets, and thicknesses required for each item of equipment, duct system, and pipe system as specified in insulation system schedules.
3. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.
4. Install insulation with longitudinal seams at top and bottom of horizontal runs.
5. Install multiple layers of insulation with longitudinal and end seams staggered.
6. Do not weld brackets, clips, or other attachment devices to piping, fittings, and specialties.
7. Keep insulation materials dry during application and finishing.
8. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.
9. Install insulation with least number of joints practical.
10. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.
    a. Install insulation continuously through hangers and around anchor attachments.
    b. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.
    c. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.

d. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.

11. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.
12. Install insulation with factory-applied jackets as follows:
    a. Draw jacket tight and smooth.
    b. Cover circumferential joints with 3-inch- (75-mm-) wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches (100 mm) o.c.
    c. Overlap jacket longitudinal seams at least 1-1/2 inches (38 mm). Install insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 2 inches (50 mm) **OR** 4 inches (100 mm), **as directed**, o.c.
        1) For below ambient services, apply vapor-barrier mastic over staples.
    d. Cover joints and seams with tape as recommended by insulation material manufacturer to maintain vapor seal.
    e. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to duct and pipe flanges and fittings.
13. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.
14. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.
15. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches (100 mm) beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.
16. For above ambient services, do not install insulation to the following:
    a. Vibration-control devices.
    b. Testing agency labels and stamps.
    c. Nameplates and data plates.
    d. Manholes.
    e. Handholes.
    f. Cleanouts.

C. Penetrations

1. Insulation Installation at Roof Penetrations: Install insulation continuously through roof penetrations.
    a. Seal penetrations with flashing sealant.
    b. For applications requiring only indoor insulation, terminate insulation above roof surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
    c. Extend jacket of outdoor insulation outside roof flashing at least 2 inches (50 mm) below top of roof flashing.
    d. Seal jacket to roof flashing with flashing sealant.
2. Insulation Installation at Underground Exterior Wall Penetrations: Terminate insulation flush with sleeve seal. Seal terminations with flashing sealant.
3. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.
    a. Seal penetrations with flashing sealant.
    b. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
    c. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least 2 inches (50 mm).
    d. Seal jacket to wall flashing with flashing sealant.

4. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.
5. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Install insulation continuously through penetrations of fire-rated walls and partitions. Terminate insulation at fire damper sleeves for fire-rated wall and partition penetrations. Externally insulate damper sleeves to match adjacent insulation and overlap duct insulation at least 2 inches (50 mm).
   a. Comply with requirements in Division 07 Section "Penetration Firestopping" for firestopping and fire-resistive joint sealers.
6. Insulation Installation at Floor Penetrations:
   a. Duct: Install insulation continuously through floor penetrations that are not fire rated. For penetrations through fire-rated assemblies, terminate insulation at fire damper sleeves and externally insulate damper sleeve beyond floor to match adjacent duct insulation. Overlap damper sleeve and duct insulation at least 2 inches (50 mm).
   b. Pipe: Install insulation continuously through floor penetrations.
   c. Seal penetrations through fire-rated assemblies. Comply with requirements in Division 07 Section "Penetration Firestopping".

D. Equipment, Tank, And Vessel Insulation Installation
1. Mineral Fiber, Pipe and Tank Insulation Installation for Tanks and Vessels: Secure insulation with adhesive and anchor pins and speed washers.
   a. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 100 **OR** 50, **as directed**, percent coverage of tank and vessel surfaces.
   b. Groove and score insulation materials to fit as closely as possible to equipment, including contours. Bevel insulation edges for cylindrical surfaces for tight joints. Stagger end joints.
   c. Protect exposed corners with secured corner angles.
   d. Install adhesively attached or self-sticking insulation hangers and speed washers on sides of tanks and vessels as follows:
      1) Do not weld anchor pins to ASME-labeled pressure vessels.
      2) Select insulation hangers and adhesive that are compatible with service temperature and with substrate.
      3) On tanks and vessels, maximum anchor-pin spacing is 3 inches (75 mm) from insulation end joints, and 16 inches (400 mm) o.c. in both directions.
      4) Do not overcompress insulation during installation.
      5) Cut and miter insulation segments to fit curved sides and domed heads of tanks and vessels.
      6) Impale insulation over anchor pins and attach speed washers.
      7) Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.
   e. Secure each layer of insulation with stainless-steel or aluminum bands. Select band material compatible with insulation materials.
   f. Where insulation hangers on equipment and vessels are not permitted or practical and where insulation support rings are not provided, install a girdle network for securing insulation. Stretch prestressed aircraft cable around the diameter of vessel and make taut with clamps, turnbuckles, or breather springs. Place one circumferential girdle around equipment approximately 6 inches (150 mm) from each end. Install wire or cable between two circumferential girdles 12 inches (300 mm) o.c. Install a wire ring around each end and around outer periphery of center openings, and stretch prestressed aircraft cable radially from the wire ring to nearest circumferential girdle. Install additional circumferential girdles along the body of equipment or tank at a minimum spacing of 48 inches (1200 mm) o.c. Use this network for securing insulation with tie wire or bands.
   g. Stagger joints between insulation layers at least 3 inches (75 mm).
   h. Install insulation in removable segments on equipment access doors, manholes, handholes, and other elements that require frequent removal for service and inspection.

i. Bevel and seal insulation ends around manholes, handholes, ASME stamps, and nameplates.
j. For equipment with surface temperatures below ambient, apply mastic to open ends, joints, seams, breaks, and punctures in insulation.

2. Flexible Elastomeric Thermal Insulation Installation for Tanks and Vessels: Install insulation over entire surface of tanks and vessels.
   a. Apply 100 percent coverage of adhesive to surface with manufacturer's recommended adhesive.
   b. Seal longitudinal seams and end joints.
3. Insulation Installation on Pumps:
   a. Fabricate metal boxes lined with insulation. Fit boxes around pumps and coincide box joints with splits in pump casings. Fabricate joints with outward bolted flanges. Bolt flanges on 6-inch (150-mm) centers, starting at corners. Install 3/8-inch- (10-mm-) diameter fasteners with wing nuts. Alternatively, secure the box sections together using a latching mechanism.
   b. Fabricate boxes from galvanized steel **OR** aluminum **OR** stainless steel, **as directed**, at least 0.040 inch (1.0 mm) **OR** 0.050 inch (1.3 mm) **OR** 0.060 inch (1.6 mm), **as directed**, thick.
   c. For below ambient services, install a vapor barrier at seams, joints, and penetrations. Seal between flanges with replaceable gasket material to form a vapor barrier.

E. General Pipe Insulation Installation
1. Requirements in this article generally apply to all insulation materials except where more specific requirements are specified in various pipe insulation material installation articles.
2. Insulation Installation on Fittings, Valves, Strainers, Flanges, and Unions:
   a. Install insulation over fittings, valves, strainers, flanges, unions, and other specialties with continuous thermal and vapor-retarder integrity, unless otherwise indicated.
   b. Insulate pipe elbows using preformed fitting insulation or mitered fittings made from same material and density as adjacent pipe insulation. Each piece shall be butted tightly against adjoining piece and bonded with adhesive. Fill joints, seams, voids, and irregular surfaces with insulating cement finished to a smooth, hard, and uniform contour that is uniform with adjoining pipe insulation.
   c. Insulate tee fittings with preformed fitting insulation or sectional pipe insulation of same material and thickness as used for adjacent pipe. Cut sectional pipe insulation to fit. Butt each section closely to the next and hold in place with tie wire. Bond pieces with adhesive.
   d. Insulate valves using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. For valves, insulate up to and including the bonnets, valve stuffing-box studs, bolts, and nuts. Fill joints, seams, and irregular surfaces with insulating cement.
   e. Insulate strainers using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Fill joints, seams, and irregular surfaces with insulating cement. Insulate strainers so strainer basket flange or plug can be easily removed and replaced without damaging the insulation and jacket. Provide a removable reusable insulation cover. For below ambient services, provide a design that maintains vapor barrier.
   f. Insulate flanges and unions using a section of oversized preformed pipe insulation. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker.
   g. Cover segmented insulated surfaces with a layer of finishing cement and coat with a mastic. Install vapor-barrier mastic for below ambient services and a breather mastic for above ambient services. Reinforce the mastic with fabric-reinforcing mesh. Trowel the mastic to a smooth and well-shaped contour.
   h. For services not specified to receive a field-applied jacket except for flexible elastomeric and polyolefin, install fitted PVC cover over elbows, tees, strainers, valves, flanges, and

unions. Terminate ends with PVC end caps. Tape PVC covers to adjoining insulation facing using PVC tape.

i. Stencil or label the outside insulation jacket of each union with the word "UNION." Match size and color of pipe labels.

3. Insulate instrument connections for thermometers, pressure gages, pressure temperature taps, test connections, flow meters, sensors, switches, and transmitters on insulated pipes, vessels, and equipment. Shape insulation at these connections by tapering it to and around the connection with insulating cement and finish with finishing cement, mastic, and flashing sealant.

4. Install removable insulation covers at locations indicated. Installation shall conform to the following:

a. Make removable flange and union insulation from sectional pipe insulation of same thickness as that on adjoining pipe. Install same insulation jacket as adjoining pipe insulation.

b. When flange and union covers are made from sectional pipe insulation, extend insulation from flanges or union long at least two times the insulation thickness over adjacent pipe insulation on each side of flange or union. Secure flange cover in place with stainless-steel or aluminum bands. Select band material compatible with insulation and jacket.

c. Construct removable valve insulation covers in same manner as for flanges except divide the two-part section on the vertical center line of valve body.

d. When covers are made from block insulation, make two halves, each consisting of mitered blocks wired to stainless-steel fabric. Secure this wire frame, with its attached insulation, to flanges with tie wire. Extend insulation at least 2 inches (50 mm) over adjacent pipe insulation on each side of valve. Fill space between flange or union cover and pipe insulation with insulating cement. Finish cover assembly with insulating cement applied in two coats. After first coat is dry, apply and trowel second coat to a smooth finish.

e. Unless a PVC jacket is indicated in field-applied jacket schedules, finish exposed surfaces with a metal jacket.

F. Calcium Silicate Insulation Installation

1. Insulation Installation on Boiler Breechings and Ducts:

a. Secure single-layer insulation with stainless-steel bands at 12-inch (300-mm) intervals and tighten bands without deforming insulation material.

b. Install 2-layer insulation with joints tightly butted and staggered at least 3 inches (75 mm). Secure inner layer with wire spaced at 12-inch (300-mm) intervals. Secure outer layer with stainless-steel bands at 12-inch (300-mm) intervals.

c. On exposed applications without metal jacket, finish insulation surface with a skim coat of mineral-fiber, hydraulic-setting cement. When cement is dry, apply flood coat of lagging adhesive and press on one layer of glass cloth. Overlap edges at least 1 inch (25 mm). Apply finish coat of lagging adhesive over glass cloth. Thin finish coat to achieve smooth, uniform finish.

2. Insulation Installation on Straight Pipes and Tubes:

a. Secure single-layer insulation with stainless-steel bands at 12-inch (300-mm) intervals and tighten bands without deforming insulation materials.

b. Install 2-layer insulation with joints tightly butted and staggered at least 3 inches (75 mm). Secure inner layer with wire spaced at 12-inch (300-mm) intervals. Secure outer layer with stainless-steel bands at 12-inch (300-mm) intervals.

c. Apply a skim coat of mineral-fiber, hydraulic-setting cement to insulation surface. When cement is dry, apply flood coat of lagging adhesive and press on one layer of glass cloth or tape. Overlap edges at least 1 inch (25 mm). Apply finish coat of lagging adhesive over glass cloth or tape. Thin finish coat to achieve smooth, uniform finish.

3. Insulation Installation on Pipe Flanges:

a. Install preformed pipe insulation to outer diameter of pipe flange.

b. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.

c. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of block insulation of same material and thickness as pipe insulation.
d. Finish flange insulation same as pipe insulation.

4. Insulation Installation on Pipe Fittings and Elbows:
   a. Install preformed sections of same material as straight segments of pipe insulation when available. Secure according to manufacturer's written instructions.
   b. When preformed insulation sections of insulation are not available, install mitered sections of calcium silicate insulation. Secure insulation materials with wire or bands.
   c. Finish fittings insulation same as pipe insulation.
5. Insulation Installation on Valves and Pipe Specialties:
   a. Install mitered segments of calcium silicate insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
   b. Install insulation to flanges as specified for flange insulation application.
   c. Finish valve and specialty insulation same as pipe insulation.

G. Cellular-Glass Insulation Installation
1. Insulation Installation on Straight Pipes and Tubes:
   a. Secure each layer of insulation to pipe with wire or bands and tighten bands without deforming insulation materials.
   b. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
   c. For insulation with factory-applied jackets on above ambient services, secure laps with outward clinched staples at 6 inches (150 mm) o.c.
   d. For insulation with factory-applied jackets on below ambient services, do not staple longitudinal tabs but secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant.
2. Insulation Installation on Pipe Flanges:
   a. Install preformed pipe insulation to outer diameter of pipe flange.
   b. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
   c. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of cellular-glass block insulation of same thickness as pipe insulation.
   d. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch (25 mm), and seal joints with flashing sealant.
3. Insulation Installation on Pipe Fittings and Elbows:
   a. Install preformed sections of same material as straight segments of pipe insulation when available. Secure according to manufacturer's written instructions.
   b. When preformed sections of insulation are not available, install mitered sections of cellular-glass insulation. Secure insulation materials with wire or bands.
4. Insulation Installation on Valves and Pipe Specialties:
   a. Install preformed sections of cellular-glass insulation to valve body.
   b. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
   c. Install insulation to flanges as specified for flange insulation application.

H. Flexible Elastomeric Insulation Installation
1. Seal longitudinal seams and end joints with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.
2. Insulation Installation on Pipe Flanges:
   a. Install pipe insulation to outer diameter of pipe flange.
   b. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.

c. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of sheet insulation of same thickness as pipe insulation.
d. Secure insulation to flanges and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

3. Insulation Installation on Pipe Fittings and Elbows:
   a. Install mitered sections of pipe insulation.
   b. Secure insulation materials and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.
4. Insulation Installation on Valves and Pipe Specialties:
   a. Install preformed valve covers manufactured of same material as pipe insulation when available.
   b. When preformed valve covers are not available, install cut sections of pipe and sheet insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
   c. Install insulation to flanges as specified for flange insulation application.
   d. Secure insulation to valves and specialties and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

I. Mineral-Fiber Insulation Installation
1. Insulation Installation on Straight Pipes and Tubes:
   a. Secure each layer of preformed pipe insulation to pipe with wire or bands and tighten bands without deforming insulation materials.
   b. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
   c. For insulation with factory-applied jackets on above ambient surfaces, secure laps with outward clinched staples at 6 inches (150 mm) o.c.
   d. For insulation with factory-applied jackets on below ambient surfaces, do not staple longitudinal tabs but secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant.
2. Insulation Installation on Pipe Flanges:
   a. Install preformed pipe insulation to outer diameter of pipe flange.
   b. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
   c. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with mineral-fiber blanket insulation.
   d. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch (25 mm), and seal joints with flashing sealant.
3. Insulation Installation on Pipe Fittings and Elbows:
   a. Install preformed sections of same material as straight segments of pipe insulation when available.
   b. When preformed insulation elbows and fittings are not available, install mitered sections of pipe insulation, to a thickness equal to adjoining pipe insulation. Secure insulation materials with wire or bands.
4. Insulation Installation on Valves and Pipe Specialties:
   a. Install preformed sections of same material as straight segments of pipe insulation when available.
   b. When preformed sections are not available, install mitered sections of pipe insulation to valve body.
   c. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
   d. Install insulation to flanges as specified for flange insulation application.
5. Blanket Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.

a. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 100 **OR** 50, **as directed**, percent coverage of duct and plenum surfaces.
b. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
c. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:
   1) On duct sides with dimensions 18 inches (450 mm) and smaller, place pins along longitudinal centerline of duct. Space 3 inches (75 mm) maximum from insulation end joints, and 16 inches (400 mm) o.c.
   2) On duct sides with dimensions larger than 18 inches (450 mm), place pins 16 inches (400 mm) o.c. each way, and 3 inches (75 mm) maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
   3) Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
   4) Do not overcompress insulation during installation.
   5) Impale insulation over pins and attach speed washers.
   6) Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.
d. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches (50 mm) from 1 edge and 1 end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch (13-mm) outward-clinching staples, 1 inch (25 mm) o.c. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.
   1) Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
   2) Install vapor stops for ductwork and plenums operating below 50 deg F (10 deg C) at 18-foot (5.5-m) intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to 2 times the insulation thickness but not less than 3 inches (75 mm).
e. Overlap unfaced blankets a minimum of 2 inches (50 mm) on longitudinal seams and end joints. At end joints, secure with steel bands spaced a maximum of 18 inches (450 mm) o.c.
f. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
g. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch- (150-mm-) wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches (150 mm) o.c.

6. Board Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.
   a. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 100 **OR** 50, **as directed**, percent coverage of duct and plenum surfaces.
   b. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
   c. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:
      1) On duct sides with dimensions 18 inches (450 mm) and smaller, place pins along longitudinal centerline of duct. Space 3 inches (75 mm) maximum from insulation end joints, and 16 inches (400 mm) o.c.
      2) On duct sides with dimensions larger than 18 inches (450 mm), space pins 16 inches (400 mm) o.c. each way, and 3 inches (75 mm) maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.

3) Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
4) Do not overcompress insulation during installation.
5) Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

d. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches (50 mm) from 1 edge and 1 end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch (13-mm) outward-clinching staples, 1 inch (25 mm) o.c. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.
1) Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
2) Install vapor stops for ductwork and plenums operating below 50 deg F (10 deg C) at 18-foot (5.5-m) intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to 2 times the insulation thickness but not less than 3 inches (75 mm).

e. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Groove and score insulation to fit as closely as possible to outside and inside radius of elbows. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.

f. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch- (150-mm-) wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches (150 mm) o.c.

J. Phenolic Insulation Installation
1. General Installation Requirements:
a. Secure single-layer insulation with stainless-steel bands at 12-inch (300-mm) intervals and tighten bands without deforming insulation materials.
b. Install 2-layer insulation with joints tightly butted and staggered at least 3 inches (75 mm). Secure inner layer with 0.062-inch (1.6-mm) wire spaced at 12-inch (300-mm) intervals. Secure outer layer with stainless-steel bands at 12-inch (300-mm) intervals.
2. Insulation Installation on Straight Pipes and Tubes:
a. Secure each layer of insulation to pipe with wire or bands and tighten bands without deforming insulation materials.
b. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
c. For insulation with factory-applied jackets on above ambient services, secure laps with outward clinched staples at 6 inches (150 mm) o.c.
d. For insulation with factory-applied jackets with vapor retarders on below ambient services, do not staple longitudinal tabs but secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant.
3. Insulation Installation on Pipe Flanges:
a. Install preformed pipe insulation to outer diameter of pipe flange.
b. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
c. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of block insulation of same material and thickness as pipe insulation.
4. Insulation Installation on Pipe Fittings and Elbows:
a. Install preformed insulation sections of same material as straight segments of pipe insulation. Secure according to manufacturer's written instructions.
5. Insulation Installation on Valves and Pipe Specialties:

a. Install preformed insulation sections of same material as straight segments of pipe insulation. Secure according to manufacturer's written instructions.
b. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
c. Install insulation to flanges as specified for flange insulation application.

K. Polyisocyanurate Insulation Installation
1. Insulation Installation on Straight Pipes and Tubes:
a. Secure each layer of insulation to pipe with tape or bands and tighten without deforming insulation materials. Orient longitudinal joints between half sections in 3 and 9 o'clock positions on the pipe.
b. For insulation with factory-applied jackets with vapor barriers, do not staple longitudinal tabs but secure tabs with additional adhesive or tape as recommended by insulation material manufacturer and seal with vapor-barrier mastic.
c. All insulation shall be tightly butted and free of voids and gaps at all joints. Vapor barrier must be continuous. Before installing jacket material, install vapor-barrier system.
2. Insulation Installation on Pipe Flanges:
a. Install preformed pipe insulation to outer diameter of pipe flange.
b. Make width of insulation section same as overall width of flange and bolts, same thickness of adjacent pipe insulation, not to exceed 1-1/2-inch (38-mm) thickness.
c. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of polyisocyanurate block insulation of same thickness as pipe insulation.
3. Insulation Installation on Fittings and Elbows:
a. Install preformed sections of same material as straight segments of pipe insulation. Secure according to manufacturer's written instructions.
4. Insulation Installation on Valves and Pipe Specialties:
a. Install preformed sections of polyisocyanurate insulation to valve body.
b. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
c. Install insulation to flanges as specified for flange insulation application.

L. Polyolefin Insulation Installation
1. Insulation Installation on Straight Pipes and Tubes:
a. Seal split-tube longitudinal seams and end joints with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.
2. Insulation Installation on Pipe Flanges:
a. Install pipe insulation to outer diameter of pipe flange.
b. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
c. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of polyolefin sheet insulation of same thickness as pipe insulation.
d. Secure insulation to flanges and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.
3. Insulation Installation on Pipe Fittings and Elbows:
a. Install mitered sections of polyolefin pipe insulation.
b. Secure insulation materials and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.
4. Insulation Installation on Valves and Pipe Specialties:
a. Install cut sections of polyolefin pipe and sheet insulation to valve body.
b. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
c. Install insulation to flanges as specified for flange insulation application.

d. Secure insulation to valves and specialties, and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

M. Polystyrene Insulation Installation
1. Insulation Installation on Straight Pipes and Tubes:
   a. Secure each layer of insulation with tape or bands and tighten bands without deforming insulation materials. Orient longitudinal joints between half sections in 3 and 9 o'clock positions on the pipe.
   b. For insulation with factory-applied jackets with vapor barriers, do not staple longitudinal tabs but secure tabs with additional adhesive or tape as recommended by insulation material manufacturer and seal with vapor-barrier mastic.
   c. All insulation shall be tightly butted and free of voids and gaps at all joints. Vapor barrier must be continuous. Before installing jacket material, install vapor-barrier system.
2. Insulation Installation on Pipe Flanges:
   a. Install preformed pipe insulation to outer diameter of pipe flange.
   b. Make width of insulation section same as overall width of flange and bolts, same thickness of adjacent pipe insulation, not to exceed 1-1/2-inch (38-mm) thickness.
   c. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of polystyrene block insulation of same thickness as pipe insulation.
3. Insulation Installation on Pipe Fittings and Elbows:
   a. Install preformed insulation sections of same material as straight segments of pipe insulation. Secure according to manufacturer's written instructions.
4. Insulation Installation on Valves and Pipe Specialties:
   a. Install preformed section of polystyrene insulation to valve body.
   b. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
   c. Install insulation to flanges as specified for flange insulation application.

N. Field-Applied Jacket Installation
1. Where glass-cloth jackets are indicated, install directly over bare insulation or insulation with factory-applied jackets.
   a. Draw jacket smooth and tight to surface with 2-inch (50-mm) overlap at seams and joints.
   b. Embed glass cloth between two 0.062-inch- (1.6-mm-) thick coats of lagging adhesive.
   c. Completely encapsulate insulation with coating, leaving no exposed insulation.
2. Where FSK jackets are indicated, install as follows:
   a. Draw jacket material smooth and tight.
   b. Install lap or joint strips with same material as jacket.
   c. Secure jacket to insulation with manufacturer's recommended adhesive.
   d. Install jacket with 1-1/2-inch (38-mm) laps at longitudinal seams and 3-inch- (75-mm-) wide joint strips at end joints.
   e. Seal openings, punctures, and breaks in vapor-retarder jackets and exposed insulation with vapor-barrier mastic.
3. Where PVC jackets are indicated, install with 1-inch (25-mm) overlap at longitudinal seams and end joints; for horizontal applications, install with longitudinal seams along top and bottom of tanks and vessels. Seal with manufacturer's recommended adhesive.
   a. Apply two continuous beads of adhesive to seams and joints, one bead under lap and the finish bead along seam and joint edge.
4. Where metal jackets are indicated, install with 2-inch (50-mm) overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless-steel bands 12 inches (300 mm) o.c. and at end joints.
5. Where PVDC jackets are indicated, install as follows:

a. Apply three separate wraps of filament tape per insulation section to secure pipe insulation to pipe prior to installation of PVDC jacket.
b. Wrap factory-presized jackets around individual pipe insulation sections with one end overlapping the previously installed sheet. Install presized jacket with an approximate overlap at butt joint of 2 inches (50 mm) over the previous section. Adhere lap seal using adhesive or SSL, and then apply 1-1/4 circumferences of appropriate PVDC tape around overlapped butt joint.
c. Continuous jacket can be spiral wrapped around a length of pipe insulation. Apply adhesive or PVDC tape at overlapped spiral edge. When electing to use adhesives, refer to manufacturer's written instructions for application of adhesives along this spiral edge to maintain a permanent bond.
d. Jacket can be wrapped in cigarette fashion along length of roll for insulation systems with an outer circumference of 33-1/2 inches (850 mm) or less. The 33-1/2-inch- (850-mm-) circumference limit allows for 2-inch- (50-mm-) overlap seal. Using the length of roll allows for longer sections of jacket to be installed at one time. Use adhesive on the lap seal. Visually inspect lap seal for "fishmouthing," and use PVDC tape along lap seal to secure joint.
e. Repair holes or tears in PVDC jacket by placing PVDC tape over the hole or tear and wrapping a minimum of 1-1/4 circumferences to avoid damage to tape edges.

O. Fire-Rated Insulation System Installation
1. Where fire-rated insulation system is indicated, secure system to ducts and duct hangers and supports to maintain a continuous fire rating.
2. Insulate duct access panels and doors to achieve same fire rating as duct.
3. Install firestopping at penetrations through fire-rated assemblies. Fire-stop systems are specified in Division 07 Section "Penetration Firestopping".

P. Finishes
1. Duct, Equipment, and Pipe Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below and as specified in Division 07.
a. Flat Acrylic Finish: Two finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.
1) Finish Coat Material: Interior, flat, latex-emulsion size.
2. Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer's recommended protective coating.
3. Color: Final color as selected by the Owner. Vary first and second coats to allow visual inspection of the completed Work.
4. Do not field paint aluminum or stainless-steel jackets.

Q. Field Quality Control
1. Perform tests and inspections.
2. Tests and Inspections:
a. Inspect ductwork, randomly selected by the Owner, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to one location(s) for each duct system defined in the "Duct Insulation Schedule, General" Article.
b. Inspect field-insulated equipment, randomly selected by the Owner, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to one location(s) for each type of equipment defined in the "Equipment Insulation Schedule" Article. For large equipment, remove only a portion adequate to determine compliance.
c. Inspect pipe, fittings, strainers, and valves, randomly selected by the Owner, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to three locations of straight pipe, three locations of threaded fittings, three locations of welded fittings, two locations of threaded strainers, two locations

of welded strainers, three locations of threaded valves, and three locations of flanged valves for each pipe service defined in the "Piping Insulation Schedule, General" Article.

3. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

R. Boiler Breeching Insulation Schedule

1. Round, exposed breeching and connector insulation shall be one of the following:
   a. Calcium Silicate: 4 inches (100 mm) thick.
   b. High-Temperature Mineral-Fiber Blanket: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.
   c. High-Temperature Mineral-Fiber Board: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
2. Round, concealed breeching and connector insulation shall be one of the following:
   a. Calcium Silicate: 4 inches (100 mm) thick.
   b. High-Temperature Mineral-Fiber Blanket: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.
   c. High-Temperature Mineral-Fiber Board: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
3. Rectangular, exposed breeching and connector insulation shall be one of the following:
   a. Calcium Silicate: 4 inches (100 mm) thick.
   b. High-Temperature Mineral-Fiber Blanket: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.
   c. High-Temperature Mineral-Fiber Board: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
4. Rectangular, concealed breeching and connector insulation shall be one of the following:
   a. Calcium Silicate: 4 inches (100 mm) thick.
   b. High-Temperature Mineral-Fiber Blanket: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) nominal density.
   c. High-Temperature Mineral-Fiber Board: 3 inches (75 mm) thick and 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.

S. Duct Insulation Schedule, General

1. Plenums and Ducts Requiring Insulation:
   a. Indoor, concealed supply and outdoor air.
   b. Indoor, exposed supply and outdoor air.
   c. Indoor, concealed return located in nonconditioned space.
   d. Indoor, exposed return located in nonconditioned space.
   e. Indoor, concealed, Type I, commercial, kitchen hood exhaust.
   f. Indoor, exposed, Type I, commercial, kitchen hood exhaust.
   g. Indoor, concealed oven and warewash exhaust.
   h. Indoor, exposed oven and warewash exhaust.
   i. Indoor, concealed exhaust between isolation damper and penetration of building exterior.
   j. Indoor, exposed exhaust between isolation damper and penetration of building exterior.
   k. Outdoor, concealed supply and return.
   l. Outdoor, exposed supply and return.
2. Items Not Insulated:
   a. Fibrous-glass ducts.
   b. Metal ducts with duct liner of sufficient thickness to comply with energy code and ASHRAE/IESNA 90.1.
   c. Factory-insulated flexible ducts.
   d. Factory-insulated plenums and casings.
   e. Flexible connectors.
   f. Vibration-control devices.
   g. Factory-insulated access panels and doors.

T. Indoor Duct And Plenum Insulation Schedule

1. Concealed, round and flat-oval, supply-air duct insulation shall be one of the following:
   a. Flexible Elastomeric: 1 inch (25 mm) thick.
   b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
   c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
   e. Polyolefin: 1 inch (25 mm) thick.
2. Concealed, round and flat-oval, return-air duct insulation shall be one of the following:
   a. Flexible Elastomeric: 1 inch (25 mm) thick.
   b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
   c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
   e. Polyolefin: 1 inch (25 mm) thick.
3. Concealed, round and flat-oval, outdoor-air duct insulation shall be one of the following:
   a. Flexible Elastomeric: 1 inch (25 mm) thick.
   b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
   c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
   e. Polyolefin: 1 inch (25 mm) thick.
4. Concealed, round and flat-oval, exhaust-air duct insulation shall be one of the following:
   a. Flexible Elastomeric: 1 inch (25 mm) thick.
   b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
   c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
   e. Polyolefin: 1 inch (25 mm) thick.
5. Concealed, rectangular, supply-air duct insulation shall be one of the following:
   a. Flexible Elastomeric: 1 inch (25 mm) thick.
   b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
   c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
   e. Polyolefin: 1 inch (25 mm) thick.

6. Concealed, rectangular, return-air duct insulation shall be one of the following:
   a. Flexible Elastomeric: 1 inch (25 mm) thick.
   b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
   c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
   e. Polyolefin: 1 inch (25 mm), **as directed**, thick.
7. Concealed, rectangular, outdoor-air duct insulation shall be one of the following:
   a. Flexible Elastomeric: 1 inch (25 mm) thick.
   b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
   c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
   e. Polyolefin: 1 inch (25 mm), **as directed**, thick.
8. Concealed, rectangular, exhaust-air duct insulation between isolation damper and penetration of building exterior shall be one of the following:
   a. Flexible Elastomeric: 1 inch (25 mm) thick.
   b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
   c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
   e. Polyolefin: 1 inch (25 mm) thick.
9. Concealed, Type I, Commercial, Kitchen Hood Exhaust Duct and Plenum Insulation: Fire-rated blanket **OR** board, **as directed**; thickness as required to achieve 2-hour fire rating.
10. Concealed, supply-air plenum insulation shall be one of the following:
   a. Flexible Elastomeric: 1 inch (25 mm) thick.
   b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
   c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
   e. Polyolefin: 1 inch (25 mm) thick.
11. Concealed, return-air plenum insulation shall be one of the following:
   a. Flexible Elastomeric: 1 inch (25 mm) thick.
   b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
   c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.

d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
e. Polyolefin: 1 inch (25 mm) thick.

12. Concealed, outdoor-air plenum insulation shall be one of the following:
    a. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
    b. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    c. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
13. Concealed, exhaust-air plenum insulation shall be one of the following:
    a. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
    b. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    c. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
14. Exposed, round and flat-oval, supply-air duct insulation shall be one of the following:
    a. Flexible Elastomeric: 1 inch (25 mm) thick.
    b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
    c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
    e. Polyolefin: 1 inch (25 mm) thick.
15. Exposed, round and flat-oval, return-air duct insulation shall be one of the following:
    a. Flexible Elastomeric: 1 inch (25 mm) thick.
    b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
    c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
    e. Polyolefin: 1 inch (25 mm) thick.
16. Exposed, round and flat-oval, outdoor-air duct insulation shall be one of the following:
    a. Flexible Elastomeric: 1 inch (25 mm) thick.
    b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
    c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
    e. Polyolefin: 1 inch (25 mm) thick.
17. Exposed, round and flat-oval, exhaust-air duct insulation shall be one of the following:
    a. Flexible Elastomeric: 1 inch (25 mm) thick.

b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
e. Polyolefin: 1 inch (25 mm) thick.

18. Exposed, rectangular, supply-air duct insulation shall be one of the following:
a. Flexible Elastomeric: 1 inch (25 mm) thick.
b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96 kg/cu. m), **as directed**, nominal density.
d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
e. Polyolefin: 1 inch (25 mm) thick.

19. Exposed, rectangular, return-air duct insulation shall be one of the following:
a. Flexible Elastomeric: 1 inch (25 mm) thick.
b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
e. Polyolefin: 1 inch (25 mm) thick.

20. Exposed, rectangular, outdoor-air duct insulation shall be one of the following:
a. Flexible Elastomeric: 1 inch (25 mm) thick.
b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
e. Polyolefin: 1 inch (25 mm) thick.

21. Exposed, rectangular, exhaust-air duct insulation shall be one of the following:
a. Flexible Elastomeric: 1 inch (25 mm) thick.
b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
e. Polyolefin: 1 inch (25 mm) thick.

22. Exposed, Type I, Commercial, Kitchen Hood Exhaust Duct and Plenum Insulation: Fire-rated blanket **OR** board, **as directed**; thickness as required to achieve 2-hour fire rating.

23. Exposed, supply-air plenum insulation shall be one of the following:
    a. Flexible Elastomeric: 1 inch (25 mm) thick.
    b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
    c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
    e. Polyolefin: 1 inch (25 mm) thick.
24. Exposed, return-air plenum insulation shall be one of the following:
    a. Flexible Elastomeric: 1 inch (25 mm) thick.
    b. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
    c. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
    e. Polyolefin: 1 inch (25 mm) thick.
25. Exposed, outdoor-air plenum insulation shall be one of the following:
    a. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
    b. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    c. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
26. Exposed, exhaust-air plenum insulation shall be one of the following:
    a. Mineral-Fiber Blanket: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
    b. Mineral-Fiber Board: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    c. Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.

U. Aboveground, Outdoor Duct And Plenum Insulation Schedule
1. Insulation materials and thicknesses are identified below. If more than one material is listed for a duct system, selection from materials listed is Contractor's option.
2. Concealed, round and flat-oval, supply-air duct insulation shall be one of the following:
    a. Mineral-Fiber Blanket: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
    b. Mineral-Fiber Board: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    c. Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
3. Concealed, round and flat-oval, return-air duct insulation shall be one of the following:
    a. Mineral-Fiber Blanket: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.

b. Mineral-Fiber Board: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
c. Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.

4. Concealed, round and flat-oval, outdoor-air duct insulation shall be one of the following:
   a. Mineral-Fiber Blanket: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed,** and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
   b. Mineral-Fiber Board: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   c. Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
5. Concealed, rectangular, supply-air duct insulation shall be one of the following:
   a. Mineral-Fiber Blanket: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
   b. Mineral-Fiber Board: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   c. Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
6. Concealed, rectangular, return-air duct insulation shall be one of the following:
   a. Mineral-Fiber Blanket: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m, **as directed**, nominal density.
   b. Mineral-Fiber Board: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   c. Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
7. Concealed, supply-air plenum insulation shall be one of the following:
   a. Mineral-Fiber Blanket: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
   b. Mineral-Fiber Board: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   c. Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
8. Concealed, return-air plenum insulation shall be one of the following:
   a. Mineral-Fiber Blanket: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
   b. Mineral-Fiber Board: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   c. Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
9. Exposed, round and flat-oval, supply-air duct insulation shall be one of the following:
   a. Mineral-Fiber Blanket: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
   b. Mineral-Fiber Board: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   c. Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
10. Exposed, round and flat-oval, return-air duct insulation shall be one of the following:

a. Mineral-Fiber Blanket: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
b. Mineral-Fiber Board: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
c. Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.

11. Exposed, rectangular, supply-air duct insulation shall be one of the following:
    a. Mineral-Fiber Blanket: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
    b. Mineral-Fiber Board: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    c. Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
12. Exposed, rectangular, return-air duct insulation shall be one of the following:
    a. Mineral-Fiber Blanket: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
    b. Mineral-Fiber Board: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    c. Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
13. Exposed, supply-air plenum insulation shall be one of the following:
    a. Mineral-Fiber Blanket: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
    b. Mineral-Fiber Board: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    c. Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
14. Exposed, return-air plenum insulation shall be one of the following:
    a. Mineral-Fiber Blanket: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, and 0.75-lb/cu. ft. (12-kg/cu. m) **OR** 1.5-lb/cu. ft. (24-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m), **as directed**, nominal density.
    b. Mineral-Fiber Board: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    c. Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.

V. Equipment Insulation Schedule
1. Insulation materials and thicknesses are identified below. If more than one material is listed for a type of equipment, selection from materials listed is Contractor's option.
2. Insulate indoor and outdoor equipment in paragraphs below that is not factory insulated.
3. Chillers: Insulate cold surfaces on chillers, including, but not limited to, evaporator bundles, condenser bundles, heat-recovery bundles, suction piping, compressor inlets, tube sheets, water boxes, and nozzles with one of the following:
    a. Cellular Glass: 2 inches (50 mm) thick.
    b. Flexible Elastomeric: 1 inch (25 mm) thick.
    c. Mineral-Fiber Board: 1 inch (25 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Mineral-Fiber Pipe and Tank: 1 inch (25 mm) thick.
    e. Phenolic: 1 inch (25 mm) thick.
    f. Polyisocyanurate: 1 inch (25 mm) thick.
    g. Polyolefin: 1 inch (25 mm) thick.
4. Heat-exchanger (water-to-water for cooling service) insulation shall be one of the following:

a. Cellular Glass: 2 inches (50 mm) thick.
b. Flexible Elastomeric: 1 inch (25 mm) thick.
c. Mineral-Fiber Board: 1 inch (25 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
d. Mineral-Fiber Pipe and Tank: 1 inch (25 mm) thick.
e. Phenolic: 1 inch (25 mm) thick.
f. Polyisocyanurate: 1 inch (25 mm) thick.
g. Polyolefin: 1 inch (25 mm) thick.

5. Heat-exchanger (water-to-water for heating service) insulation shall be one of the following:
   a. Calcium Silicate: 3 inches (75 mm) thick.
   b. Cellular Glass: 3 inches (75 mm) thick.
   c. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   d. Mineral-Fiber Pipe and Tank: 2 inches (50 mm) thick.
6. Steam-to-hot-water converter insulation shall be one of the following:
   a. Calcium Silicate: 3 inches (75 mm) thick.
   b. Cellular Glass: 3 inches (75 mm) thick.
   c. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   d. Mineral-Fiber Pipe and Tank: 2 inches (50 mm) thick.
7. Hot-water-to-steam converter insulation shall be one of the following:
   a. Calcium Silicate: 3 inches (75 mm) thick.
   b. Cellular Glass: 3 inches (75 mm) thick.
   c. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   d. Mineral-Fiber Pipe and Tank: 2 inches (50 mm) thick.
8. Chilled-water pump insulation shall be one of the following:
   a. Cellular Glass: 3 inches (75 mm) thick.
   b. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   c. Phenolic: 2 inches (50 mm) thick.
   d. Polyisocyanurate: 1-1/2 inches (38 mm) thick.
9. Condenser-water pump insulation shall be one of the following:
   a. Cellular Glass: 2 inches (50 mm) thick.
   b. Mineral-Fiber Board: 1 inch (25 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
   c. Phenolic: 1 inch (25 mm) thick.
   d. Polyisocyanurate: 1-1/2 inches (38 mm) thick.
10. Dual-service heating and cooling pump insulation shall be one of the following:
    a. Cellular Glass: 3 inches (75 mm) thick.
    b. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    c. Phenolic: 2 inches (50 mm) thick.
    d. Polyisocyanurate: 1 inch (25 mm) thick.
11. Heating-hot-water pump insulation shall be one of the following:
    a. Calcium Silicate: 3 inches (75 mm) thick.
    b. Cellular Glass: 3 inches (75 mm) thick.
    c. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
12. Heat-recovery pump insulation shall be one of the following:
    a. Cellular Glass: 2 inches (50 mm) thick.
    b. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    c. Phenolic: 1 inch (25 mm) thick.
    d. Polyisocyanurate: 1-1/2 inches (38 mm) thick.

13. Steam condensate pump and boiler feedwater pump insulation shall be one of the following:
    a. Calcium Silicate: 3 inches (75 mm) thick.
    b. Cellular Glass: 3 inches (75 mm) thick.
    c. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Mineral-Fiber Pipe and Tank: 2 inches (50 mm) thick.
14. Chilled-water expansion/compression tank insulation shall be one of the following:
    a. Cellular Glass: 1-1/2 inches (38 mm) thick.
    b. Flexible Elastomeric: 1 inch (25 mm) thick.
    c. Mineral-Fiber Board: 1 inch (25 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Mineral-Fiber Pipe and Tank: 1 inch (25 mm) thick.
    e. Phenolic: 1 inch (25 mm) thick.
    f. Polyisocyanurate: 1 inch (25 mm) thick.
    g. Polyolefin: 1 inch (25 mm) thick.
15. Condenser-water expansion/compression tank insulation shall be one of the following:
    a. Cellular Glass: 1-1/2 inches (38 mm) thick.
    b. Flexible Elastomeric: 1 inch (25 mm) thick.
    c. Mineral-Fiber Board: 1 inch (25 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Mineral-Fiber Pipe and Tank: 1 inch (25 mm) thick.
    e. Phenolic: 1 inch (25 mm) thick.
    f. Polyisocyanurate: 1 inch (25 mm) thick.
    g. Polyolefin: 1 inch (25 mm) thick.
16. Dual-service heating and cooling expansion/compression tank insulation shall be one of the following:
    a. Cellular Glass: 1-1/2 inches (38 mm) thick.
    b. Flexible Elastomeric: 1 inch (25 mm) thick.
    c. Mineral-Fiber Board: 1 inch (25 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Mineral-Fiber Pipe and Tank: 1 inch (25 mm) thick.
    e. Phenolic: 1 inch (25 mm) thick.
    f. Polyisocyanurate: 1 inch (25 mm) thick.
    g. Polyolefin: 1 inch (25 mm) thick.
17. Heating-hot-water expansion/compression tank insulation shall be one of the following:
    a. Calcium Silicate: 2 inches (50 mm) thick.
    b. Cellular Glass: 1-1/2 inches (38 mm) thick.
    c. Mineral-Fiber Board: 1 inch (25 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Mineral-Fiber Pipe and Tank: 1 inch (25 mm) thick.
18. Heat-recovery expansion/compression tank insulation shall be one of the following:
    a. Cellular Glass: 1-1/2 inches (38 mm) thick.
    b. Flexible Elastomeric: 1 inch (25 mm) thick.
    c. Mineral-Fiber Board: 1 inch (25 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Mineral-Fiber Pipe and Tank: 1 inch (25 mm) thick.
    e. Phenolic: 1 inch (25 mm) thick.
    f. Polyisocyanurate: 1 inch (25 mm) thick.
    g. Polyolefin: 1 inch (25 mm) thick.
19. Chilled-water air-separator insulation shall be one of the following:
    a. Cellular Glass: 2 inches (50 mm) thick.
    b. Flexible Elastomeric: 1 inch (25 mm) thick.
    c. Mineral-Fiber Board: 1 inch (25 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Mineral-Fiber Pipe and Tank: 1 inch (25 mm) thick.
    e. Phenolic: 1 inch (25 mm) thick.

f. Polyisocyanurate: 1 inch (25 mm) thick.
g. Polyolefin: 1 inch (25 mm) thick.

20. Condenser-water air-separator insulation shall be one of the following:
    a. Cellular Glass: 2 inches (50 mm) thick.
    b. Flexible Elastomeric: 1 inch (25 mm) thick.
    c. Mineral-Fiber Board: 1 inch (25 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Mineral-Fiber Pipe and Tank: 1 inch (25 mm) thick.
    e. Phenolic: 1 inch (25 mm) thick.
    f. Polyisocyanurate: 1 inch (25 mm) thick.
    g. Polyolefin: 1 inch (25 mm) thick.
21. Dual-service heating and cooling air-separator insulation shall be one of the following:
    a. Cellular Glass: 2 inches (50 mm) thick.
    b. Flexible Elastomeric: 1 inch (25 mm) thick.
    c. Mineral-Fiber Board: 1 inch (25 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Mineral-Fiber Pipe and Tank: 1 inch (25 mm) thick.
    e. Phenolic: 1 inch (25 mm) thick.
    f. Polyisocyanurate: 1 inch (25 mm) thick.
    g. Polyolefin: 1 inch (25 mm) thick.
22. Heating-hot-water air-separator insulation shall be one of the following:
    a. Calcium Silicate: 3 inches (75 mm) thick.
    b. Cellular Glass: 3 inches (75 mm) thick.
    c. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Mineral-Fiber Pipe and Tank: 2 inches (50 mm) thick.
23. Heat-recovery air-separator insulation shall be one of the following:
    a. Cellular Glass: 2 inches (50 mm) thick.
    b. Flexible Elastomeric: 1 inch (25 mm) thick.
    c. Mineral-Fiber Board: 1 inch (25 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Mineral-Fiber Pipe and Tank: 1 inch (25 mm) thick.
    e. Phenolic: 1 inch (25 mm) thick.
    f. Polyisocyanurate: 1 inch (25 mm) thick.
    g. Polyolefin: 1 inch (25 mm) thick.
24. Thermal storage tank (brine, water, ice) insulation shall be one of the following:
    a. Cellular Glass: 4 inches (100 mm) thick.
    b. Mineral-Fiber Board: 3 inches (75 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    c. Mineral-Fiber Pipe and Tank: 3 inches (75 mm) thick.
    d. Phenolic: 3 inches (75 mm) thick.
    e. Polyisocyanurate (Outdoor Application Only): 3 inches (75 mm) thick.
    f. Polystyrene (Outdoor Application Only): 3 inches (75 mm) thick.
25. Deaerator insulation shall be one of the following:
    a. Calcium Silicate: 3 inches (75 mm) thick.
    b. Cellular Glass: 3 inches (75 mm) thick.
    c. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Mineral-Fiber Pipe and Tank: 2 inches (50 mm) thick.
26. Steam condensate tank and receiver insulation shall be one of the following:
    a. Calcium Silicate: 3 inches (75 mm) thick.
    b. Cellular Glass: 3 inches (75 mm) thick.
    c. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Mineral-Fiber Pipe and Tank: 2 inches (50 mm) thick.

27. Steam flash-tank, flash-separator, and blow-off-tank insulation shall be one of the following:
    a. Calcium Silicate: 3 inches (75 mm) thick.
    b. Cellular Glass: 3 inches (75 mm) thick.
    c. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    d. Mineral-Fiber Pipe and Tank: 2 inches (50 mm) thick.
28. Piping system filter-housing insulation shall be one of the following:
    a. Cellular Glass: 3 inches (75 mm) thick.
    b. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    c. Mineral-Fiber Pipe and Tank: 2 inches (50 mm) thick.
29. Outdoor, aboveground, heated, fuel-oil storage tank insulation shall be one of the following:
    a. Cellular Glass: 3 inches (75 mm) thick.
    b. Mineral-Fiber Board: 2 inches (50 mm) thick and 2-lb/cu. ft. (32-kg/cu. m) **OR** 3-lb/cu. ft. (48-kg/cu. m) **OR** 6-lb/cu. ft. (96-kg/cu. m), **as directed**, nominal density.
    c. Mineral-Fiber Pipe and Tank: 2 inches (50 mm) thick.
    d. Polyisocyanurate: 1-1/2 inches (38 mm) thick.

W. Piping Insulation Schedule, General
1. Acceptable preformed pipe and tubular insulation materials and thicknesses are identified for each piping system and pipe size range. If more than one material is listed for a piping system, selection from materials listed is Contractor's option.
2. Items Not Insulated: Unless otherwise indicated, do not install insulation on the following:
    a. Drainage piping located in crawl spaces.
    b. Underground piping.
    c. Chrome-plated pipes and fittings unless there is a potential for personnel injury.

X. Indoor Piping Insulation Schedule
1. Condensate and Equipment Drain Water below 60 Deg F (16 Deg C):
    a. All Pipe Sizes: Insulation shall be one of the following:
        1) Cellular Glass: 1-1/2 inches (38 mm) thick.
        2) Flexible Elastomeric: 3/4 inch (19 mm) **OR** 1 inch (25 mm), **as directed**, thick.
        3) Mineral-Fiber, Preformed Pipe Insulation, Type I: 1/2 inch (13 mm) **OR** 1 inch (25 mm), **as directed**, thick.
        4) Phenolic: 1 inch (25 mm) thick.
        5) Polyisocyanurate: 1 inch (25 mm) thick.
        6) Polyolefin: 3/4 inch (19 mm) **OR** 1 inch (25 mm), **as directed**, thick.
2. Chilled Water and Brine, 40 Deg F (5 Deg C) and below:
    a. NPS 3 (DN 80) and Smaller: Insulation shall be one of the following:
        1) Cellular Glass: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
        2) Mineral-Fiber, Preformed Pipe, Type I **OR** Pipe Insulation Wicking System, **as directed**: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
        3) Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
        4) Polyisocyanurate: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm), **as directed**, thick.
    b. NPS 4 (DN 100) to NPS 12 (DN 300): Insulation shall be one of the following:
        1) Cellular Glass: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
        2) Mineral-Fiber, Preformed Pipe, Type I **OR** Pipe Insulation Wicking System, **as directed**: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
        3) Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
        4) Polyisocyanurate: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm), **as directed**, thick.
    c. NPS 14 (DN 350) and Larger: Insulation shall be one of the following:
        1) Cellular Glass: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.

2) Mineral-Fiber, Preformed Pipe, Type I **OR** Pipe Insulation Wicking System, **as directed**: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
3) Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
4) Polyisocyanurate: 1-1/2 inches (38 mm) thick.

3. Chilled Water and Brine, above 40 Deg F (5 Deg C):
   a. NPS 12 (DN 300) and Smaller: Insulation shall be one of the following:
      1) Cellular Glass: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
      2) Flexible Elastomeric: 1 inch (25 mm) thick.
      3) Mineral-Fiber, Preformed Pipe, Type I **OR** Pipe Insulation Wicking System, **as directed**: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
      4) Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      5) Polyisocyanurate: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm), **as directed**, thick.
      6) Polyolefin: 1 inch (25 mm) thick.
   b. NPS 14 (DN 350) and Larger: Insulation shall be one of the following:
      1) Cellular Glass: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      2) Mineral-Fiber Preformed Pipe, Type I **OR** Pipe Insulation Wicking System, **as directed**: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      3) Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      4) Polyisocyanurate: 1-1/2 inches (38 mm) thick.
4. Condenser-Water Supply and Return:
   a. NPS 12 (DN 300) and Smaller: Insulation shall be one of the following:
      1) Cellular Glass: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
      2) Flexible Elastomeric: 1 inch (25 mm) thick.
      3) Mineral-Fiber, Preformed Pipe, Type I: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
      4) Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm), **as directed**, thick.
      5) Polyisocyanurate: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm), **as directed**, thick.
      6) Polyolefin: 1 inch (25 mm) thick.
   b. NPS 14 (DN 350) and Larger: Insulation shall be one of the following:
      1) Cellular Glass: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      2) Mineral-Fiber, Preformed Pipe, Type I: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      3) Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      4) Polyisocyanurate: 1-1/2 inches (38 mm) thick.
5. Heating-Hot-Water Supply and Return, 200 Deg F (93 Deg C) and below:
   a. NPS 12 (DN 300) and Smaller: Insulation shall be one of the following:
      1) Cellular Glass: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
      2) Mineral-Fiber, Preformed Pipe, Type I: 1 inch (25 mm) **OR** 2 inches (50 mm), **as directed**, thick.
      3) Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      4) Polyisocyanurate: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm), **as directed**, thick.
   b. NPS 14 (DN 350) and Larger: Insulation shall be one of the following:
      1) Cellular Glass: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      2) Mineral-Fiber, Preformed Pipe, Type I: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      3) Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      4) Polyisocyanurate: 1-1/2 inches (38 mm) thick.

6. Heating-Hot-Water Supply and Return, above 200 Deg F (93 Deg C):
   a. NPS 3/4 (DN 20) and Smaller: Insulation shall be one of the following:
      1) Calcium Silicate: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      2) Cellular Glass: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      3) Mineral-Fiber, Preformed Pipe, Type I or II: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
   b. NPS 1 (DN 25) and Larger: Insulation shall be one of the following:
      1) Calcium Silicate: 3 inches (75 mm) **OR** 4 inches (100 mm), **as directed**, thick.
      2) Cellular Glass: 3 inches (75 mm) **OR** 4 inches (100 mm), **as directed**, thick.
      3) Mineral-Fiber, Preformed Pipe, Type I or II: 3 inches (75 mm) **OR** 4 inches (100 mm), **as directed**, thick.
7. Steam and Steam Condensate, 350 Deg F (177 Deg C) and below:
   a. NPS 3/4 (DN 20) and Smaller: Insulation shall be one of the following:
      1) Calcium Silicate: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      2) Cellular Glass: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      3) Mineral-Fiber, Preformed Pipe, Type I or II: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
   b. NPS 1 (DN 25) and Larger: Insulation shall be one of the following:
      1) Calcium Silicate: 3 inches (75 mm) **OR** 4 inches (100 mm), **as directed**, thick.
      2) Cellular Glass: 3 inches (75 mm) **OR** 4 inches (100 mm), **as directed**, thick.
      3) Mineral-Fiber, Preformed Pipe, Type I or II: 3 inches (75 mm) **OR** 4 inches (100 mm), **as directed**, thick.
8. Steam and Steam Condensate, above 350 Deg F (177 Deg C):
   a. NPS 3/4 (DN 20) and Smaller: Insulation shall be one of the following:
      1) Calcium Silicate: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      2) Cellular Glass: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      3) Mineral-Fiber, Preformed Pipe, Type I or II: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
   b. NPS 1 (DN 25) and Larger: Insulation shall be one of the following:
      1) Calcium Silicate: 3 inches (75 mm) **OR** 4 inches (100 mm), **as directed**, thick.
      2) Cellular Glass: 3 inches (75 mm) **OR** 4 inches (100 mm), **as directed**, thick.
      3) Mineral-Fiber, Preformed Pipe, Type I or II: 3 inches (75 mm) **OR** 4 inches (100 mm), **as directed**, thick.
9. Refrigerant Suction and Hot-Gas Piping:
   a. All Pipe Sizes: Insulation shall be one of the following:
      1) Cellular Glass: 1-1/2 inches (38 mm) thick.
      2) Flexible Elastomeric: 1 inch (25 mm) thick.
      3) Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch (25 mm) thick.
      4) Phenolic: 1 inch (25 mm) thick.
      5) Polyisocyanurate: 1 inch (25 mm) thick.
      6) Polyolefin: 1 inch (25 mm) thick.
10. Refrigerant Suction and Hot-Gas Flexible Tubing:
   a. All Pipe Sizes: Insulation shall be one of the following:
      1) Flexible Elastomeric: 1 inch (25 mm) thick.
      2) Polyolefin: 1 inch (25 mm) thick.
11. Dual-Service Heating and Cooling, 40 to 200 Deg F (5 to 93 Deg C):
   a. NPS 12 (DN 300) and Smaller: Insulation shall be one of the following:
      1) Cellular Glass: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
      2) Mineral-Fiber, Preformed Pipe, Type I: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**, thick.
      3) Phenolic: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
      4) Polyisocyanurate: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm), **as directed**, thick.
   b. NPS 14 (DN 350) and Larger: Insulation shall be one of the following:
      1) Cellular Glass: 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.

2) Mineral-Fiber, Preformed Pipe, Type I: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
3) Phenolic: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, thick.
4) Polyisocyanurate: 1-1/2 inches (38 mm) thick.

12. Heat-Recovery Piping:
    a. All Pipe Sizes: Insulation shall be one of the following:
        1) Cellular Glass: 1-1/2 inches (38 mm) thick.
        2) Flexible Elastomeric: 1 inch (25 mm) thick.
        3) Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch (25 mm) thick.
        4) Phenolic: 1 inch (25 mm) thick.
        5) Polyisocyanurate: 1 inch (25 mm) thick.
        6) Polyolefin: 1 inch (25 mm) thick.
13. Hot Service Drains:
    a. All Pipe Sizes: Insulation shall be one of the following:
        1) Calcium Silicate: 1-1/2 inches (38 mm) thick.
        2) Cellular Glass: 1-1/2 inches (38 mm) thick.
        3) Mineral-Fiber, Preformed Pipe, Type I or II: 1 inch (25 mm) thick.
14. Hot Service Vents:
    a. All Pipe Sizes: Insulation shall be one of the following:
        1) Calcium Silicate: 1-1/2 inches (38 mm) thick.
        2) Cellular Glass: 1-1/2 inches (38 mm) thick.
        3) Mineral-Fiber, Preformed Pipe, Type I or II: 1 inch (25 mm) thick.

Y. Outdoor, Aboveground Piping Insulation Schedule
1. Chilled Water and Brine:
    a. All Pipe Sizes: Insulation shall be one of the following:
        1) Cellular Glass: 3 inches (75 mm) thick.
        2) Flexible Elastomeric: 3 inches (75 mm) thick.
        3) Mineral-Fiber, Preformed Pipe Insulation, Type I: 3 inches (75 mm) thick.
        4) Phenolic: 2 inches (50 mm) thick.
        5) Polyisocyanurate: 2 inches (50 mm) thick.
        6) Polyolefin: 3 inches (75 mm) thick.
        7) Polystyrene: 2 inches (50 mm) thick.
2. Condenser-Water Supply and Return:
    a. All Pipe Sizes: Insulation shall be one of the following:
        1) Cellular Glass: 2 inches (50 mm) thick.
        2) Flexible Elastomeric: 2 inches (50 mm) thick.
        3) Mineral-Fiber, Preformed Pipe Insulation, Type I: 2 inches (50 mm) thick.
        4) Phenolic: 2 inches (50 mm) thick.
        5) Polyisocyanurate: 2 inches (50 mm) thick.
        6) Polyolefin: 2 inches (50 mm) thick.
        7) Polystyrene: 2 inches (50 mm) thick.
3. Heating-Hot-Water Supply and Return, 200 Deg F (93 Deg C) and below:
    a. All Pipe Sizes: Insulation shall be one of the following:
        1) Cellular Glass: 3 inches (75 mm) thick.
        2) Mineral-Fiber, Preformed Pipe Insulation, Type I: 2 inches (50 mm) thick.
        3) Phenolic: 2 inches (50 mm) thick.
        4) Polyisocyanurate: 2 inches (50 mm) thick.
4. Heating-Hot-Water Supply and Return, above 200 Deg F (93 Deg C):
    a. All Pipe Sizes: Insulation shall be one of the following:
        1) Calcium Silicate: 3 inches (75 mm) thick.
        2) Cellular Glass: 3 inches (75 mm) thick.
        3) Mineral-Fiber, Preformed Pipe Insulation, Type I or II: 2 inches (50 mm) thick.
5. Steam and Steam Condensate, 350 Deg F (177 Deg C) and below:

a. All Pipe Sizes: Insulation shall be one of the following:
   1) Calcium Silicate: 4 inches (100 mm) thick.
   2) Cellular Glass: 4 inches (100 mm) thick.
   3) Mineral-Fiber, Preformed Pipe Insulation, Type I or II: 3 inches (75 mm) thick.

6. Steam and Steam Condensate, above 350 Deg F (177 Deg C):
   a. All Pipe Sizes: Insulation shall be one of the following:
      1) Calcium Silicate: 5 inches (125 mm) thick.
      2) Cellular Glass: 5 inches (125 mm) thick.
      3) Mineral-Fiber, Preformed Pipe Insulation, Type I or II: 4 inches (100 mm) thick.
7. Refrigerant Suction and Hot-Gas Piping:
   a. All Pipe Sizes: Insulation shall be one of the following:
      1) Cellular Glass: 2 inches (50 mm) thick.
      2) Flexible Elastomeric: 2 inches (50 mm) thick.
      3) Mineral-Fiber, Preformed Pipe Insulation, Type I: 2 inches (50 mm) thick.
      4) Phenolic: 2 inches (50 mm) thick.
      5) Polyisocyanurate: 2 inches (50 mm) thick.
      6) Polyolefin: 2 inches (50 mm) thick.
      7) Polystyrene: 2 inches (50 mm) thick.
8. Refrigerant Suction and Hot-Gas Flexible Tubing:
   a. All Pipe Sizes: Insulation shall be one of the following:
      1) Flexible Elastomeric: 2 inches (50 mm) thick.
      2) Polyolefin: 2 inches (50 mm) thick.
9. Heat-Recovery Piping:
   a. All Pipe Sizes: Insulation shall be one of the following:
      1) Cellular Glass: 2 inches (50 mm) thick.
      2) Flexible Elastomeric: 2 inches (50 mm) thick.
      3) Mineral-Fiber, Preformed Pipe Insulation, Type I: 2 inches (50 mm) thick.
      4) Phenolic: 2 inches (50 mm) thick.
      5) Polyisocyanurate: 2 inches (50 mm) thick.
      6) Polyolefin: 2 inches (50 mm) thick.
      7) Polystyrene: 2 inches (50 mm) thick.
10. Dual-Service Heating and Cooling:
   a. All Pipe Sizes: Insulation shall be one of the following:
      1) Cellular Glass: 3 inches (75 mm) thick.
      2) Mineral-Fiber, Preformed Pipe Insulation, Type I: 2 inches (50 mm) thick.
      3) Phenolic: 2 inches (50 mm) thick.
      4) Polyisocyanurate: 2 inches (50 mm) thick.
11. Hot Service Drains:
   a. All Pipe Sizes: Insulation shall be one of the following:
      1) Calcium Silicate: 1-1/2 inches (38 mm) thick.
      2) Cellular Glass: 1-1/2 inches (38 mm) thick.
      3) Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch (25 mm) thick.
12. Hot Service Vents:
   a. All Pipe Sizes: Insulation shall be one of the following:
      1) Calcium Silicate: 1-1/2 inches (38 mm) thick.
      2) Cellular Glass: 1-1/2 inches (38 mm) thick.
      3) Mineral-Fiber, Preformed Pipe Insulation, Type II: 1 inch (25 mm) thick.
13. Fuel Oil Piping, Heated:
   a. All Pipe Sizes: Insulation shall be one of the following:
      1) Cellular Glass: 2 inches (50 mm) thick.
      2) Mineral-Fiber, Preformed Pipe Insulation, Type I: 2 inches (50 mm) thick.

Z. Outdoor, Underground Piping Insulation Schedule
   1. Loose-fill insulation, for belowground piping, is specified in Division 28.
   2. Chilled Water, All Sizes: Cellular glass, 2 inches (50 mm) thick.
   3. Condenser-Water Supply and Return, All Sizes: Cellular glass, 2 inches (50 mm) thick.

4. Heating-Hot-Water Supply and Return, All Sizes, 200 Deg F (93 Deg C) and below: Cellular glass, 3 inches (75 mm) thick.
5. Heating-Hot-Water Supply and Return, All Sizes, above 200 Deg F (93 Deg C):
   a. Calcium Silicate: 3 inches (75 mm) thick.
   b. Cellular Glass: 3 inches (75 mm) thick.
6. Steam and Steam Condensate, All Sizes, 350 Deg F (177 Deg C) and below:
   a. Calcium Silicate: 4 inches (100 mm) thick.
   b. Cellular Glass: 4 inches (100 mm) thick.
7. Steam and Steam Condensate, All Sizes, above 350 Deg F (177 Deg C):
   a. Calcium Silicate: 5 inches (125 mm) thick.
   b. Cellular Glass: 5 inches (125 mm) thick.
8. Dual-Service Heating and Cooling, All Sizes, 40 to 200 Deg F (4 to 93 Deg C): Cellular glass, 3 inches (75 mm) thick.
9. Fuel Oil Piping, All Sizes, Heated: Cellular glass, 2 inches (50 mm) thick.

AA. Indoor, Field-Applied Jacket Schedule
1. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.
2. If more than one material is listed, selection from materials listed is Contractor's option.
3. Ducts and Plenums, Concealed:
   a. None.
   b. PVC **OR** PVC, Color-Coded by System, **as directed**: 20 mils (0.5 mm) **OR** 30 mils (0.8 mm), **as directed**, thick.
   c. Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm) **OR** 0.040 inch (1.0 mm), **as directed**, thick.
   d. Painted Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm), **as directed**, thick.
   e. Stainless Steel, Type 304 **OR** Type 316, **as directed**, Smooth 2B Finish **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.010 inch (0.25 mm) **OR** 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm), **as directed**, thick.
4. Ducts and Plenums, Exposed:
   a. None.
   b. PVC **OR** PVC, Color-Coded by System, **as directed**: 20 mils (0.5 mm) **OR** 30 mils (0.8 mm), **as directed**, thick.
   c. Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm) **OR** 0.040 inch (1.0 mm), **as directed**, thick.
   d. Painted Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm), **as directed**, thick.
   e. Stainless Steel, Type 304 **OR** Type 316, **as directed**, Smooth 2B Finish **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.010 inch (0.25 mm) **OR** 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm), **as directed**, thick.
5. Equipment, Concealed:
   a. None.
   b. PVC **OR** PVC, Color-Coded by System, **as directed**: 20 mils (0.5 mm) **OR** 30 mils (0.8 mm), **as directed**, thick.
   c. Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm) **OR** 0.040 inch (1.0 mm), **as directed**, thick.
   d. Painted Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm), **as directed**, thick.

e. Stainless Steel, Type 304 **OR** Type 316, **as directed**, Smooth 2B Finish **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.010 inch (0.25 mm) **OR** 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm), **as directed**, thick.

6. Equipment, Exposed, up to 48 Inches (1200 mm) in Diameter or with Flat Surfaces up to 72 Inches (1800 mm):
   a. None.
   b. PVC **OR** PVC, Color-Coded by System, **as directed**: 20 mils (0.5 mm) **OR** 30 mils (0.8 mm), **as directed**, thick.
   c. Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm) **OR** 0.040 inch (1.0 mm), **as directed**, thick.
   d. Painted Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm), **as directed**, thick.
   e. Stainless Steel, Type 304 **OR** Type 316, **as directed**, Smooth 2B Finish **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.010 inch (0.25 mm) **OR** 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm), **as directed**, thick.
7. Equipment, Exposed, Larger Than 48 Inches (1200 mm) in Diameter or with Flat Surfaces Larger Than 72 Inches (1800 mm):
   a. None.
   b. Aluminum **OR** Painted Aluminum, **as directed**, Smooth **OR** Stucco Embossed, **as directed**, with 1-1/4-Inch- (32-mm-) Deep Corrugations **OR** 2-1/2-Inch- (65-mm-) Deep Corrugations **OR** 4-by-1-Inch (100-by-25-mm) Box Ribs, **as directed**: 0.032 inch (0.81 mm) **OR** 0.040 inch (1.0 mm), **as directed**, thick.
   c. Stainless Steel, Type 304 **OR** Type 316, **as directed**, Smooth **OR** Stucco Embossed, **as directed**, with 1-1/4-Inch- (32-mm-) Deep Corrugations **OR** 2-1/2-Inch- (65-mm-) Deep Corrugations **OR** 4-by-1-Inch (100-by-25-mm) Box Ribs, **as directed**: 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm), **as directed**, thick.
8. Piping, Concealed:
   a. None.
   b. PVC **OR** PVC, Color-Coded by System, **as directed**: 20 mils (0.5 mm) **OR** 30 mils (0.8 mm), **as directed**, thick.
   c. Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm) **OR** 0.040 inch (1.0 mm), **as directed**, thick.
   d. Painted Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm), **as directed**, thick.
   e. Stainless Steel, Type 304 **OR** Type 316, **as directed**, Smooth 2B Finish **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.010 inch (0.25 mm) **OR** 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm), **as directed**, thick.
9. Piping, Exposed:
   a. None.
   b. PVC **OR** PVC, Color-Coded by System, **as directed**: 20 mils (0.5 mm) **OR** 30 mils (0.8 mm), **as directed**, thick.
   c. Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm) **OR** 0.040 inch (1.0 mm), **as directed**, thick.
   d. Painted Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm), **as directed**, thick.
   e. Stainless Steel, Type 304 **OR** Type 316, **as directed**, Smooth 2B Finish **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.010 inch (0.25 mm) **OR** 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm), **as directed**, thick.

BB. Outdoor, Field-Applied Jacket Schedule

1. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.
2. If more than one material is listed, selection from materials listed is Contractor's option.
3. Ducts and Plenums, Concealed:
   a. None.
   b. PVC **OR** PVC, Color-Coded by System, **as directed**: 20 mils (0.5 mm) **OR** 30 mils (0.8 mm), **as directed**, thick.
   c. Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm) **OR** 0.040 inch (1.0 mm), **as directed**, thick.
   d. Painted Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm), **as directed**, thick.
   e. Stainless Steel, Type 304 **OR** Type 316, **as directed**, Smooth 2B Finish **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.010 inch (0.25 mm) **OR** 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm), **as directed**, thick.
4. Ducts and Plenums, Exposed, up to 48 Inches (1200 mm) in Diameter or with Flat Surfaces up to 72 Inches (1800 mm):
   a. Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm) **OR** 0.040 inch (1.0 mm), **as directed**, thick.
   b. Painted Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm), **as directed**, thick.
   c. Stainless Steel, Type 304 **OR** Type 316, **as directed**, Smooth 2B Finish **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.010 inch (0.25 mm) **OR** 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm), **as directed**, thick.
5. Ducts and Plenums, Exposed, Larger Than 48 Inches (1200 mm) in Diameter or with Flat Surfaces Larger Than 72 Inches (1800 mm):
   a. Aluminum **OR** Painted Aluminum, **as directed**, Smooth **OR** Stucco Embossed, **as directed**, with 1-1/4-Inch- (32-mm-) Deep Corrugations **OR** 2-1/2-Inch- (65-mm-) Deep Corrugations **OR** 4-by-1-Inch (100-by-25-mm) Box Ribs, **as directed**: 0.032 inch (0.81 mm) **OR** 0.040 inch (1.0 mm), **as directed**, thick.
   b. Stainless Steel, Type 304 **OR** Type 316, **as directed**, Smooth **OR** Stucco Embossed, **as directed**, with 1-1/4-Inch- (32-mm-) Deep Corrugations **OR** 2-1/2-Inch- (65-mm-) Deep Corrugations **OR** 4-by-1-Inch (100-by-25-mm) Box Ribs, **as directed**: 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm), **as directed**, thick.
6. Equipment, Concealed:
   a. None.
   b. PVC **OR** PVC, Color-Coded by System, **as directed**: 20 mils (0.5 mm) **OR** 30 mils (0.8 mm), **as directed,** thick.
   c. Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm) **OR** 0.040 inch (1.0 mm), **as directed**, thick.
   d. Painted Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm), **as directed**, thick.
   e. Stainless Steel, Type 304 **OR** Type 316, **as directed**, Smooth 2B Finish **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.010 inch (0.25 mm) **OR** 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm), **as directed**, thick.
7. Equipment, Exposed, up to 48 Inches (1200 mm) in Diameter or with Flat Surfaces up to 72 Inches (1800 mm):
   a. Aluminum **OR** Painted Aluminum, **as directed**, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**, with Z-Shaped Locking Seam, **as directed**: 0.016 inch (0.41 mm)

OR 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm) **OR** 0.040 inch (1.0 mm), **as directed**, thick.

b. Stainless Steel, Type 304 **OR** Type 316, **as directed**, Smooth 2B Finish **OR** Corrugated **OR** Stucco Embossed, **as directed** with Z-Shaped Locking Seam, **as directed**: 0.010 inch (0.25 mm) **OR** 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm), **as directed**, thick.

8. Equipment, Exposed, Larger Than 48 Inches (1200 mm) in Diameter or with Flat Surfaces Larger Than 72 Inches (1800 mm):
   a. Aluminum **OR** Painted Aluminum, **as directed**, Smooth **OR** Stucco Embossed, **as directed**, with 1-1/4-Inch- (32-mm-) Deep Corrugations **OR** 2-1/2-Inch- (65-mm-) Deep Corrugations **OR** 4-by-1-Inch (100-by-25-mm) Box Ribs, **as directed**: 0.032 inch (0.81 mm) **OR** 0.040 inch (1.0 mm), **as directed**, thick.
   b. Stainless Steel, Type 304 **OR** Type 316, **as directed**, Smooth **OR** Stucco Embossed, **as directed**, with 1-1/4-Inch- (32-mm-) Deep Corrugations **OR** 2-1/2-Inch- (65-mm-) Deep Corrugations **OR** 4-by-1-Inch (100-by-25-mm) Box Ribs, **as directed**: 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm), **as directed**, thick.
9. Piping, Concealed:
   a. None.
   b. PVC **OR** PVC, Color-Coded by System, **as directed**: 20 mils (0.5 mm) **OR** 30 mils (0.8 mm), **as directed**, thick.
   c. Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm) **OR** 0.040 inch (1.0 mm), **as directed**, thick.
   d. Painted Aluminum, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm), **as directed**, thick.
   e. Stainless Steel, Type 304 **OR** Type 316, **as directed**, Smooth 2B Finish **OR** Corrugated **OR** Stucco Embossed, **as directed**: 0.010 inch (0.25 mm) **OR** 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm), **as directed**, thick.
10. Piping, Exposed:
   a. PVC: 20 mils (0.5 mm) **OR** 30 mils (0.8 mm) **OR** 40 mils (1.0 mm), **as directed**, thick.
   b. Aluminum **OR** Painted Aluminum, **as directed**, Smooth **OR** Corrugated **OR** Stucco Embossed, **as directed**, with Z-Shaped Locking Seam, **as directed**: 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm) **OR** 0.032 inch (0.81 mm) **OR** 0.040 inch (1.0 mm), **as directed**, thick.
   c. Stainless Steel, Type 304 **OR** Type 316, **as directed**, Smooth 2B Finish **OR** Corrugated **OR** Stucco Embossed, **as directed**, with Z-Shaped Locking Seam, **as directed**: 0.010 inch (0.25 mm) **OR** 0.016 inch (0.41 mm) **OR** 0.020 inch (0.51 mm) **OR** 0.024 inch (0.61 mm), **as directed**, thick.

CC. Underground, Field-Installed Insulation Jacket
1. For underground direct-buried piping applications, install underground direct-buried jacket over insulation material.

END OF SECTION 23 07 13 00

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Task	Specification	Specification Description
23 07 16 00	23 07 13 00	HVAC Insulation

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SECTION 23 09 00 00 - BAS CONTROLS CONTRACTOR

1.1 SCOPE OF WORK

A. The BAS Controls Contractor shall be a factory authorized Teletrol Systems Inc. manufacturer's representative in good standing with Teletrol. The BAS Controls Contractor shall provide proof of authorization with their proposal.

B. The BAS Controls Contractor shall furnish and install a fully integrated building automation system, incorporating direct digital control (DDC) for electrical metering and data archiving, energy management, equipment monitoring and control, and other subsystems as herein specified.

C. All materials and equipment used shall be commercially available standard components, regularly manufactured for this and/or other systems. Custom devices and components shall not be permitted. All systems and components shall have been thoroughly tested and proven in actual use, and designed to work with the Teletrol Systems Inc. controllers and products.

D. The BAS Controls Contractor shall be responsible for all BAS and Temperature Control wiring for a complete and operable system. All wiring shall be done in accordance with all local and national codes.

1.2 WORK BY OTHERS

A. The Mechanical Contractor shall install all wells, valves, taps, dampers, flow stations, etc. furnished by the BAS Controls Contractor.

B. The Electrical Contractor shall provide:
1. 120V power to all BAS controllers and/or interface panels
2. Wiring of all power feeds through all disconnect starters to electrical motors
3. Wiring of any remote start/stop switches and manual or automatic motor speed control devices not furnished by BAS Controls Contractor.

1.3 RELATED WORK

A. Division 01000 General and Special Conditions

B. Division 15000 Mechanical

C. Division 16000 Electrical

1.4 QUALITY ASSURANCE

A. The BAS shall be engineered, installed, commissioned and serviced by Teletrol factory trained personnel regularly employed by the BAS Controls Contractor.

B. Materials and equipment shall be the catalogued products of manufacturers regularly engaged in production and installation of automatic temperature control systems and shall be manufacturer's latest standard design that complies with the specification requirements.

1.5 SUBMITTALS

A. Submit 3 complete sets of documentation in the following phased delivery schedule:
   1. Valve and damper schedules
   2. Equipment data cut sheets
   3. System schematics, including:
      a. sequence of operations narrative
      b. point names and addresses
      c. interface wiring diagrams
      d. panel layouts
      e. system riser diagrams
   4. Auto-CAD compatible as-built drawings

B. Upon project completion, submit operation and maintenance manuals, consisting of the following:
   1. Index sheet, listing contents in alphabetical order
   2. Manufacturer's equipment parts list of all functional system components
   3. Printed Narrative Description of all sequence of operations
   4. List of all connected points, showing panels to which they are connected
   5. D size printed copies of as-built wiring diagrams and panel layouts
   6. Operator and Installation Manual(s)
   7. Schematic showing panel locations, Conduit routing, and all cables
   8. Printed and documented copy of approved, commissioned control programs
   9. Digital format copy of all control programs and configuration files on CD
   10. Digital format copy of CADD files, showing system schematics and wiring

1.6 WARRANTY

A. Provide all services, materials and equipment necessary for the successful operation of the entire BAS system for a period of one year after beneficial use, based on the final installed sequence of operation and operating program.

B. The Warranty shall include the adjustment, required testing, and repair of the system including all computer equipment, transmission equipment and all sensors and control devices.

C. The Warranty shall include on-line support services which shall allow the BAS Controls Contractor to dial in over telephone lines to monitor and control the facility's building automation system. The BAS Controls Contractor shall provide remote support to the facility shall be within 2 hours of the time that the problem is reported. This coverage shall be extended to include normal business hours, after business hours, weekends and holidays.

1.7 PRODUCTS

A. Acceptable BAS Manufacturers
   1. Teletrol Systems Inc. **NO SUBSTITUTES SHALL BE PERMITTED.**

B. Networking Communications
   1. The design of the BAS shall network operator workstations and stand-alone DDC Controllers. The network architecture shall permit three levels of networks: the building or site administrative LAN or WAN; a high performance BAS controller peer-to-peer network; and a subnetwork for application specific controllers.
   2. All PC workstation interfaces, either network resident or connected via dial-up modems, shall have the ability to access all point status or execute control functions for any device connected to any of the networks. Multiple PC Workstations shall be able to access the controllers at the same time over the same networks. No hardware or software limits shall be imposed on the number of devices with global access to the network data at any time.

C. High Performance BAS Controller Network
   1. This network shall support fully programmable controllers and shall communicate with other controllers via the peer-to-peer network for transmission of global data.
   2. Telecommunication Capability:
      a. Auto-dial/auto-answer communications shall be provided to allow DDC Controllers to communicate with remote operator stations and/or remote terminals via telephone lines, as indicated in the sequence of operations.
      b. Auto-dial DDC Controllers shall automatically place calls to workstations to report alarms or other significant events.
      c. Operators at dial-up workstations shall be able to perform all control functions, all report functions and all database generation and modification functions as described for workstations connected via the network. The fact that communications are taking place with remote DDC Controllers over telephone lines shall be completely transparent to an operator.

D. DDC Controller
   1. DDC Controllers shall be stand-alone, multi-tasking, multi-user, real-time digital control processors consisting of processors, communication controllers, power supplies and input/output modules. Controller size shall be sufficient to meet the requirements of this specification and the attached points list. Each controller shall support a minimum of one (1) application specific controller subnetwork.
   2. Each DDC Controller shall have sufficient memory to support its own operating system and databases, including:
      a. Control processes and energy management applications
      b. Alarm management applications including custom alarm messages for each level alarm for each point in the system
      c. Historical/trend data for points specified
      d. Maintenance support applications
      e. Custom processes
      f. Operator I/O
      g. Dial-up communications
      h. Manual override monitoring
   3. Each DDC Controller shall support industry standard inputs and outputs.
   4. Provide all processors, power supplies and communication controllers complete so that the implementation of a point only requires the addition of the appropriate point input/output termination module and wiring.
   5. DDC Controllers shall provide a minimum two RS-232C serial data communication ports for operation of operator I/O devices such as industry standard printers, operator terminals, modems and portable laptop operator's terminals and communication with other non-BAS microproccessor based equipment. DDC Controllers shall allow temporary use of portable devices without interrupting the normal operation of permanently connected modems, printers or terminals.
   6. As indicated in the point I/O schedule, the operator shall have the ability to manually override automatic or centrally executed commands at the DDC Controller via local, point discrete, on-board hand/off/auto operator override switches for digital control type points.
      a. Switches shall be mounted either within the DDC Controllers key-accessed enclosure, or externally mounted with each switch keyed to prevent unauthorized overrides.
      b. DDC Controllers shall monitor the status of all overrides and inform the operator that automatic control has been inhibited. DDC Controllers shall also collect override activity information for reports.
         Note: Provide I/O schedule for points needing manual override
      c. DDC Controllers shall provide an LED status indication for each digital input or output for verification of point conditions without the need for an operator I/O device. Status indication shall be visible without opening the panel door.
   7. Each DDC Controller shall continuously perform self-diagnostics, communication diagnosis and diagnosis of all panel components. The DDC Controller shall provide both local and remote

annunciation of any detected component failures, low battery conditions or repeated failure to establish communication.

8. Isolation shall be provided at all peer-to-peer network terminations, as well as all field point terminations to suppress induced voltage transients consistent with IEEE Standards 587-1980.
9. In the event of the loss of normal power, there shall be an orderly shutdown of all DDC Controllers to prevent the loss of database or operating system software. Non-volatile memory shall be incorporated for all critical controller configuration data and battery backup shall be provided to support the real-time clock and all volatile memory for a minimum of 72 hours.
    a. Upon restoration of normal power, the DDC Controller shall automatically and gracefully resume full operation without manual intervention.
    b. Should DDC Controller memory be lost for any reason, the user shall have the capability of reloading the DDC Controller via the local RS-232C port, via telephone line dial-in, or from a network workstation PC.
10. Provide a separate DDC Controller for each AHU or other HVAC system as indicated in Section 3.2. It is intended that each unique system be provided with its own point resident DDC Controller.

E. DDC CONTROLLER RESIDENT SOFTWARE FEATURES

1. General:
    a. The software programs specified in this Section shall be provided as an integral part of DDC Controllers and shall not be dependent upon any higher level computer for execution.
2. Control Software Description:
    a. The DDC Controllers shall have the ability to perform the following pre-tested control algorithms:
        1) Two-position control
        2) Proportional control
        3) Proportional plus integral control
        4) Proportional, integral, plus derivative control
3. DDC Controllers shall have the ability to perform any or all the following energy management routines:
    a. Time-of-day scheduling
    b. Calendar-based scheduling
    c. Temporary schedule overrides
    d. Start-Stop Time Optimization
    e. Automatic Daylight Savings Time Switchover
    f. Night setback control
    g. Enthalpy switchover (economizer)
    h. Peak demand limiting
    i. Temperature-compensated duty cycling
4. DDC Controllers shall be able to execute custom, job-specific processes defined by the user, to automatically perform calculations and special control routines.
    a. A single process shall be able to incorporate measured or calculated data from any and all other DDC Controllers on the network. In addition, a single process shall be able to issue commands to points in any and all other DDC Controllers on the network.
    b. Processes shall be able to generate operator messages and advisories to operator I/O devices. A process shall be able to directly send a message to a specified device or cause the execution of a dial-up connection to a remote device such as a printer or pager.
5. Alarm management shall be provided to monitor and direct alarm information to operator devices. Each DDC Controller shall perform distributed, independent alarm analysis and filtering to minimize operator interruptions due to non-critical alarms, minimize network traffic and prevent alarms from being lost. At no time shall the DDC Controllers ability to report alarms be affected by operator activity at a PC workstation, local I/O device or communications with other panels on the network.
    a. All alarm or point change reports shall include the point's English language description and the time and date of occurrence.

b. The user shall be able to define the specific system reaction for each point. Alarms shall be prioritized to minimize nuisance reporting and to speed operator response to critical alarms. A minimum of four priority levels shall be provided for each point. Point priority levels shall be combined with user definable destination categories (PC, printer, DDC Controller, etc.) to provide full flexibility in defining the handling of system alarms. Each DDC Controller shall automatically inhibit the reporting of selected alarms during system shutdown and start-up. Users shall have the ability to manually inhibit alarm reporting for each point.

c. Alarm reports and messages will be directed to a user-defined list of operator devices or PCs.

d. In addition to the point's descriptor and the time and date, the user shall be able to print, display or store a 76 character alarm message to more fully describe the alarm condition or direct operator response.

e. In dial-up applications, operator-selected alarms shall initiate a call to a remote operator device.

6. A variety of historical data collection utilities shall be provided to manually or automatically sample, store and display system data for points as specified in the I/O summary.

a. Any point, physical or calculated may be designated for trending. Any point, regardless of physical location in the network, may be collected and stored in each DDC Controllers point group. Two methods of collection shall be allowed: either by a pre-defined time interval or upon a pre-defined change of value. Sample intervals of 1 minute to 7 days shall be provided. Each DDC Controller shall have a dedicated RAM-based buffer for trend data and shall be capable of storing a minimum of 14,000 time/date stamped data samples. Downloaded trend data shall be available for use in 3rd party personal computer applications.

b. DDC Controllers shall provide high resolution sampling capability for verification of control loop performance. Operator-initiated automatic and manual loop tuning algorithms shall be provided for operator-selected PID control loops as identified in the point I/O summary.

1) Loop tuning shall be capable of being initiated either locally at the DDC Controller, from a network workstation or remotely using dial-in modems. For all loop tuning functions, access shall be limited to authorized personnel through password protection.

7. DDC Controllers shall automatically accumulate and store run-time data for digital input and output points and automatically sample, calculate and store totals for analog and digital pulse input type points, as specified in the point I/O summary.

F. APPLICATION SPECIFIC CONTROLLERS (ASC)

1. Each DDC Controller shall be able to extend its performance and capacity through the addition of application specific controllers (ASCs).

2. Each ASC shall operate as a stand-alone controller, capable of performing its specified control responsibilities independently of other ASC's in the network.

3. ASC's shall be capable of control of the terminal device independent of the manufacturer of the terminal device.

G. ASC Terminal Equipment Controllers:

1. Provide for control of each piece of equipment, including, but not limited to, the following:

a. Variable Air Volume (VAV) boxes

b. Constant Air Volume (CAV) boxes

c. Dual Duct Terminal Boxes

d. Fan Coil Units

e. Computer Room Air Conditioning units (CRAC units)

f. Heat Pumps

g. Unit Ventilators

h. Room Pressurization

2. Controllers shall include all point inputs and outputs necessary to perform the specified control sequences. Analog outputs shall be industry standard signals such as 10V floating control or 0-20mA allowing for interface to a variety of modulating actuators. Terminal controllers utilizing proprietary control signals for actuators shall not be acceptable.

H. PERSONAL COMPUTER OPERATOR WORKSTATION HARDWARE

1. Personal computer operator workstations shall be provided for command entry, information management, network alarm management and database management functions. All real-time control functions shall be resident in the DDC Controllers to facilitate greater fault tolerance and reliability.

a. Provide (x) workstation(s) of equal capability located at _____

b. Workstation shall consist of an SXGA 19 " color monitor, personal computer with minimum 128 MB RAM, 20 GB hard drive, 3-1/2" diskette drive, mouse and 101-key enhanced keyboard. Personal computer shall be an IBM Compatible PC and shall include a minimum 800 MHZ Pentium III processor.

2. Provide a printer at each workstation location for recording alarms, operator transactions and systems reports.

I. WORKSTATION OPERATOR INTERFACE

1. The Basic User Interface shall be the ENSEMBLE software as furnished by Teletrol Systems Inc.
2. The Dynamic Graphical User Interface shall be the PANORAMA software as furnished by Teletrol Systems Inc.
   a. (xx) color graphic floor plan displays and system schematics for each piece of mechanical equipment, including air handling units, chilled water systems and hot water boiler systems, shall be provided by the BAS Controls Contractor as indicated in the point I/O summary of this specification to optimize system performance analysis and speed alarm recognition.
   b. The operator interface shall allow users to access the various system schematics and floor plans via an intuitive navigation and penetration scheme, using menu selection or text-based commands.
   c. Dynamic temperature values, humidity values, flow values and status indication shall be shown in their actual respective locations and shall automatically update to represent current conditions without operator intervention.
   d. The screen layout and design shall allow the user to simultaneously view several graphics at a time to analyze total building operation or to allow the display of a graphic associated with an alarm to be viewed without interrupting work in progress.

J. FIELD DEVICES

1. All devices and equipment shall be approved for installation in Los Angeles County.
2. Temperature Sensors - with accuracy of + 0.5 deg F @ 77 deg F)
3. Humidity Sensors - with accuracy of + 3 % RH @ 77 deg F, range of 20% to 95% RH, including hysteresis, linearity, and repeatability
4. Pressure Sensors and Pressure Transducers
5. Dampers, sized for specific application
6. Damper Operators, sized for specific application
7. Automatic Control Valves, sized for specific application
8. Air Volume Measurement devices
9. Smoke Detectors and Firestats
10. Electronic-to-Pneumatic Transducers
11. Differential Pressure Switch

1.8 EXECUTION

A. PROJECT MANAGEMENT - Provide a designated project manager who will be responsible for the following:

1. Establish and maintain the project schedule
2. On-site coordination with all applicable trades and subcontractors
3. Authorized to accept and execute orders or instructions from owner/architect
4. Attend project meetings as necessary to avoid conflicts and delays
5. Make necessary field decisions relating to this scope of work
6. Coordination/Single point of contact

B. SEQUENCE OF OPERATION – Job Specific – Per Job Requirements

C. POINT SCHEDULE MATRIX – I/O SUMMARY

1. The contractor shall collaborate with the Owner directly to determine the Owner's preference for naming conventions, etc. before entering the data in to the system.

D. START-UP AND COMMISSIONING

1. When installation of the system is complete, calibrate equipment and verify transmission media operation before the system is placed on-line. All testing, calibration, adjustments and final field tests shall be completed by the BAS Controls Contractor. Verify that all systems are operable from local controls in the specified failure mode upon panel failure or loss of power.
2. Provide any recommendation for system modification in writing to owner. Do not make any system modification, including operating parameters and control settings, without prior approval of owner.

E. EXISTING CONTROL DEVICES

1. All proposals for the control work shall be based on the premise that existing control devices are operational and are not in need of repair or replacement, unless otherwise noted.
2. This subcontractor shall notify the Owner's representative of existing control devices that need to be replaced or repaired that may be noted in the process of installation of the new work.

F. TRAINING

1. The contractor shall provide a Teletrol factory trained instructor to give full instruction to designated personnel in the operation of the system installed. Instructors shall be thoroughly familiar with all aspects of the actual installation and of the subject matter they are to teach. The contractor shall provide all students with a student binder containing product specific training for the system installed. All training shall be held during normal working hours of 8:00 am to 4:30 PM weekdays.
2. Provide hours of training for Owner's designated operating personnel. Training shall include:
   a. Explanation of drawings, operations and maintenance manuals
   b. Walk-through of the job to locate control components
   c. Operator workstation and peripherals
   d. DDC controller and ASC operation/function
   e. Operator control functions including graphic generation and field panel programming
   f. Operation of portable operator's terminal
   g. Explanation of adjustment, calibration and replacement procedures
   h. Student binder with training modules
3. Since the Owner may require personnel to have more comprehensive understanding of the hardware and software, additional training must be available from the Contractor.

END OF SECTION 23 09 00 00

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Task	Specification	Specification Description
23 09 00 00	22 15 13 00a	HVAC Instrumentation And Controls
23 09 13 56	22 15 13 00a	HVAC Instrumentation And Controls

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SECTION 23 09 23 00 - ENCLOSED CONTROLLERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for enclosed controllers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section includes the following enclosed controllers rated 600 V and less:
   a. Full-voltage manual.
   b. Full-voltage magnetic.
   c. Reduced-voltage magnetic.
   d. Reduced-voltage solid state.
   e. Multispeed.

C. Definitions
1. CPT: Control power transformer.
2. MCCB: Molded-case circuit breaker.
3. MCP: Motor circuit protector.
4. N.C.: Normally closed.
5. N.O.: Normally open.
6. OCPD: Overcurrent protective device.
7. SCR: Silicon-controlled rectifier.

D. Performance Requirements
1. Seismic Performance: Enclosed controllers shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
   a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

E. Submittals
1. Product Data: For each type of enclosed controller. Include manufacturer's technical data on features, performance, electrical characteristics, ratings, and enclosure types and finishes.
2. Shop Drawings: For each enclosed controller. Include dimensioned plans, elevations, sections, details, and required clearances and service spaces around controller enclosures.
   a. Show tabulations of the following:
      1) Each installed unit's type and details.
      2) Factory-installed devices.
      3) Nameplate legends.
      4) Short-circuit current rating of integrated unit.
      5) Listed and labeled for integrated short-circuit current (withstand) rating of OCPDs in combination controllers by an NRTL acceptable to authorities having jurisdiction.
      6) Features, characteristics, ratings, and factory settings of individual OCPDs in combination controllers.
   b. Wiring Diagrams: For power, signal, and control wiring.
3. Qualification Data: For qualified testing agency.
4. Seismic Qualification Certificates: For enclosed controllers, accessories, and components, from manufacturer.
   a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

5. Field quality-control reports.
6. Operation and Maintenance Data: For enclosed controllers to include in emergency, operation, and maintenance manuals. Include the following:
   a. Routine maintenance requirements for enclosed controllers and installed components.
   b. Manufacturer's written instructions for testing and adjusting circuit breaker and MCP trip settings.
   c. Manufacturer's written instructions for setting field-adjustable overload relays.
   d. Manufacturer's written instructions for testing, adjusting, and reprogramming reduced-voltage solid-state controllers.
7. Load-Current and Overload-Relay Heater List: Compile after motors have been installed, and arrange to demonstrate that selection of heaters suits actual motor nameplate full-load currents.
8. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed, and arrange to demonstrate that switch settings for motor running overload protection suit actual motors to be protected.

F. Quality Assurance
1. Testing Agency Qualifications: Member company of NETA or an NRTL.
   a. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.
2. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
3. Comply with NFPA 70.
4. IEEE Compliance: Fabricate and test enclosed controllers according to IEEE 344 to withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".

G. Delivery, Storage, And Handling
1. Store enclosed controllers indoors in clean, dry space with uniform temperature to prevent condensation. Protect enclosed controllers from exposure to dirt, fumes, water, corrosive substances, and physical damage.
2. If stored in areas subject to weather, cover enclosed controllers to protect them from weather, dirt, dust, corrosive substances, and physical damage. Remove loose packing and flammable materials from inside controllers; install temporary electric heating, with at least 250 W per controller **OR** connect factory-installed space heaters to temporary electrical service, **as directed**.

H. Project Conditions
1. Environmental Limitations: Rate equipment for continuous operation under the following conditions unless otherwise indicated:
   a. Ambient Temperature: Not less than minus 22 deg F (minus 30 deg C) and not exceeding 104 deg F (40 deg C).
   b. Altitude: Not exceeding 6600 feet (2010 m).
2. Interruption of Existing Electrical Systems: Do not interrupt electrical systems in facilities occupied by the Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:
   a. Notify the Owner no fewer than two days in advance of proposed interruption of electrical systems.
   b. Indicate method of providing temporary utilities.
   c. Do not proceed with interruption of electrical systems without the Owner's written permission.
   d. Comply with NFPA 70E.

I. Coordination
1. Coordinate layout and installation of enclosed controllers with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.
2. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 3.
3. Coordinate installation of roof curbs, equipment supports, and roof penetrations.

1.2 PRODUCTS

A. Full-Voltage Controllers
1. General Requirements for Full-Voltage Controllers: Comply with NEMA ICS 2, general purpose, Class A.
2. Motor-Starting Switches: "Quick-make, quick-break" toggle or push-button action; marked to show whether unit is off or on.
   a. Configuration: Nonreversing **OR** Reversing **OR** Two speed, **as directed**.
   b. Flush **OR** Surface, **as directed**, mounting.
   c. Red **OR** Green, **as directed**, pilot light.
   d. Additional Nameplates: FORWARD and REVERSE for reversing switches **OR** HIGH and LOW for two-speed switches, **as directed**.
3. Fractional Horsepower Manual Controllers: "Quick-make, quick-break" toggle or push-button action; marked to show whether unit is off, on, or tripped.
   a. Configuration: Nonreversing **OR** Two speed, **as directed**.
   b. Overload Relays: Inverse-time-current characteristics; NEMA ICS 2, Class 10 tripping characteristics; heaters matched to nameplate full-load current of actual protected motor; external reset push button; bimetallic type **OR** melting alloy type, **as directed**.
   c. Flush **OR** Surface, **as directed**, mounting.
   d. Red **OR** Green, **as directed**, pilot light.
   e. Additional Nameplates: HIGH and LOW for two-speed controllers.
4. Integral Horsepower Manual Controllers: "Quick-make, quick-break" toggle or push-button action; marked to show whether unit is off, on, or tripped.
   a. Configuration: Nonreversing **OR** Reversing **OR** Two speed, **as directed**.
   b. Overload Relays: Inverse-time-current characteristics; NEMA ICS 2, Class 10 tripping characteristics; heaters and sensors in each phase, matched to nameplate full-load current of actual protected motor and having appropriate adjustment for duty cycle; external reset push button; bimetallic type **OR** melting alloy type, **as directed**.
   c. Flush **OR** Surface, **as directed**, mounting.
   d. Red **OR** Green, **as directed**, pilot light.
   e. Additional Nameplates: FORWARD and REVERSE for reversing controllers **OR** HIGH and LOW for two-speed controllers, **as directed**.
   f. N.O. **OR** N.C., **as directed**, auxiliary contact.
5. Magnetic Controllers: Full voltage, across the line, electrically held.
   a. Configuration: Nonreversing **OR** Reversing, **as directed**.
   b. Contactor Coils: Pressure-encapsulated type with coil transient suppressors, **as directed**.
      1) Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.
   c. Power Contacts: Totally enclosed, double-break, silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.
   d. Control Circuits: 24 **OR** 120, **as directed**,-V ac; obtained from integral CPT, with primary and secondary fuses, **as directed**, with CPT **OR** control power source, **as directed**, of sufficient capacity to operate integral devices and remotely located pilot, indicating, and control devices.
      1) CPT Spare Capacity: 50 **OR** 100 **OR** 200, **as directed**, VA.
   e. Melting Alloy Overload Relays:

1) Inverse-time-current characteristic.
2) Class 10 **OR** Class 20 **OR** Class 30, **as directed**, tripping characteristic.
3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.

f. Bimetallic Overload Relays:
1) Inverse-time-current characteristic.
2) Class 10 **OR** Class 20 **OR** Class 30, **as directed**, tripping characteristic.
3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
4) Ambient compensated.
5) Automatic resetting.

g. Solid-State Overload Relay:
1) Switch or dial selectable for motor running overload protection.
2) Sensors in each phase.
3) Class 10 **OR** Class 20 **OR** Class 10/20 selectable, **as directed**, tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.
4) Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
5) Analog communication module.

h. N.C. **OR** N.O., **as directed**, isolated overload alarm contact.

i. External overload reset push button.

6. Combination Magnetic Controller: Factory-assembled combination of magnetic controller, OCPD, and disconnecting means.

a. Fusible Disconnecting Means:
1) NEMA KS 1, heavy-duty, horsepower-rated, fusible switch with clips or bolt pads to accommodate Class J **OR** Class R **OR** indicated, **as directed**, fuses.
2) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
3) Auxiliary Contacts: N.O./N.C., arranged to activate before switch blades open.

b. Nonfusible Disconnecting Means:
1) NEMA KS 1, heavy-duty, horsepower-rated, nonfusible switch.
2) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
3) Auxiliary Contacts: N.O./N.C., arranged to activate before switch blades open.

c. MCP Disconnecting Means:
1) UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents, instantaneous-only circuit breaker with front-mounted, field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
2) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
3) Auxiliary contacts "a" and "b" arranged to activate with MCP handle.
4) N.C. **OR** N.O., **as directed**, alarm contact that operates only when MCP has tripped.
5) Current-limiting module to increase controller short-circuit current (withstand) rating to 100 kA.

d. MCCB Disconnecting Means:
1) UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents; thermal-magnetic MCCB, with inverse time-current element for low-level overloads and instantaneous magnetic trip element for short circuits.
2) Front-mounted, adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
3) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
4) Auxiliary contacts "a" and "b" arranged to activate with MCCB handle.

5) N.C. **OR** N.O., **as directed**, alarm contact that operates only when MCCB has tripped.

B. Reduced-Voltage Magnetic Controllers
1. General Requirements for Reduced-Voltage Magnetic Controllers: Comply with NEMA ICS 2, general purpose, Class A; closed-transition; adjustable time delay on transition.
2. Reduced-Voltage Magnetic Controllers: Reduced voltage, electrically held.
a. Configuration:
1) Wye-Delta Controller: Four contactors, with a three-phase starting resistor/reactor bank.
2) Part-Winding Controller: Separate START and RUN contactors, field-selectable for 1/2- or 2/3-winding start mode, with either six- or nine-lead motors; with separate overload relays for starting and running sequences.
3) Autotransformer Reduced-Voltage Controller: Medium-duty service, with integral overtemperature protection; taps for starting at 50, 65, and 80 percent of line voltage; two START and one RUN contactors.
b. Contactor Coils: Pressure-encapsulated type with coil transient suppressors, **as directed**.
1) Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.
c. Power Contacts: Totally enclosed, double-break, silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.
d. Control Circuits: 24 **OR** 120, **as directed**,-V ac; obtained from integral CPT, with primary and secondary fuses, **as directed**, with CPT **OR** control power source, **as directed**, of sufficient capacity to operate integral devices and remotely located pilot, indicating, and control devices.
1) CPT Spare Capacity: 50 **OR** 100 **OR** 200, **as directed**, VA.
e. Melting Alloy Overload Relays:
1) Inverse-time-current characteristic.
2) Class 10 **OR** Class 20 **OR** Class 30, **as directed**, tripping characteristic.
3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
f. Bimetallic Overload Relays:
1) Inverse-time-current characteristic.
2) Class 10 **OR** Class 20 **OR** Class 30, **as directed**, tripping characteristic.
3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
4) Ambient compensated.
5) Automatic resetting.
g. Solid-State Overload Relay:
1) Switch or dial selectable for motor running overload protection.
2) Sensors in each phase.
3) Class 10 **OR** Class 20 **OR** Class 10/20 selectable, **as directed**, tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.
4) Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
5) Analog communication module.
h. N.C. **OR** N.O., **as directed**, isolated overload alarm contact.
i. External overload reset push button.
3. Combination Reduced-Voltage Magnetic Controller: Factory-assembled combination of reduced-voltage magnetic controller, OCPD, and disconnecting means.
a. Fusible Disconnecting Means:
1) NEMA KS 1, heavy-duty, horsepower-rated, fusible switch with clips or bolt pads to accommodate Class J **OR** Class R **OR** indicated, **as directed**, fuses.
2) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

3) Auxiliary Contacts: N.O./N.C., arranged to activate before switch blades open.

b. Nonfusible Disconnecting Means:
1) NEMA KS 1, heavy-duty, horsepower-rated, nonfusible switch.
2) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
3) Auxiliary Contacts: N.O./N.C., arranged to activate before switch blades open.

c. MCP Disconnecting Means:
1) UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents, instantaneous-only circuit breaker with front-mounted, field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
2) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
3) Auxiliary contacts "a" and "b" arranged to activate with MCP handle.
4) N.C. **OR** N.O., **as directed**, alarm contact that operates only when MCP has tripped.
5) Current-limiting module to increase controller short-circuit current (withstand) rating to 100 kA.

d. MCCB Disconnecting Means:
1) UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents; thermal-magnetic MCCB, with inverse time-current element for low-level overloads and instantaneous magnetic trip element for short circuits.
2) Front-mounted, adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
3) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
4) Auxiliary contacts "a" and "b" arranged to activate with MCCB handle.
5) N.C. **OR** N.O., **as directed**, alarm contact that operates only when MCCB has tripped.

C. Reduced-Voltage Solid-State Controllers
1. General Requirements for Reduced-Voltage Solid-State Controllers: Comply with UL 508.
2. Reduced-Voltage Solid-State Controllers: An integrated unit with power SCRs, heat sink, microprocessor logic board, door-mounted digital display and keypad, bypass contactor, and overload relay; suitable for use with NEMA MG 1, Design B, polyphase, medium induction motors.
a. Configuration: Standard duty **OR** Severe duty, **as directed**; nonreversible **OR** reversible, **as directed**.
b. Starting Mode: Voltage ramping **OR** Current limit **OR** Torque control **OR** Torque control with voltage boost, **as directed**; field selectable, **as directed**.
c. Stopping Mode: Coast to stop **OR** Adjustable torque deceleration **OR** Adjustable braking, **as directed**; field selectable, **as directed**.
d. Shorting (Bypass) Contactor: Operates automatically when full voltage is applied to motor, and bypasses the SCRs. Solid-state controller protective features shall remain active when the shorting contactor is in the bypass mode.
e. Shorting and Input Isolation, **as directed**, Contactor Coils: Pressure-encapsulated type; manufacturer's standard operating voltage, matching control power or line voltage, depending on contactor size and line-voltage rating. Provide coil transient suppressors, **as directed**.
f. Logic Board: Identical for all ampere ratings and voltage classes, with environmental protective coating.
g. Control Circuits: 24 **OR** 120, **as directed**,-V ac; obtained from integral CPT, with primary and secondary fuses, **as directed**, with CPT **OR** control power source, **as directed**, of sufficient capacity to operate integral devices and remotely located pilot, indicating, and control devices.
1) CPT Spare Capacity: 100 **OR** 200, **as directed**, VA.

h. Adjustable acceleration-rate control using voltage or current ramp, and adjustable starting torque control with up to 400 percent current limitation for 20 seconds.

i. SCR bridge shall consist of at least two SCRs per phase, providing stable and smooth acceleration with **OR** without, **as directed**, external feedback from the motor or driven equipment.

j. Keypad, front accessible; for programming the controller parameters, functions, and features; shall be manufacturer's standard and include not less than the following functions:
   1) Adjusting motor full-load amperes, as a percentage of the controller's rating.
   2) Adjusting current limitation on starting, as a percentage of the motor full-load current rating.
   3) Adjusting linear acceleration and deceleration ramps, in seconds.
   4) Initial torque, as a percentage of the nominal motor torque.
   5) Adjusting torque limit, as a percentage of the nominal motor torque.
   6) Adjusting maximum start time, in seconds.
   7) Adjusting voltage boost, as a percentage of the nominal supply voltage.
   8) Selecting stopping mode, and adjusting parameters.
   9) Selecting motor thermal overload protection class between 5 and 30.
   10) Activating and de-activating protection modes.
   11) Selecting or activating communication modes.

k. Digital display, front accessible; for showing motor, controller, and fault status; shall be manufacturer's standard and include not less than the following:
   1) Controller Condition: Ready, starting, running, stopping.
   2) Motor Condition: Amperes, voltage, power factor, power, and thermal state.
   3) Fault Conditions: Controller thermal fault, motor overload alarm and trip, motor underload, overcurrent, shorted SCRs, line or phase loss, phase reversal, and line frequency over or under normal.

l. Controller Diagnostics and Protection:
   1) Microprocessor-based thermal protection system for monitoring SCR and motor thermal characteristics, and providing controller overtemperature and motor-overload alarm and trip; settings selectable via the keypad.
   2) Protection from line-side reverse phasing; line-side and motor-side phase loss; motor jam, stall, and underload conditions; and line frequency over or under normal.
   3) Input isolation contactor that opens when the controller diagnostics detect a faulted solid-state component or when the motor is stopped.
      OR
      Shunt trip that opens the disconnecting means when the controller diagnostics detect a faulted solid-state component.

m. Remote Output Features:
   1) All outputs prewired to terminal blocks.
   2) Form C status contacts that change state when controller is running.
   3) Form C alarm contacts that change state when a fault condition occurs.

n. Optional Features:
   1) Analog output for field-selectable assignment of motor operating characteristics; 0 to 10-V dc **OR** 4 to 20-mA dc, **as directed**.
   2) Additional field-assignable Form C contacts, as indicated, for alarm outputs.
   3) Surge suppressors in solid-state power circuits providing three-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.
   4) Full-voltage bypass contactor operating automatically **OR** manually, with NORMAL/BYPASS selector switch, **as directed**. Power contacts shall be totally enclosed, double break, and silver-cadmium oxide; and assembled to allow inspection and replacement without disturbing line or load wiring.
   5) Melting Alloy Overload Relays:
      a) Inverse-time-current characteristic.
      b) Class 10 **OR** Class 20 **OR** Class 30, **as directed**, tripping characteristic.

c) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.

6) Bimetallic Overload Relays:
   a) Inverse-time-current characteristic.
   b) Class 10 **OR** Class 20 **OR** Class 30, **as directed**, tripping characteristic.
   c) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
   d) Ambient compensated.
   e) Automatic resetting.
7) Solid-State Overload Relay:
   a) Switch or dial selectable for motor running overload protection.
   b) Sensors in each phase.
   c) Class 10 **OR** Class 20 **OR** Class 30, **as directed**, tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.
   d) Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
   e) Analog communication module.
8) N.C. **OR** N.O., **as directed**, isolated overload alarm contact.
9) External overload reset push button.

3. Combination Reduced-Voltage Solid-State Controller: Factory-assembled combination of reduced-voltage solid-state controller, OCPD, and disconnecting means.
   a. Fusible Disconnecting Means:
      1) NEMA KS 1, heavy-duty, horsepower-rated, fusible switch with clips or bolt pads to accommodate Class J **OR** Class L **OR** indicated, **as directed**, fuses.
      2) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
      3) Auxiliary Contacts: N.O./N.C., arranged to activate before switch blades open.
   b. MCP Disconnecting Means:
      1) UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents, instantaneous-only circuit breaker with front-mounted, field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
      2) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
      3) Auxiliary contacts "a" and "b" arranged to activate with MCP handle.
      4) N.C. **OR** N.O., **as directed**, alarm contact that operates only when MCP has tripped.
      5) Current-limiting module to increase controller short-circuit current (withstand) rating to 100 kA.
   c. MCCB Disconnecting Means:
      1) UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents; thermal-magnetic MCCB, with inverse time-current element for low-level overloads and instantaneous magnetic trip element for short circuits.
      2) Front-mounted, adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
      3) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
      4) Auxiliary contacts "a" and "b" arranged to activate with MCCB handle.
      5) N.C. **OR** N.O., **as directed**, alarm contact that operates only when MCCB has tripped.
   d. Molded-Case Switch Disconnecting Means:
      1) UL 489, NEMA AB 1, and NEMA AB 3, with in-line fuse block for Class J or L power fuses (depending on ampere rating), providing an interrupting capacity to comply with available fault currents; MCCB with fixed, high-set instantaneous trip only.
      2) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.

3) Auxiliary contacts "a" and "b" arranged to activate with molded-case switch handle.
4) N.C. **OR** N.O., **as directed**, alarm contact that operates only when molded-case switch has tripped.

D. Multispeed Magnetic Controllers
1. General Requirements for Multispeed Magnetic Controllers: Comply with NEMA ICS 2, general purpose, Class A.
2. Multispeed Magnetic Controllers: Two speed, full voltage, across the line, electrically held.
a. Configuration: Nonreversing **OR** Reversing, **as directed**; consequent pole **OR** two winding, **as directed**.
b. Contactor Coils: Pressure-encapsulated type with coil transient suppressors, **as directed**.
1) Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.
c. Power Contacts: Totally enclosed, double break, silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.
d. Control Circuits: 24 **OR** 120, **as directed**,-V ac; obtained from integral CPT, with primary and secondary fuses, **as directed**, with CPT **OR** control power source, **as directed**, of sufficient capacity to operate integral devices and remotely located pilot, indicating, and control devices.
1) CPT Spare Capacity: 50 **OR** 100 **OR** 200, **as directed**, VA.
e. Compelling relays shall ensure that motor will start only at low speed.
f. Accelerating timer relays shall ensure properly timed acceleration through speeds lower than that selected.
g. Decelerating timer relays shall ensure automatically timed deceleration through each speed.
h. Antiplugging timer relays shall ensure a time delay when transferring from FORWARD to REVERSE and back.
i. Melting Alloy Overload Relays:
1) Inverse-time-current characteristic.
2) Class 10 **OR** Class 20 **OR** Class 30, **as directed**, tripping characteristic.
3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
j. Bimetallic Overload Relays:
1) Inverse-time-current characteristic.
2) Class 10 **OR** Class 20 **OR** Class 30, **as directed**, tripping characteristic.
3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
4) Ambient compensated.
5) Automatic resetting.
k. Solid-State Overload Relay:
1) Switch or dial selectable for motor running overload protection.
2) Sensors in each phase.
3) Class 10 **OR** Class 20 **OR** Class 10/20 selectable, **as directed**, tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.
4) Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
5) Analog communication module.
l. N.C. **OR** N.O., **as directed**, isolated overload alarm contact.
m. External overload reset push button.
3. Combination Multispeed Magnetic Controller: Factory-assembled combination of reduced-voltage magnetic controller, OCPD, and disconnecting means.
a. Fusible Disconnecting Means:
1) NEMA KS 1, heavy-duty, horsepower-rated, fusible switch with clips or bolt pads to accommodate Class J **OR** Class R **OR** indicated, **as directed**, fuses.

2) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
3) Auxiliary Contacts: N.O./N.C., arranged to activate before switch blades open.

b. Nonfusible Disconnecting Means:
1) NEMA KS 1, heavy-duty, horsepower-rated, nonfusible switch.
2) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
3) Auxiliary Contacts: N.O./N.C., arranged to activate before switch blades open.

c. MCP Disconnecting Means:
1) UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents, instantaneous-only circuit breaker with front-mounted, field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
2) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
3) Auxiliary contacts "a" and "b" arranged to activate with MCP handle.
4) N.C. **OR** N.O., **as directed**, alarm contact that operates only when MCP has tripped.
5) Current-limiting module to increase controller short-circuit current (withstand) rating to 100 kA.

d. MCCB Disconnecting Means:
1) UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents; thermal-magnetic MCCB, with inverse time-current element for low-level overloads and instantaneous magnetic trip element for short circuits.
2) Front-mounted, adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
3) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
4) Auxiliary contacts "a" and "b" arranged to activate with MCCB handle.
5) N.C. **OR** N.O., **as directed**, alarm contact that operates only when MCCB has tripped.

E. Enclosures
1. Enclosed Controllers: NEMA ICS 6, to comply with environmental conditions at installed location.
a. Dry and Clean Indoor Locations: Type 1.
b. Outdoor Locations: Type 3R **OR** Type 4X, **as directed**.
c. Kitchen **OR** Wash-Down, **as directed**, Areas: Type 4X, stainless steel.
d. Other Wet or Damp Indoor Locations: Type 4.
e. Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: Type 12.
f. Hazardous Areas Indicated on Drawings: Type 7 **OR** Type 9, **as directed**.

F. Accessories
1. General Requirements for Control Circuit and Pilot Devices: NEMA ICS 5; factory installed in controller enclosure cover unless otherwise indicated.
a. Push Buttons, Pilot Lights, and Selector Switches: Heavy **OR** Standard, **as directed**,-duty, oiltight, **as directed**, type.
1) Push Buttons: Covered **OR** Lockable **OR** Recessed **OR** Shielded **OR** Shrouded **OR** Unguarded, **as directed**, types; maintained **OR** momentary, **as directed**, as indicated.
2) Pilot Lights: Incandescent **OR** LED **OR** Neon **OR** Resistor **OR** Transformer, **as directed**, types; colors as indicated; push to test, **as directed**.
3) Selector Switches: Rotary type.
b. Elapsed Time Meters: Heavy duty with digital readout in hours; nonresettable **OR** resettable, **as directed**.

c. Meters: Panel type, 2-1/2-inch (64-mm) minimum size with 90- or 120-degree scale and plus or minus two percent accuracy. Where indicated, provide selector switches with an off position.

2. N.C. **OR** N.O. **OR** Reversible N.C./N.O., **as directed**, auxiliary contact(s).
3. Control Relays: Auxiliary and adjustable pneumatic **OR** solid-state, **as directed**, time-delay relays.
4. Phase-Failure, Phase-Reversal, and Undervoltage and Overvoltage Relays: Solid-state sensing circuit with isolated output contacts for hard-wired connections. Provide adjustable undervoltage, overvoltage, and time-delay settings.
5. Breather and drain assemblies, to maintain interior pressure and release condensation in Type 4 **OR** Type 4X **OR** Type 7 **OR** Type 9, **as directed**, enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.
6. Space heaters, with N.C. auxiliary contacts, to mitigate condensation in Type 3R **OR** Type 4X **OR** Type 12, **as directed**, enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.
7. Sun shields installed on fronts, sides, and tops of enclosures installed outdoors and subject to direct and extended sun exposure.
8. Cover gaskets for Type 1 enclosures.
9. Terminals for connecting power factor correction capacitors to the line **OR** load, **as directed**, side of overload relays.
10. Spare control wiring terminal blocks, quantity as indicated; unwired **OR** wired, **as directed**.

1.3 EXECUTION

A. Examination

1. Examine areas and surfaces to receive enclosed controllers, with Installer present, for compliance with requirements and other conditions affecting performance of the Work.
2. Examine enclosed controllers before installation. Reject enclosed controllers that are wet, moisture damaged, or mold damaged.
3. Proceed with installation only after unsatisfactory conditions have been corrected.

B. Installation

1. Wall-Mounted Controllers: Install enclosed controllers on walls with tops at uniform height unless otherwise indicated, and by bolting units to wall or mounting on lightweight structural-steel channels bolted to wall. For controllers not at walls, provide freestanding racks complying with Division 26 Section "Hangers And Supports For Electrical Systems".
2. Floor-Mounted Controllers: Install enclosed controllers on 4-inch (100-mm) nominal-thickness concrete base. Comply with requirements for concrete base specified in Division 03 Section "Cast-in-place Concrete".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   d. Install anchor bolts to elevations required for proper attachment to supported equipment.
3. Seismic Bracing: Comply with requirements specified in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".
4. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.
5. Install fuses in each fusible-switch enclosed controller.
6. Install fuses in control circuits if not factory installed. Comply with requirements in Division 26 Section "Fuses".
7. Install heaters in thermal overload relays. Select heaters based on actual nameplate full-load amperes after motors have been installed.

8. Install, connect, and fuse thermal-protector monitoring relays furnished with motor-driven equipment.
9. Install power factor correction capacitors. Connect to the line **OR** load, **as directed**, side of overload relays. If connected to the load side of overload relays, adjust overload heater sizes to accommodate the reduced motor full-load currents.
10. Comply with NECA 1.

C. Identification
1. Identify enclosed controllers, components, and control wiring. Comply with requirements for identification specified in Division 26 Section "Identification For Electrical Systems".
   a. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
   b. Label each enclosure with engraved nameplate.
   c. Label each enclosure-mounted control and pilot device.

D. Control Wiring Installation
1. Install wiring between enclosed controllers and remote devices and facility's central control system, **as directed**. Comply with requirements in Division 26 Section "Control-voltage Electrical Power Cables".
2. Bundle, train, and support wiring in enclosures.
3. Connect selector switches and other automatic-control selection devices where applicable.
   a. Connect selector switches to bypass only those manual- and automatic-control devices that have no safety functions when switch is in manual-control position.
   b. Connect selector switches with enclosed-controller circuit in both manual and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor overload protectors.

E. Field Quality Control
1. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
2. Perform tests and inspections.
3. Acceptance Testing Preparation:
   a. Test insulation resistance for each enclosed controller, component, connecting supply, feeder, and control circuit.
   b. Test continuity of each circuit.
4. Tests and Inspections:
   a. Inspect controllers, wiring, components, connections, and equipment installation. Test and adjust controllers, components, and equipment, **as directed**.
   b. Test insulation resistance for each enclosed-controller element, component, connecting motor supply, feeder, and control circuits.
   c. Test continuity of each circuit.
   d. Verify that voltages at controller locations are within plus or minus 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify the Owner before starting the motor(s).
   e. Test each motor for proper phase rotation.
   f. Perform each electrical test and visual and mechanical inspection stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
   g. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
   h. Perform the following infrared (thermographic) scan tests and inspections and prepare reports:
      1) Initial Infrared Scanning: After Final Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each multi-pole enclosed controller. Remove front panels so joints and connections are accessible to portable scanner.
      2) Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each multi-pole enclosed controller 11 months after date of Final Completion.

3) Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

i. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

5. Enclosed controllers will be considered defective if they do not pass tests and inspections.
6. Prepare test and inspection reports including a certified report that identifies enclosed controllers and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

F. Adjusting
1. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.
2. Adjust overload-relay heaters or settings if power factor correction capacitors are connected to the load side of the overload relays.
3. Adjust the trip settings of MCPs and thermal-magnetic circuit breakers with adjustable instantaneous trip elements. Initially adjust to six times the motor nameplate full-load ampere ratings and attempt to start motors several times, allowing for motor cooldown between starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping. Do not exceed eight times the motor full-load amperes (or 11 times for NEMA Premium Efficient motors if required). Where these maximum settings do not allow starting of a motor, notify the Owner before increasing settings.
4. Set the taps on reduced-voltage autotransformer controllers at 50 **OR** 65 **OR** 80, **as directed**, percent.
5. Set field-adjustable switches and program microprocessors for required start and stop sequences in reduced-voltage solid-state controllers.
6. Set field-adjustable circuit-breaker trip ranges as specified in Division 26 Section "Overcurrent Protective Device Coordination Study", **as directed**.

G. Protection
1. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions until enclosed controllers are ready to be energized and placed into service.
2. Replace controllers whose interiors have been exposed to water or other liquids prior to Final Completion.

H. Demonstration
1. Train the Owner's maintenance personnel to adjust, operate, and maintain enclosed controllers, and to use and reprogram microprocessor-based, reduced-voltage solid-state controllers, **as directed**.

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Task	Specification	Specification Description
23 09 23 00	22 15 13 00a	HVAC Instrumentation And Controls

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SECTION 23 11 23 00 - RELIEF WELLS

1.1 GENERAL

A. Description Of Work
   1. This specification covers the furnishing and installation of materials for relief wells. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Submittals
   1. Shop Drawings: Submit shop drawings.
   2. Statements
      a. Before installation, all well screen shall be approved.
      b. The filter pack material and its gradation shall be approved before it is placed.
      c. Submit the cement grout mixture proportion to be used in plugging abandoned wells.
   3. Reports: Submit sampling and testing reports for each relief well, logs of the borings, well screen and riser pipe, backfill material, and pump tests. Register each well with the state as required by the state in which the well is installed.

C. Regulatory Requirements: The state statutory and regulatory requirements form a part of this specification.

1.2 PRODUCTS

A. Well Screen: The Contractor may, at its option, furnish and install well screen of any of the alternate types specified. The clear inside diameter of the screen shall be as directed by the Owner. Screen openings shall be uniform in size and pattern, and shall be spaced approximately equally around the circumference of the pipe.
   1. PVC Pipe Screen: Pipe, fittings, and screen shall be of the size and types specified. Pipe, fittings, and screen shall conform to ASTM D 1784, ASTM D 1785, ASTM D 2466, or ASTM D 2467. All joints in the PVC pipe shall include couplings and shall be glued with a solvent cement conforming to ASTM D 2564. The PVC pipe strength properties shall be equivalent to PVC 1120 Schedule 40 **OR** 80, **as directed**, unthreaded plastic pipe.
      a. Couplings: Couplings shall be bonded socket **OR** threaded, **OR** certilock, **as directed**, type. Fittings shall be produced of the same material and equal quality as specified for plastic pipe screen. Socket type fitting connections of pipe sections shall be bonded with solvent cement. The determination of the proportions and preparation of adhesives, the method of application, and the procedure used for making and curing the connections shall be the responsibility of the Contractor. The system for making joints at the relief well site shall provide a curing period adequate to develop the ultimate strength of the solvent cement. Self-tapping screws or other devices for holding pipe in the couplings during the setting period may be utilized as long as the screws do not penetrate the inside of the pipe. In no case shall a newly-made joint in the casing be stressed, lowered into the relief well, or be submerged in water prior to complete curing of the solvent cement adhesive.
      b. Perforations: The PVC well screen shall be mill slot **OR** continuous wire wrapped rod base **OR** continuous wire wrapped rod base on perforated pipe **OR** continuous wire wrapped on perforated pipe screen **OR** similar to that manufactured by Johnson Well Equipment, Inc., Pensacola, FL, telephone (904) 453-3131, **as directed**. All well screen shall have smooth, sharp-edged openings free of burns, chipped edges, or broken areas on the interior and exterior surfaces of the pipe. The slots or groups of slots shall be distributed in a uniform pattern around the periphery of the pipe and shall be oriented with the length of the slot parallel to, normal to, or diagonal with the axis of the pipe.

2. Fiberglass Pipe Screen: Fiberglass pipe screen and fittings shall be manufactured from thermosetting epoxy resins and glass fiber by either a centrifugal casting process or by a filament winding process. Glass fiber used shall be continuous filament, electrical glass with a finish compatible with epoxy resins. Each glass fiber or filament shall be thoroughly impregnated with epoxy resin. Fiberglass pipe wall thickness, strength and durability requirements shall be equivalent to the Fiberglass/Epoxy pipe produced by Fiberglass Resources Corporation of Farmingdale, New York or Burgess Well Company, Inc., Minden, Nebraska, telephone (308) 832-1642. All fiberglass pipe and fittings shall be round and straight, of uniform quality and workmanship, and free from all defects including indentation, delamination, bends, cracks, blisters, porosity, dry spots, resin segregation and resin-starved areas. The inside of the pipe and fittings shall be smooth and uniform. The impregnation of the glass fiber with resin shall be such that when the pipe is cut or slotted, no fraying or looseness of glass fiber occurs.
   a. Couplings: Couplings for fiberglass pipe sections shall be socket threaded or mechanical key-type couplings. The couplings shall be manufactured of the same materials used for the fiberglass pipe specified herein and may be either cast integrally with the pipe sections or as separate components for attachment to the pipe in the manufacturers plant. Key-type couplings shall consist of male and female halves designed for joining and locking together by means of a key strip inserted in grooves in the coupling halves. The minimum wall thickness remaining at any grooved section shall not be less than the minimum thickness specified for pipe. Key strips and locking strips shall be of fiberglass, plastic or other non-corrosive material capable of withstanding shearing and bearing stresses equivalent to the design load for the coupling. Socket type fitting connections of the pipe sections shall be bonded with epoxy adhesive. The epoxy materials and bonding agents shall be as recommended by the pipe manufacturer. Self-tapping screws or other devices for holding adhesive-joined pipe in the couplings during the curing period may be utilized. In no case shall a newly-made joint in the casing pipe be lowered into the relief well, or be submerged in water prior to complete curing of the adhesive.
   b. Perforations: All fiberglass well screen shall be mill slot **OR** continuous wire wrapped rod base, **as directed**. All relief well screen shall have smooth, sharp-edged openings free of burrs, chipped edges, or broken areas on the interior and exterior surfaces of the pipe. The slots or groups of slots shall be distributed in a uniform pattern around the periphery of the pipe and shall be oriented with the length of the slot parallel to, normal to, or diagonal with the axis of the pipe.
3. Steel Pipe Screen: Steel well screen shall consist of perforated or slotted sections of steel pipe conforming to the requirements of ASTM A 53.
   a. Couplings: Couplings for steel pipe screen shall be welded joints or threaded couplings. Welding shall be performed in accordance with requirements in ASME B31.9. Couplings shall meet the material requirements specified for steel pipe screen, except perforations shall be omitted. All threaded pipe and fittings shall be threaded in accordance with ASME B1.20.1. All threaded pipe sections may be field connected. Couplings shall be given the same protection against corrosion as specified for the well screen pipe. Protective coatings damaged while making couplings shall have the areas recoated.
   b. Perforations: All steel pipe to be used as relief well screen shall be provided with perforations which shall consist of either machine-cut slots; drilled or punched openings. The slots or groups of slots shall be distributed in a uniform pattern around the periphery of the pipe and shall be oriented with the length of the slot parallel to, normal to, or diagonal with the axis of the pipe. The pattern of the openings shall be uniformly spaced around the periphery of the pipe.
4. Stainless Steel Well Screen: The perforated well screen and fittings shall be fabricated entirely from stainless steel conforming to ASTM A 312/A 312M, Type 304, 304-L, 316 or 316-L. The well screen shall be of stainless steel with a keystone wire-wrapped continuous slot strainer equivalent to that manufactured by Howard Smith Screen Company, Houston, TX, telephone (713) 869-5771 or Johnson Screens, St. Paul, MN 55164, telephone (612) 636-3900.
   a. Couplings: Couplings for the stainless steel well screen shall consist of the same material as the well screen and shall be threaded, flanged, and/or fitted with a welding ring. The

couplings shall conform in design to the couplings recommended by the manufacturer of the well screen.

b. Tailpipe for Well Screen: The tailpipe for each well screen shall be made of the same material and at least the same minimum thickness as the riser pipe and shall include a bottom plug.

B. Riser Pipe: The relief well riser pipe material and method of manufacture shall conform to the requirements specified in paragraph WELL SCREEN, except that the screen perforations or opening shall be omitted. The relief well riser pipe diameter and discharge details shall be as directed. Couplings to the well screen and between riser pipe sections shall be as specified in paragraph COUPLING.

C. Filter Pack: Material for the filter pack around the riser pipes and screens shall be a washed grave, **OR** washed sand **OR** dry processed sand, **as directed**, composed of hard, tough, and durable particles free from adherent coating. The filter pack shall not be crushed stone. The filter pack material shall contain no detrimental quantities of organic matter nor soft, friable, thin, or elongated particles in accordance with the quality requirements in ASTM C 33, Table 1 and Table 3, Class 5S, and in ASTM E 11, Table 1.

D. Outlet For Relief Well: Check Valve.

1. The check valve shall be a one piece reinforced all rubber (neoprene) check valve with an integral elastomer flange similar and equal to the Red Valve Series 35, manufactured by Red Valve Company, Inc., 700 North Bell Ave., Pittsburgh, PA 15106, telephone (412) 279-0044. The backup ring for the check valve shall be stainless steel. Stainless steel bolts, washers, and nuts shall be used to fasten the valves onto the flanged end of the pipes. The check valve shall be installed with the flared end duck bill in a vertical position.
OR
Fabricate check valves of brass **OR** stainless steel **OR** aluminum, **as directed**, plate, threaded fasteners and rods. Fabricate sealing disc of silicone sponge rubber free of porous areas, foreign materials, and visible defects.
2. Workmanship and metalwork fabrication of check valves shall be as directed. Install check valves accurately vertically and adjust to the required elevation.

E. Concrete: Concrete shall conform to the requirements specified in Division 03 Section "Cast-in-place Concrete".

1.3 EXECUTION

A. Drilling: Wells may be drilled by the reverse rotary circulation method or other method approved, which will ensure proper placement of the well screen, riser pipe, and filter pack. Methods which involve radical displacement of the formation, or which may reduce the yield of the well, will not be permitted. Excavated material shall be disposed of as directed.

1. Reverse Circulation Method: If the reverse circulation method is used for drilling wells, all of the drilling fluid shall be removed from the filter pack and the natural pervious formation. If in the opinion of the Owner the walls of the hole above the top of the filter pack require support during development operations, a temporary casing similar to that specified in paragraph TEMPORARY CASING shall be placed so as to extend from the ground surface to at least 3 ft (1 m) below the top of the filter pack. The diameter of the hole shall be such as will permit the placement of the minimum thickness of filter pack as specified in paragraph FILTER PACK PLACEMENT. The drilling fluid shall be a suspension of fine grained soil or shall be a commercial product of a recognized manufacturer, shall be approved by the Owner, and shall have the characteristic of being readily removable from the filter pack and the walls of the formation by development as specified in paragraph DEVELOPMENT. The use of bentonite will not be permitted.
2. Temporary Casing: Temporary well casing of either iron or steel of sufficient length to case to the bottom of all borings shall be available at the construction site. the Owner will direct the use of a temporary casing to the bottom of the boring during drilling and placement of screen, riser, and

filter pack when it believes it is necessary to provide adequate support to the sides of the hole. When the walls of the boring will require support only during development operations a temporary casing will be required to extend only to a depth 3 ft (3 m) below the top of the filter pack. The temporary casing, shall have sufficient thickness to retain its shape and maintain a true section throughout its depth, and may be in sections of any convenient length. The temporary casing shall be such as to permit its removal without disturbing the filter pack, riser, or well screen. The setting of temporary casing shall be such that no cavity will be created outside of it at any point along its length. In the event the temporary casing should become unduly distorted or bent it shall be discarded and a new casing shall be used during installation of any additional relief wells.

B. Installation Of Riser Pipe And Screen

1. Assembly: All riser pipe and screen shall be in good condition before installation and all couplings and other accessory parts shall be securely fastened in place. The successive lengths of pipe shall be arranged to provide accurate placement of the screen sections in the bore hole. The riser-pipe shall be provided with an approved cap and a flanged top section, the top of which shall be set at the elevation directed. Centralizers shall be attached to the assembled riser pipe and screen in such numbers and of a type that they will satisfactorily center the riser pipe and screen in the well and will hold it securely in position while the filter pack material is being placed.
2. Joints: Sections of relief well pipe shall be joined together as specified in paragraph COUPLINGS. Joints shall be designed and constructed to have the strength of the pipe and where possible a strength capable to support the weight of the relief well stem as it is lowered into the hole. When not practicable to construct joints that will support the weight of the relief well stem, the stem shall be supported at the lower end by any approved means that will assure that the joints do not open while being lowered into place in the well.
3. Installation: The assembled riser pipe and screen shall be placed in the bore hole in such manner as to avoid jarring impacts and to ensure that the assembly is centered and not damaged or disconnected. The screen shall be suspended in the hole and not resting on the bottom of the hole. After the screen and riser pipe have been placed, a filter pack shall be constructed around the screen section as specified in paragraph FILTER PACK PLACEMENT and the well developed as specified in paragraph DEVELOPMENT. The top of the riser pipe shall be held at the designated elevation during placement of the filter pack.
4. Check for Plumbness and Alignment: The well shall be constructed and all casing set round, plumb, and true. The Contractor shall perform the following tests after the installation of the well but prior to backfilling, and before its acceptance. Additional tests may be made during the performance of the work at the option of the Contractor. Should the Contractor fail to correct, at no additional cost to the Owner, any faulty alignment or plumbness disclosed as a result of these tests, the Owner may refuse to accept the well. the Owner may waive the requirements for plumbness if in its judgement the Contractor has exercised all possible care in constructing the well and the defect is due to circumstances beyond its control or if the utility of the completed well is not materially affected or if the cost of necessary remedial measures will be excessive. In no event will the provisions with respect to alignment be waived.
    a. Plumbness: Plumbness shall be tested by use of a plumb line. The plummet shall be suspended from a small diameter wire rope and its point of suspension shall be in the exact center of the plummet. The plummet shall be sufficiently heavy to stretch the wire rope taut. The wire rope shall pass over a guide sheave which shall be positioned above the top of the well and adjusted horizontally so that the plummet hangs in the center of the well. Displacement of the wire rope during the plumbness check shall be measured by means of a transparent plastic sheet on which a number of concentric circles shall be scribed or drawn, and which is centered on the top of the well. The exact center of these circles shall be marked, and then a slot, slightly larger than the plumb line and extending from this center to the edge, shall be cut in the plastic sheet. As the plummet is lowered, any out-of-plumb condition of the well will be indicated by the wire rope tending to drift away from the center, and the plastic sheet shall be rotated until the slot is oriented in the direction of this drift, while at all times maintaining the center of the concentric circles coincident with the center of the well. Measurement of the amount of drift shall be made

along the edge of the slot for each increment by which the plummet is lowered into the well. Drift at any depth shall be determined by multiplying the measured plumb line displacement by the total length of the plumb line and dividing the result by the fixed distance between the guide sheave and the top of the well. If desired, alignment may be calculated from the plumbness data in lieu of the alignment check described in paragraph ALIGNMENT. Should the well vary from the vertical in excess of allowable, the plumbness of the well shall be corrected by the Contractor at no additional cost to the Owner.

b. Alignment: Alignment shall be tested by lowering into the well a section of cylinder or a dummy of the same length. The outside diameter of cylinder shall be smaller than the inside diameter of the well. Should the cylinder fail to move freely throughout the length of the well, the alignment of the well shall be corrected by the Contractor at no additional expense to the Owner.

C. Filter Pack Placement: After the well screen and riser pipe have been installed, the filter pack material shall be placed by tremie, when using a well graded material, in an approved manner such that segregation will not occur. When using a uniform graded filter material, the material may be poured around the well screen at a rate that will prevent bridging of the material. The material shall be placed around all sides of the screen to assure that the screen is not pushed against the side of the bore hole causing the screen to come in contact with foundation material or prevent the proper thickness of filter from being placed uniformly around the screen. The filter pack shall be placed at a constant rate from the start of placement until it has reached the elevation directed. If a tremie is required, a double string of tremie pipe shall be used. The pipes shall be placed on opposite sides of the screen and/or casing, that is, 180 degrees apart, and shall be guided in such a manner that they will remain in this position throughout the placing process. The tremie pipes shall be set in place, filled completely with filter pack prior to being lifted off the bottom of the hole. The filter pack in the tremie pipe shall be kept above the water surface in the well throughout the placing process. In no case shall the gradation of the filter pack fall outside of the range specified in paragraph FILTER PACK.

D. Development

1. General: Following placement of filter pack materials, the Contractor shall develop the relief well by jetting, surging, intermittent pumping, or other approved methods as may be necessary to give the maximum yield of water. At the time of development of any relief well, the well shall be free of drawdown or surcharge effects due to pump testing, developing or drilling at another location. The Contractor shall be responsible for maintaining at the relief well the needed access and work area and clearance in the relief well necessary to accomplish development. The Contractor shall furnish, install, or construct the necessary discharge line and troughs to conduct and dispose of the discharge a sufficient distance from the work areas to prevent damage. Development shall be conducted to achieve a stable well of maximum efficiency and shall be continued until a satisfactory sand test, as specified in paragraph SAND TEST, is obtained. As development proceeds, filter pack material shall be added to the annular space around the screen to maintain the top elevation of the filter pack to the specified elevation. The Contractor shall provide an open tube or other approved means for accurately determining the water level in the well under all conditions. If at any time during the development process it becomes apparent in the opinion of the Owner that the well may be damaged, development operations shall be immediately terminated. the Owner may require a change in method if the method selected does not accomplish the desired results. the Owner may order that wells which continue to produce excessive amounts of fines after development for 6 hours be abandoned, plugged, and backfilled, and may require the Contractor to construct new wells nearby. All materials pulled into the well by the development process shall be removed prior to performing the pumping test.

a. Jetting: Jetting should be performed using either a single or double ring jet. The jetting tool shall be constructed of high-strength material and conservatively designed and proportioned so that it will withstand high pressures. The jetting tool shall have two hydraulically balanced nozzles spaced 180 degrees **OR** four diameter holes spaced 90 degrees, **as directed**, apart and which shall exert the jetting force horizontally through the screen slots. The rings shall be constructed such that the tips of the jets shall be within 1/2 in. (13 mm) from the inner surface of the well screen. The pump used in conjunction with

the jetting tool shall be capable of providing a minimum jetting fluid exit velocity of 150 feet per second (45 meters per second). Prior to commencing jetting, and following each jetting cycle, all sand and/or other materials shall be removed from inside the screen. All wells shall be pumped during the jetting cycle to remove incoming sand and other material. Such pumping shall be at a rate not less than 115 percent of the rate at which fluid is introduced through the jetting tool. This will allow a flow of material into the well as it is being developed. Water used for development shall be free of sand. the Owner may require other means of developing the well such as intermittent pumping method, variation of the intermittent pumping method, or surge block if it appears that the development of the well is not producing the desired results.

b. Intermittent Pumping: Intermittent pumping shall be performed by pumping the well at a capacity sufficient to produce a rapid drawdown, stopping the pump (backflow through pump will not be permitted) to permit the water surface to rise to its former elevation, and repeating this procedure. Cycle time for this procedure will vary as directed but will not be more than 3 cycles per minute. A deep well turbine pump, or electric submersible pump with check valve, shall be used with any attachment necessary to accomplish rapid starting and stopping for intermittent pumping. The intake shall be set below the maximum expected drawdown in the well. Prior to commencing intermittent pumping, and periodically during development by this method, all sand and/or other materials shall be removed from inside the screen. The amount of drawdown may be decreased if, in the opinion of the Owner, the efficiency of the well might otherwise be impaired.

c. Surging: Surging of the well shall require use of a circular block which is smaller in diameter than the inside diameter of the relief well and is constructed of a material which will not damage the screen if the block comes in contact with the screen, and a bailer or pump to remove materials drawn into the well. The surging shall be continued for a period of approximately one hour or until little or no additional material from the foundation or filter pack can be pulled through the screen. The surge block shall be moved by a steady motion up and down the full length of the well screen. Prior to commencing surging, and periodically during development by this method, all sand and/or other materials shall be removed from inside the screen. All materials pulled into the well by the surging process shall be removed by the Contractor.

E. Backfilling: After the well has been developed, additional filter pack shall be added if necessary to meet the requirements of paragraph FILTER PACK PLACEMENT. Then the annular space above the filter pack, shall be backfilled by first placing a layer of concrete sand on the filter pack and then filling the remainder of the space up to the finished ground surface **OR** well pit, **as directed**, with grout or concrete. The concrete backfill shall be placed to a depth at least equal to the existing impervious blanket. For PVC riser pipe, after the well has been developed, additional filter pack shall be added if necessary for it to meet the requirements of paragraph FILTER PACK PLACEMENT. Then the remaining annular space above the filter pack shall be backfilled by first placing a layer of concrete sand on the filter pack and then filling the remainder of the space up to the finished ground surface **OR** well pit, **as directed**, with bentonite. The temporary casing, if used, shall be withdrawn in increments as the backfill is placed. The Contractor shall fill with impervious material to original grade all pits such as those incidental to the reverse rotary circulation method of drilling.

F. Plugging Of Abandoned Wells: The Contractor has the option of attempting to remove the well screen. If the well screen can be removed, the Contractor will grout the bore hole starting from the bottom of the hole. The grouting shall start at the elevation of the bottom of the tailpipe of the well. If the well screen can not be removed or breaks off during the removal attempt, the Contractor shall still be responsible for grouting the well from the bottom of the tailpipe to within 3 ft (1 m) of ground surface. Either of the above abandonment procedures may require the Contractor to redrill the hole so that the bore hole can be grouted. The well shall be grouted from the bottom of the tailpipe. After the grout has setup the riser pipe shall be cutoff. Then the hole shall be backfilled. The cement grout mixture proportion to be used shall be submitted for approval.

G. Tests

1. Pump Test: Upon completion but before acceptance, each well shall be subjected to a pump test of which a sand test will form a part. The Contractor shall provide a deep well turbine pump, capable of producing the specified drawdowns over periods of time sufficient to satisfactorily perform the pump test specified herein. The intake shall be set below the maximum expected drawdown in the well. The amount of sand shall be measured after each test. The pump shall be complete with either gasoline, diesel, or electric motor of adequate size. In case an electric motor is used, the Contractor shall provide, without additional cost to the Owner, the electric power and the necessary wiring. The Contractor shall provide an open tube or other approved means for accurately determining the water level in the well. The Contractor shall furnish and install an orifice meter of approved design or other approved equipment for the purpose of measuring the discharge from the well during the pumping test. The Contractor shall furnish, install, or construct the necessary pipe discharge line, troughs, or ditches necessary to dispose of the pumping test discharge a sufficient distance from the work area to prevent damage. The tests will be conducted under the direction of the Owner and may be made as soon as each well is completed. Test data will be recorded by the Owner. The Contractor shall test each well by pumping continuously for a minimum of 6 hours. Prior to starting the pump test all material shall be removed from the bottom of the well. If the test is interrupted, other than by order of the Owner, prior to the completion of the specified period of continuous operation, the test shall be re-run. In addition to the required pumping test, the Owner may direct the Contractor to perform additional pump tests. Such additional testing shall conform in general to the requirements specified herein except that the duration of the tests and the approximate draw-down will be determined by the Owner. In the event that sand or other material collects in the well as a result of the pump test, accurate measurements shall be taken as to the quantity of material in the well and all such material shall be removed by the Contractor. Upon completion of the pump test, the Contractor shall remove all equipment, discharge lines, electrical lines, lumber, and debris, and shall backfill any excavated areas with impervious material.
2. Sand Test: As part of each Pump Test or at the end of each intermittent pumping a determination of the amount of sand (filter pack and/or foundation material) a well is producing shall be performed. Prior to starting the sand test all material shall be removed from the bottom of the tailpipe. After the pump is at the desired pumping rate the flow from the discharge shall be diverted into a container that will collect all the sand being carried by the water **OR** through a Rossum Sand Tester, **as directed**. Upon completion of the test the amount of sand in the tailpipe shall be determined to verify that no material is being deposited in the bottom of the well.
3. Filter Pack Sampling and Testing: The Contractor shall verify that all materials conform to the specifications before delivery to the project. The particle size distribution of the filter pack shall be sampled and tested by the Contractor in accordance with ASTM C 136 and ASTM D 75. Within 48 hours before being placed in the relief well to be back-filled, the filter pack shall be sampled from the material stockpiled at the project site. There shall be at least one particle size distribution test on the filter pack for each well. A pump test shall be performed in accordance with technical provisions herein specified.
4. Reports: Reports shall include, for each relief well, logs of the boring, elevations of the well screen, top of riser pipe, bottom of the tailpipe, filter pack gradation, quantity of filter pack added during development, pump test, sand test, and report of backfilling. The log of backfill material shall include the filter pack particle size distribution test data, and notes concerning installation and development of the relief well. The pump test log shall include the duration of the test and the draw-down response data with time in the pumped well, in adjacent wells, and in nearby piezometers. The relief well log and the pump test log shall be submitted to the Owner. The Contractor shall also submit a report of the well installation to the appropriate public agency and in the form required by state statutory and/or regulatory requirements specified in paragraph REGULATORY REQUIREMENTS.

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SECTION 23 11 23 00a - MONITORING WELLS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for monitoring wells including drilling, casing, well screen, gravel packing, grouting, development, monitoring device, and incidental related work complete and ready for operation. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. General Requirements
1. Each system, including equipment, materials, installation, and performance, shall be in accordance with local, State, and Federal regulations, ASTM D 5092, and EPA 600-4-89-034 except as modified herein. Consider the advisory or recommended provisions to be mandatory, as though the word "shall" has been substituted for the word "should" wherever it appears. Reference to the "Project Representative" and the "Owner" shall be interpreted to mean the Owner. Additional requirements are included under Division 01 Section "Temporary Facilities And Controls". Mark and secure monitoring wells to avoid unauthorized access and tampering.

C. Submittals:
1. Shop Drawings: Well construction.
2. Product Data
   a. Well casing
   b. Well screen
   c. Filter pack
   d. Neat cement grout
   e. Bentonite seal
3. Certificates
   a. Well Drilling/Development Material Handling Plan
   b. Health and Safety Plan
   c. Field Sampling and Laboratory Testing Plan
   d. Treatment facility permit
   e. Installation Survey Report
   f. Well Development Report
   g. Borehole Analysis Report
4. Closeout Submittals
   a. Well Construction Permit
   b. Shipment manifests
   c. Delivery certificates
   d. Treatment and disposal certificates

D. Delivery, Storage, And Handling
1. Deliver materials in an undamaged condition. Unload and store with minimal handling. Store materials in on-site enclosures or under protective coverings. Store plastic piping and jointing materials, and rubber gaskets under cover, out of direct sunlight. Store materials off the ground. Keep insides of pipes and fittings free of dirt and debris. Replace defective or damaged materials with new materials.

E. Quality Assurance
1. Required Drawings: Submit well construction drawings showing components and details of well casing, well screen, filter pack, annular seal, and associated items. Drawings shall be prepared by a State certified professional geologist or hydrogeologist, or by a State registered professional

civil engineer, hereafter referred to as the Contractor's Professional Consultant (CPC). Drawings shall be sealed.

2. Well Drilling/Development Material Handling Plan: A material handling plan shall be furnished by the Contractor 15 days prior to initiation of the work that describes phases of dealing with the potentially contaminated soil and groundwater, including the following: a schedule to be employed in the well drilling and development stages, a sequence of operations, the method of drilling and development, material hauling, proposed equipment, handling of the contaminated materials, soil and water testing requirements, and safety precautions and requirements.
3. Health and Safety Plan (HASP): Describe safety precautions for each phase of the project as specifically related to handling of soil and water removed during well drilling and development operations. Identify appropriate requirements of 29 CFR 1910 and COE EM-385-1-1. Identify safety equipment and procedures to be available and used during the project. Furnish the name and qualifications based on education, training, and work experience of the proposed Health and Safety Officer (HASO) and the members of the drill crew. The CPC may perform the responsibilities of the HASO if properly qualified.
4. Field Sampling and Laboratory Testing Plan: Describe field sampling methods and quality control procedures. Identify laboratory and laboratory methods to be used for contamination testing. Sample reports shall show sample identification for location, date, time, sample method, contamination level, name of individual sampler, identification of laboratory, and quality control procedures.
5. Treatment Facility Permit: Verification that the proposed treatment facility is permitted to accept the contaminated materials specified, prior to the start of excavation.
6. Well Development Report: Provide report, containing the following data for each well: project name and location, well designation, date and time of well installation, date and time of well development, static water level from top of well casing before development and 24 hours after development, field measurements of pH, temperature, and specific conductivity, depth of well from top of casing to bottom of well, screen length, description of development methodology size/capacity of pump or bailer, pumping rate, and recharge rate.
7. Well Construction Permit: Submit a completed permit application and a proposed method of construction to the appropriate state agency prior to construction of the well. Construction of the wells will not be allowed until an approved Well Construction Permit has been submitted to the Owner.
8. Shipment Manifests: Copies of manifests and other documentation required for shipment of waste materials within 24 hours after removal of waste from the site. Shipment manifests shall be signed by the Owner.
9. Delivery Certificates: Verification that the wastes were actually delivered to the approved treatment facility, within 7 days of shipment.
10. Treatment and Disposal Certificates: Verification that the wastes were successfully treated and remediated to the levels specified herein.

1.2 PRODUCTS

A. Well Casing
1. Stainless Steel Piping: ASTM A 312/A 312M, Type 304, Schedule 40S, with flush threaded joint end fittings. Threaded joints shall be wrapped with fluoropolymer tape, and provided with nitrile O-ring gaskets.
2. PVC Piping: ASTM F 480, Type 1, Grade 1, PVC 12454, NSF wc or NSF pw, Schedule 40 **OR** 80, **as directed**, with flush threaded joint fittings. Threaded joints shall be wrapped with fluoropolymer tape, and provided with nitrile O-ring gaskets.

B. Well Screen: Well screens shall be located as directed. The length of each screen shall be as directed. Slot size shall be as required to meet project requirements. Slotted openings shall be distributed uniformly around the circumference of the screen. Open area shall approach the formation's natural porosity.

1. Stainless Steel Screens: ASTM A 312/A 312M, Type 304, Schedule 40S, continuous slot construction, wire wound, with flush threaded joint ends.
2. PVC Screens: ASTM D 1785, PVC 1120, NSF wc or NSF pw, Schedule 40 **OR** 80, **as directed**, screen, Schedule 80, machine-slotted construction, flush threaded joint ends. Slots shall be even in width, length, and separation.

C. Primary Filter Pack: Provide clean, durable, well-rounded, and washed quartz or granite, with less than 5 percent non-siliceous material. The filter pack shall not contain organic matter or friable materials. The filter pack shall allow free flow of water in the well, and shall prevent the infiltration of aquifer materials. Filter pack shall have a 30 percent finer than (d-30) grain size size as required to meet project requirements, and a uniformity coefficient less than 2.5, in accordance with ASTM C 117 and ASTM C 136.

D. Secondary Filter Pack: Gradation in accordance with ASTM D 5092. Provide clean, durable, well-rounded, and washed quartz or granite. Pack shall not contain organic matter or friable materials.

E. Annular Sealants
1. Bentonite Seal: Provide powdered, granular, pelletized, or chipped sodium **OR** calcium, **as directed**, montmorillonite in sealed containers from a commercial source, free of impurities. Diameter of pellets shall be less than one fifth the diameter of the borehole annular space to prevent bridging. Bentonite base grout shall be in accordance with ASTM D 5092.
2. Neat Cement Grout: Provide neat cement grout in accordance with ASTM D 5092. Cement shall be in accordance with ASTM C 150. Quick setting admixtures shall not be allowed. Drilling mud or cuttings shall not be used as a sealing material.

F. Bottom Plugs: Provide flush threaded solid plug at the bottom of the well. Plug shall be the same material as the well casing **OR** screen to which it is attached, **as directed**. Joints shall be wrapped with fluoropolymer tape and provided with nitrile O-ring gaskets.

G. Locking Well Cap: Provide flush threaded, weatherproof, and non-removable locking well cap on the top of the well. Well cap shall be of the same material as the well casing to which it is attached. Well cap shall accommodate padlock. Provide a long shackled padlock in accordance with ASTM F 883. Provide two keys for the padlock, and turn them over to the Owner. Locks at the well site shall be keyed alike.

H. Well Head Completions: Clearly mark and secure the well to avoid unauthorized access and tampering. Cast the words "MONITORING WELL" on the well head cover. Provide a sign reading, "WELL IS FOR MONITORING AND IS NOT SAFE FOR DRINKING." Provide stamped metal identification tag as follows:

DO NOT DISTURB
ID #: Date:
Installed By:
Total Depth:
Screened Interval:
TOC Elevation:
Other:
For Information, Call:

1. Aboveground Completions: Provide protective outer casing around the well casing extending above grade. The diameter of the protective outer casing shall be a minimum of 4 in. (100 mm) larger than the well casing diameter. The top of the protective outer casing shall extend a minimum of 6 in. (150 mm) above the top of the well casing cap. The protective outer casing shall be set in cement grout and the bottom of the protective well casing shall extend below the depth of the frost line **OR** to the depth indicated, **as directed**. A 1/4 in. (6 mm) diameter weep hole shall be drilled in the protective outer casing 3 in. (75 mm) above the ground surface. The annular space between the protective outer casing and the well casing shall be filled with pea gravel or coarse sand to just below the level of the cap on the well casing. The locking well cap

shall be provided on top of the protective outer casing. Provide 6 in. (150 mm) diameter steel pipe bollards, filled with concrete as indicated to protect the exposed well head.

a. Protective Outer Casing and Bollards: ASTM A 53, Type E or S, Grade B.

b. Well Casing Cap: Provide cap on top of the protective outer casing. Cap shall be flush threaded and of the same material as the protective outer casing. Threaded joints shall be wrapped with fluoropolymer tape and provided with nitrile O-ring gaskets.

2. At-Grade Completions: Provide cast iron **OR** aluminum, **as directed**, vault box, 30 by 30 in. (750 by 750 mm) **OR** 12 in. (300 mm) diameter, **as directed**, with watertight frame and cover. Vault shall support H-20 loading for traffic areas **OR** a 100,000 lb. (45,360 kg) loading for airfield locations, **as directed**. The frame shall be 6 in. (150 mm) deep, and shall be set in a concrete collar a minimum of 8 in. (200 mm) thick, and extending 4 in. (100 mm) beyond the edge of the frame in all directions. Frame and concrete collar shall be set flush with the level of the existing pavement **OR** set 3 in. (75 mm) above the existing grade, **as directed**. Locking well cap shall be provided on top of the well casing, which will terminate inside the vault as indicated.

I. Polyethylene Sheeting: ASTM D 4397.

1.3 EXECUTION

A. General: Notify the Owner at least 15 days prior to commencement of work. Locations of wells shall be as indicated. Drilling, installation, and development of the monitoring wells shall be supervised, directed, and monitored by the CPC. Drilling, sampling, and well development equipment introduced to the well shall be decontaminated before and after each use in accordance with ASTM D 5088.

B. Drilling: Borehole shall be advanced using conventional 10 in. (250 mm) hollow-stem auger **OR** solid auger **OR** rotary wash, **as directed**, drilling methods. If it is the opinion of the CPC that an alternate drilling method is required, justification for a boring method change shall be submitted to the Owner, and approval for the change granted prior to drilling. Drill crew shall be experienced and trained in drilling and safety requirements for contaminated sites.

1. Sampling: Obtain samples in accordance with ASTM D 1586 or ASTM D 1587. Perform standard penetration tests at the following depths 0.0 to 1.5 ft (0 to 450 mm); 1.5 to 3.0 ft (450 to 900 mm); 3.0 to 4.5 ft (900 to 1350 mm); and 5 ft (1500 mm) centers or at changes in soil formation thereafter. Each soil sample shall be screened in the field with an organic vapor analyzer/flame ionization device (OVA/FID) capable of detecting vapors to a minimum of one ppm. Log boring in accordance with ASTM D 2487 and ASTM D 2488. Groundwater elevation shall be indicated.

2. Analysis: The CPC shall review the log data from each borehole and compare the data with the well design requirements. The CPC shall verify the adequacy of the well design, or shall offer a proposed modification to the design based on the geologic and hydrogeologic data obtained from the borehole. This review and analysis shall be conducted for each borehole **OR** for one borehole considered representative of the entire project, **as directed**. The CPC shall submit the borehole boring logs, the analysis of the well design, and any proposed design modifications to the Owner in a Borehole Analysis Report. Any modifications to the well design approved by the Owner shall be considered a change to the contract documents and shall be negotiated in accordance with the "CHANGES" clause.

3. Alignment: Verify that the well is straight by lowering a 10 ft (3 m) section of steel pipe 1/4 in. (6 mm) smaller in diameter than the inside diameter of the casing in to the well. For wells deeper than 200 ft (60 m), Contractor shall verify that the well is plumb.

C. Soil Removed From The Borehole

1. Temporary Containment of Soil Removed from the Borehole: Soil removed from the borehole shall be placed in a temporary containment area. Provide a temporary containment area near the well site. Cover containment area with 10 mil (0.25 mm) reinforced polyethylene sheeting. Place soil removed from the borehole[s] on the impervious barrier and cover with 6 mil (0.15 mm) reinforced polyethylene sheeting. Provide a straw bale berm around the outer limits of the

containment area and cover with polyethylene sheets. Secure edges of sheets with weights to keep the polyethylene sheeting in place. Water runoff shall be diverted from the stockpiled material. As an option, soil may be stockpiled in trucks suitable for transporting contaminated soils as specified herein.

2. Testing Requirements for Stockpiled Soils
   a. Sampling: A minimum of one composite sample shall be developed and analyzed for each required test for every 100 cu. yds. (76.4 cu. m) or fraction thereof from a composite stockpile of soil removed from all well sites. To develop a composite sample of the size necessary to run the required tests, the Contractor shall take several samples from different areas along the surface and in the center of the stockpile. These samples shall be combined and thoroughly mixed to develop the composite sample.
   b. Testing
      1) The soil shall contain no free liquid as demonstrated by EPA SW-846, Method 9095, paint filter liquids test.
      2) The sum of benzene, toluene, ethyl benzene, and xylene (BTEX) concentrations shall be determined by using EPA SW-846, Method 5030/8020.
      3) TPH (total petroleum hydrocarbons) concentrations shall be determined by using EPA SW-846, Method 8015, which has been modified for use with soil.
      4) Material shall be tested for TOX (total organic halogens) in accordance with EPA SW-846, Method 9020.
      5) Material shall be analyzed for full TCLP in accordance with EPA SW-846, Method 1311 and for ignitability, corrosivity, and reactivity.
      6) Material shall be tested for polychlorinated biphenyls (PCB's) in accordance with EPA SW-846, Method 8080.
      7) Moisture content of the sample shall be determined in accordance with EPA Method 160.3.
   c. Disposal of Stockpiled Soils
      1) Soils exhibiting TPH less than 100 ppm, BTEX less than 10 ppm, TOX less than 100 ppm, passing TCLP tests, and testing negative for PCB's shall be considered clean as shall be disposed of on-site, as directed by the Owner.
      2) Soils failing the TCLP test or exhibiting TOX greater than 100 ppm shall be managed in accordance with applicable State and local regulations. Payment for disposal of materials failing the TCLP metals test or TOX test shall be made in accordance with the "CHANGES" clause of the General Conditions.
      3) If the concentration of total BTEX is greater than 10 ppm or TPH greater than 100 ppm, the soil shall be treated and disposed of at a permitted soil recycling facility.

D. Well Installation: Well installation shall be in accordance with ASTM D 5092 and EPA 600-4-89-034, and as indicated on the well construction drawings submitted by the CPC and approved by the Owner. Borehole shall be stable and shall be verified straight before beginning installation.
   1. Casings and Screens: Well casings, screens, plugs, and caps shall be decontaminated prior to delivery by the manufacturer and shall be certified clean. Materials shall be delivered, stored, and handled in such manner as to ensure that grease, oil, or other contaminants do not contact any portion of the well screen and casing assembly prior to installation. If directed by the Owner, the well screen and casing assembly shall be cleaned with high pressure water prior to installation. Personnel shall wear clean cotton or surgical gloves while handling the assembly. Centralizers shall be used to ensure that the well screen and casing assembly is installed concentrically in the borehole. When the assembly has been installed at the appropriate elevation, it shall be adequately secured to preclude movement during placement of the filter packs and annular seals. The top of the well casing shall be capped during filter pack placement.
   2. Primary and Secondary Filter Packs: Primary and secondary filter packs shall be placed as indicated on the approved well construction drawings to fill the entire annular space between the screen and casing assembly and the outside wall of the borehole. Place both the primary and secondary filters with a tremie pipe in accordance with EPA 600-4-89-034 and ASTM D 5092. Placement of the primary and secondary filters by gravity or free fall methods is not allowed. Control speed of filter placement to prevent bridging and to allow for settlement. Prior to

commencement of work, equipment and methods required to place filters shall be approved by the Owner.

3. Bentonite Seal: Bentonite shall be placed as a slurry through a tremie pipe. Control speed of bentonite placement to prevent bridging or segregation of slurry. Additional water shall be added to the annular space as directed by the CPC to ensure complete hydration of the bentonite. Bentonite shall cure a minimum of 48 hours before the placement of cement grout to ensure complete hydration and expansion of the bentonite.
4. Neat Cement Grout: Cement grout shall be placed in the annular space above the bentonite seal as indicated on the well construction drawings. Cement grout shall be placed as a slurry through a tremie pipe, and injected under pressure to reduce chance of voids. Grout shall be injected in one continuous operation until full strength grout flows out at the ground surface without evidence of drilling cuttings or fluid. Cement grout shall cure a minimum of 48 hours before beginning well development operations.
5. Well Head Completions: Well head completions shall be as indicated and as specified herein.

E. Well Development: Well development shall be in accordance with EPA 600-4-89-034 and ASTM D 5092 except as modified herein. Bailing, surging, and pumping/overpumping/backwashing are acceptable development methods. Air surging and jetting are prohibited. Method of development shall be chosen by the CPC and approved by the Owner. Well development shall not begin until the well installation is complete and accepted by the Owner. Well development operations shall be conducted continuously until development water flows clear and free of drilling fluids, cuttings, or other materials. At such time representative water samples shall be tested for pH, temperature, and specific conductivity in accordance with EPA 600-4-79-20. Samples shall be taken every 3 hours. When stabilized readings of these parameters, as accepted by the Owner, have been achieved for 12 consecutive hours, well development operations shall cease.

F. Water From Well Development Operations: Water from the well development operations shall be containerized in accordance with State and local regulations. One sample shall be taken and analyzed for each required test for every 1000 gallons (3780 liters) of stored water from well development operations.

1. Testing
   a. The sum of benzene, toluene, ethyl benzene, and xylene (BTEX) concentrations shall be determined by using EPA SW-846, Method 8020.
   b. TPH (total petroleum hydrocarbons) concentrations shall be determined by using EPA SW-846, Method 8015.
2. Disposal of Containerized Water
   a. Water exhibiting TPH less than 0.5 ppm and BTEX less than 1 ppb shall be considered clean and shall be disposed of on-site as directed by the Owner.
   b. If the concentration of total BTEX is greater than 1 ppb or TPH greater than 0.5 ppm, the water shall be treated and disposed of at a permitted facility.

G. Transportation Of Contaminated Soil And Water: The Contractor shall be solely responsible for complying with Federal, State, and local requirements for transporting contaminated materials through the applicable jurisdictions and shall bear responsibility and cost for any noncompliance. In addition to those requirements, the Contractor shall do the following:

1. Inspect and document vehicles and containers for proper operation and covering.
2. Inspect vehicles and containers for proper markings, manifest documents, and other requirements for waste shipment.
3. Perform and document decontamination procedures prior to leaving the worksite and again before leaving the disposal site.

H. Disposal Of Contaminated Soil And Water: Contaminated materials removed from the site shall be disposed of in a treatment/disposal facility permitted to accept such materials.

I. Installation Survey: Upon completion of well installation and development and acceptance by the Owner therefor, the Contractor vertical and horizontal position of each well shall be determined by a registered land surveyor licensed in the State where the work is located . The survey shall document the vertical elevations of the top of the casing pipe and the ground surface elevation adjacent to each well. Survey shall be accurate to the nearest 0.01 ft (3 mm). This data shall be submitted with a well location map as the Installation Survey Report.

J. Cleanup: Upon completion of the well construction, remove debris and surplus materials from the jobsite.

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SECTION 23 11 23 00b - FACILITY NATURAL-GAS PIPING

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for facility natural gas piping. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Pipes, tubes, and fittings.
b. Piping specialties.
c. Piping and tubing joining materials.
d. Valves.
e. Pressure regulators.
f. Service meters.
g. Mechanical sleeve seals.
h. Grout.
i. Concrete bases.

C. Definitions
1. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct shafts, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspaces, and tunnels.
2. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.
3. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.

D. Performance Requirements
1. Minimum Operating-Pressure Ratings:
a. Piping and Valves: 100 psig (690 kPa) minimum unless otherwise indicated.
b. Service Regulators: 65 psig (450 kPa) **OR** 100 psig (690 kPa), **as directed**, minimum unless otherwise indicated.
c. Minimum Operating Pressure of Service Meter: 5 psig (34.5 kPa) **OR** 10 psig (69 kPa) **OR** 20 psig (138 kPa) **OR** 65 psig (450 kPa), **as directed**.
2. Natural-Gas System Pressure within Buildings: 0.5 psig (3.45 kPa) or less **OR** More than 0.5 psig (3.45 kPa) but not more than 2 psig (13.8 kPa) **OR** More than 2 psig (13.8 kPa) but not more than 5 psig (34.5 kPa), **as directed**.
OR
Natural-Gas System Pressures within Buildings: Two pressure ranges. Primary pressure is more than 0.5 psig (3.45 kPa) but not more than 2 psig (13.8 kPa), and is reduced to secondary pressure of 0.5 psig (3.45 kPa) or less.
OR
Natural-Gas System Pressures within Buildings: Two pressure ranges. Primary pressure is more than 2 psig (13.8 kPa) but not more than 5 psig (34.5 kPa), and is reduced to secondary pressure of more than 0.5 psig (3.45 kPa) but not more than 2 psig (13.8 kPa).
OR
Natural-Gas System Pressures within Buildings: Three pressure ranges. Primary pressure is more than 2 psig (13.8 kPa) but not more than 5 psig (34.5 kPa), and is reduced to secondary pressures of more than 0.5 psig (3.45 kPa) but not more than 2 psig (13.8 kPa), and is reduced again to pressures of 0.5 psig (3.45 kPa) or less.

3. Delegated Design: Design restraints and anchors for natural-gas piping and equipment, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

E. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings: For facility natural-gas piping layout. Include plans, piping layout and elevations, sections, and details for fabrication of pipe anchors, hangers, supports for multiple pipes, alignment guides, expansion joints and loops, and attachments of the same to building structure. Detail location of anchors, alignment guides, and expansion joints and loops.
3. Delegated-Design Submittal: For natural-gas piping and equipment indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
   a. Detail fabrication and assembly of seismic restraints.
   b. Design Calculations: Calculate requirements for selecting seismic restraints.
4. Welding certificates.
5. Field quality-control reports.
6. Operation and maintenance data.

F. Quality Assurance
1. Steel Support Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
2. Pipe Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.
3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

G. Delivery, Storage, And Handling
1. Handling Flammable Liquids: Remove and dispose of liquids from existing natural-gas piping according to requirements of authorities having jurisdiction.
2. Deliver pipes and tubes with factory-applied end caps. Maintain end caps through shipping, storage, and handling to prevent pipe end damage and to prevent entrance of dirt, debris, and moisture.
3. Store and handle pipes and tubes having factory-applied protective coatings to avoid damaging coating, and protect from direct sunlight.
4. Protect stored PE pipes and valves from direct sunlight.

H. Project Conditions
1. Interruption of Existing Natural-Gas Service: Do not interrupt natural-gas service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide purging and startup of natural-gas supply according to requirements indicated:
   a. Notify Owner no fewer than two days in advance of proposed interruption of natural-gas service.
   b. Do not proceed with interruption of natural-gas service without Owner's written permission.

1.2 PRODUCTS

A. Pipes, Tubes, And Fittings
1. Steel Pipe: ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.
   a. Malleable-Iron Threaded Fittings: ASME B16.3, Class 150, standard pattern.
   b. Wrought-Steel Welding Fittings: ASTM A 234/A 234M for butt welding and socket welding.
   c. Unions: ASME B16.39, Class 150, malleable iron with brass-to-iron seat, ground joint, and threaded ends.

d. Forged-Steel Flanges and Flanged Fittings: ASME B16.5, minimum Class 150, including bolts, nuts, and gaskets of the following material group, end connections, and facings:
   1) Material Group: 1.1.
   2) End Connections: Threaded or butt welding to match pipe.
   3) Lapped Face: Not permitted underground.
   4) Gasket Materials: ASME B16.20, metallic, flat, asbestos free, aluminum o-rings, and spiral-wound metal gaskets.
   5) Bolts and Nuts: ASME B18.2.1, carbon steel aboveground and stainless steel underground.
e. Protective Coating for Underground Piping: Factory-applied, three-layer coating of epoxy, adhesive, and PE.
   1) Joint Cover Kits: Epoxy paint, adhesive, and heat-shrink PE sleeves.
f. Mechanical Couplings:
   1) Stainless-steel **OR** Steel, **as directed**, flanges and tube with epoxy finish.
   2) Buna-nitrile seals.
   3) Stainless-steel **OR** Steel, **as directed**, bolts, washers, and nuts.
   4) Coupling shall be capable of joining PE pipe to PE pipe, steel pipe to PE pipe, or steel pipe to steel pipe.
   5) Steel body couplings installed underground on plastic pipe shall be factory equipped with anode.

2. Corrugated, Stainless-Steel Tubing: Comply with ANSI/IAS LC 1.
   a. Tubing: ASTM A 240/A 240M, corrugated, Series 300 stainless steel.
   b. Coating: PE with flame retardant.
      1) Surface-Burning Characteristics: As determined by testing identical products according to ASTM E 84 by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
         a) Flame-Spread Index: 25 or less.
         b) Smoke-Developed Index: 50 **OR** 450, **as directed**, or less.
   c. Fittings: Copper-alloy mechanical fittings with ends made to fit and listed for use with corrugated stainless-steel tubing and capable of metal-to-metal seal without gaskets. Include brazing socket or threaded ends complying with ASME B1.20.1.
   d. Striker Plates: Steel, designed to protect tubing from penetrations.
   e. Manifolds: Malleable iron or steel with factory-applied protective coating. Threaded connections shall comply with ASME B1.20.1 for pipe inlet and corrugated tubing outlets.
   f. Operating-Pressure Rating: 5 psig (34.5 kPa).
3. Aluminum Tubing: Comply with ASTM B 210 and ASTM B 241/B 241M.
   a. Aluminum Alloy: Alloy 5456 is prohibited.
   b. Protective Coating: Factory-applied coating capable of resisting corrosion on tubing in contact with masonry, plaster, insulation, water, detergents, and sewerage.
   c. Flare Fittings: Comply with ASME B16.26 and SAE J513.
      1) Copper-alloy fittings.
      2) Metal-to-metal compression seal without gasket.
      3) Dryseal threads shall comply with ASME B1.20.3.
4. Drawn-Temper Copper Tube: Comply with ASTM B 88, Type K (ASTM B 88M, Type A) **OR** ASTM B 88, Type L (ASTM B 88M, Type B) **OR** ASTM B 837, Type G, **as directed**.
   a. Copper Fittings: ASME B16.22, wrought copper, and streamlined pattern.
   b. Bronze Flanges and Flanged Fittings: ASME B16.24, Class 150.
      1) Gasket Material: ASME B16.20, metallic, flat, asbestos free, aluminum o-rings, and spiral-wound metal gaskets.
      2) Bolts and Nuts: ASME B18.2.1, carbon steel or stainless steel.
   c. Protective Coating for Underground Tubing: Factory-applied, extruded PE a minimum of 0.022 inch (0.56 mm) thick.
5. Annealed-Temper Copper Tube: Comply with ASTM B 88, Type K (ASTM B 88M, Type A) **OR** ASTM B 88, Type L (ASTM B 88M, Type B) **OR** ASTM B 837, Type G, **as directed**.
   a. Copper Fittings: ASME B16.22, wrought copper, and streamlined pattern.
   b. Flare Fittings: Comply with ASME B16.26 and SAE J513.

1) Copper fittings with long nuts.
2) Metal-to-metal compression seal without gasket.
3) Dryseal threads complying with ASME B1.20.3.

c. Protective Coating for Underground Tubing: Factory-applied, extruded PE a minimum of 0.022 inch (0.56 mm) thick.

6. Tin-Lined Copper Tube: ASTM B 280, seamless, annealed, with interior tin-plated lining.
   a. Flare Fittings: Comply with ASME B16.26 and SAE J513.
      1) Copper fittings with long nuts.
      2) Metal-to-metal compression seal without gasket.
      3) Dryseal threads complying with ASME B1.20.3.
7. PE Pipe: ASTM D 2513, SDR 11.
   a. PE Fittings: ASTM D 2683, socket-fusion type or ASTM D 3261, butt-fusion type with dimensions matching PE pipe.
   b. PE Transition Fittings: Factory-fabricated fittings with PE pipe complying with ASTM D 2513, SDR 11; and steel pipe complying with ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.
   c. Anodeless Service-Line Risers: Factory fabricated and leak tested.
      1) Underground Portion: PE pipe complying with ASTM D 2513, SDR 11 inlet.
      2) Casing: Steel pipe complying with ASTM A 53/A 53M, Schedule 40, black steel, Type E or S, Grade B, with corrosion-protective coating covering. Vent casing aboveground, **as directed**.
      3) Aboveground Portion: PE transition fitting.
      4) Outlet shall be threaded or flanged or suitable for welded connection.
      5) Tracer wire connection.
      6) Ultraviolet shield.
      7) Stake supports with factory finish to match steel pipe casing or carrier pipe.
   d. Transition Service-Line Risers: Factory fabricated and leak tested.
      1) Underground Portion: PE pipe complying with ASTM D 2513, SDR 11 inlet connected to steel pipe complying with ASTM A 53/A 53M, Schedule 40, Type E or S, Grade B, with corrosion-protective coating for aboveground outlet.
      2) Outlet shall be threaded or flanged or suitable for welded connection.
      3) Bridging sleeve over mechanical coupling.
      4) Factory-connected anode.
      5) Tracer wire connection.
      6) Ultraviolet shield.
      7) Stake supports with factory finish to match steel pipe casing or carrier pipe.
   e. Plastic Mechanical Couplings, NPS 1-1/2 (DN 40) and Smaller: Capable of joining PE pipe to PE pipe.
      1) PE body with molded-in, stainless-steel support ring.
      2) Buna-nitrile seals.
      3) Acetal collets.
      4) Electro-zinc-plated steel stiffener.
   f. Plastic Mechanical Couplings, NPS 2 (DN 50) and Larger: Capable of joining PE pipe to PE pipe, steel pipe to PE pipe, or steel pipe to steel pipe.
      1) Fiber-reinforced plastic body.
      2) PE body tube.
      3) Buna-nitrile seals.
      4) Acetal collets.
      5) Stainless-steel bolts, nuts, and washers.
   g. Steel Mechanical Couplings: Capable of joining plain-end PE pipe to PE pipe, steel pipe to PE pipe, or steel pipe to steel pipe.
      1) Stainless-steel **OR** Steel, **as directed**, flanges and tube with epoxy finish.
      2) Buna-nitrile seals.
      3) Stainless-steel **OR** Steel, **as directed**, bolts, washers, and nuts.
      4) Factory-installed anode for steel-body couplings installed underground.

B. Piping Specialties
1. Appliance Flexible Connectors:
   a. Indoor, Fixed-Appliance Flexible Connectors: Comply with ANSI Z21.24.
   b. Indoor, Movable-Appliance Flexible Connectors: Comply with ANSI Z21.69.
   c. Outdoor, Appliance Flexible Connectors: Comply with ANSI Z21.75.
   d. Corrugated stainless-steel tubing with polymer coating.
   e. Operating-Pressure Rating: 0.5 psig (3.45 kPa).
   f. End Fittings: Zinc-coated steel.
   g. Threaded Ends: Comply with ASME B1.20.1.
   h. Maximum Length: 72 inches (1830 mm).
2. Quick-Disconnect Devices: Comply with ANSI Z21.41.
   a. Copper-alloy convenience outlet and matching plug connector.
   b. Nitrile seals.
   c. Hand operated with automatic shutoff when disconnected.
   d. For indoor or outdoor applications.
   e. Adjustable, retractable restraining cable.
3. Y-Pattern Strainers:
   a. Body: ASTM A 126, Class B, cast iron with bolted cover and bottom drain connection.
   b. End Connections: Threaded ends for NPS 2 (DN 50) and smaller; flanged ends for NPS 2-1/2 (DN 65) and larger.
   c. Strainer Screen: 40 **OR** 60, **as directed**,-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.
   d. CWP Rating: 125 psig (862 kPa).
4. Basket Strainers:
   a. Body: ASTM A 126, Class B, high-tensile cast iron with bolted cover and bottom drain connection.
   b. End Connections: Threaded ends for NPS 2 (DN 50) and smaller; flanged ends for NPS 2-1/2 (DN 65) and larger.
   c. Strainer Screen: 40 **OR** 60, **as directed**,-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.
   d. CWP Rating: 125 psig (862 kPa).
5. T-Pattern Strainers:
   a. Body: Ductile or malleable iron with removable access coupling and end cap for strainer maintenance.
   b. End Connections: Grooved ends.
   c. Strainer Screen: 40 **OR** 60, **as directed**,-mesh startup strainer, and perforated stainless-steel basket with 57 percent free area.
   d. CWP Rating: 750 psig (5170 kPa).
6. Weatherproof Vent Cap: Cast- or malleable-iron increaser fitting with corrosion-resistant wire screen, with free area at least equal to cross-sectional area of connecting pipe and threaded-end connection.

C. Joining Materials
1. Joint Compound and Tape: Suitable for natural gas.
2. Welding Filler Metals: Comply with AWS D10.12/D10.12M for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.
3. Brazing Filler Metals: Alloy with melting point greater than 1000 deg F (540 deg C) complying with AWS A5.8/A5.8M. Brazing alloys containing more than 0.05 percent phosphorus are prohibited.

D. Manual Gas Shutoff Valves
1. See "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles for where each valve type is applied in various services.
2. General Requirements for Metallic Valves, NPS 2 (DN 50) and Smaller: Comply with ASME B16.33.
   a. CWP Rating: 125 psig (862 kPa).

b. Threaded Ends: Comply with ASME B1.20.1.
c. Dryseal Threads on Flare Ends: Comply with ASME B1.20.3.
d. Tamperproof Feature: Locking feature for valves indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
e. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction for valves 1 inch (25 mm) and smaller.
f. Service Mark: Valves 1-1/4 inches (32 mm) to NPS 2 (DN 50) shall have initials "WOG" permanently marked on valve body.

3. General Requirements for Metallic Valves, NPS 2-1/2 (DN 65) and Larger: Comply with ASME B16.38.
   a. CWP Rating: 125 psig (862 kPa).
   b. Flanged Ends: Comply with ASME B16.5 for steel flanges.
   c. Tamperproof Feature: Locking feature for valves indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
   d. Service Mark: Initials "WOG" shall be permanently marked on valve body.
4. One-Piece, Bronze Ball Valve with Bronze Trim: MSS SP-110.
   a. Body: Bronze, complying with ASTM B 584.
   b. Ball: Chrome-plated brass.
   c. Stem: Bronze; blowout proof.
   d. Seats: Reinforced TFE; blowout proof.
   e. Packing: Separate packnut with adjustable-stem packing threaded ends.
   f. Ends: Threaded, flared, or socket as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
   g. CWP Rating: 600 psig (4140 kPa).
   h. Listing: Valves NPS 1 (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
   i. Service: Suitable for natural-gas service with "WOG" indicated on valve body.
5. Two-Piece, Full-Port, Bronze Ball Valves with Bronze Trim: MSS SP-110.
   a. Body: Bronze, complying with ASTM B 584.
   b. Ball: Chrome-plated bronze.
   c. Stem: Bronze; blowout proof.
   d. Seats: Reinforced TFE; blowout proof.
   e. Packing: Threaded-body packnut design with adjustable-stem packing.
   f. Ends: Threaded, flared, or socket as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
   g. CWP Rating: 600 psig (4140 kPa).
   h. Listing: Valves NPS 1 (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
   i. Service: Suitable for natural-gas service with "WOG" indicated on valve body.
6. Two-Piece, Regular-Port Bronze Ball Valves with Bronze Trim: MSS SP-110.
   a. Body: Bronze, complying with ASTM B 584.
   b. Ball: Chrome-plated bronze.
   c. Stem: Bronze; blowout proof.
   d. Seats: Reinforced TFE.
   e. Packing: Threaded-body packnut design with adjustable-stem packing.
   f. Ends: Threaded, flared, or socket as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
   g. CWP Rating: 600 psig (4140 kPa).
   h. Listing: Valves NPS 1 (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
   i. Service: Suitable for natural-gas service with "WOG" indicated on valve body.
7. Bronze Plug Valves: MSS SP-78.
   a. Body: Bronze, complying with ASTM B 584.
   b. Plug: Bronze.

c. Ends: Threaded, socket, or flanged as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
d. Operator: Square head or lug type with tamperproof feature where indicated.
e. Pressure Class: 125 psig (862 kPa).
f. Listing: Valves NPS 1 (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
g. Service: Suitable for natural-gas service with "WOG" indicated on valve body.

8. Cast-Iron, Nonlubricated Plug Valves: MSS SP-78.
   a. Body: Cast iron, complying with ASTM A 126, Class B.
   b. Plug: Bronze or nickel-plated cast iron.
   c. Seat: Coated with thermoplastic.
   d. Stem Seal: Compatible with natural gas.
   e. Ends: Threaded or flanged as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
   f. Operator: Square head or lug type with tamperproof feature where indicated.
   g. Pressure Class: 125 psig (862 kPa).
   h. Listing: Valves NPS 1 (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
   i. Service: Suitable for natural-gas service with "WOG" indicated on valve body.
9. Cast-Iron, Lubricated Plug Valves: MSS SP-78.
   a. Body: Cast iron, complying with ASTM A 126, Class B.
   b. Plug: Bronze or nickel-plated cast iron.
   c. Seat: Coated with thermoplastic.
   d. Stem Seal: Compatible with natural gas.
   e. Ends: Threaded or flanged as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
   f. Operator: Square head or lug type with tamperproof feature where indicated.
   g. Pressure Class: 125 psig (862 kPa).
   h. Listing: Valves NPS 1 (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
   i. Service: Suitable for natural-gas service with "WOG" indicated on valve body.
10. PE Ball Valves: Comply with ASME B16.40.
    a. Body: PE.
    b. Ball: PE.
    c. Stem: Acetal.
    d. Seats and Seals: Nitrile.
    e. Ends: Plain or fusible to match piping.
    f. CWP Rating: 80 psig (552 kPa).
    g. Operating Temperature: Minus 20 to plus 140 deg F (Minus 29 to plus 60 deg C).
    h. Operator: Nut or flat head for key operation.
    i. Include plastic valve extension.
    j. Include tamperproof locking feature for valves where indicated on Drawings.
11. Valve Boxes:
    a. Cast-iron, two-section box.
    b. Top section with cover with "GAS" lettering.
    c. Bottom section with base to fit over valve and barrel a minimum of 5 inches (125 mm) in diameter.
    d. Adjustable cast-iron extensions of length required for depth of bury.
    e. Include tee-handle, steel operating wrench with socket end fitting valve nut or flat head, and with stem of length required to operate valve.

E. Motorized Gas Valves
1. Automatic Gas Valves: Comply with ANSI Z21.21.
   a. Body: Brass or aluminum.
   b. Seats and Disc: Nitrile rubber.
   c. Springs and Valve Trim: Stainless steel.

d. Normally closed.
e. Visual position indicator.
f. Electrical **OR** Mechanical, **as directed**, operator for actuation by appliance automatic shutoff device.

2. Electrically Operated Valves: Comply with UL 429.
   a. Pilot operated.
   b. Body: Brass or aluminum.
   c. Seats and Disc: Nitrile rubber.
   d. Springs and Valve Trim: Stainless steel.
   e. 120-V ac, 60 Hz, Class B, continuous-duty molded coil, and replaceable.
   f. NEMA ICS 6, Type 4, coil enclosure.
   g. Normally closed.
   h. Visual position indicator.

F. Earthquake Valves
1. Earthquake Valves: Comply with ASCE 25.
   a. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction.
   b. Maximum Operating Pressure: 5 psig (34.5 kPa).
   c. Cast-aluminum body with nickel-plated chrome steel internal parts.
   d. Nitrile-rubber valve washer.
   e. Sight windows for visual indication of valve position.
   f. Threaded end connections complying with ASME B1.20.1.
   g. Wall mounting bracket with bubble level indicator.
2. Earthquake Valves: Comply with ASCE 25.
   a. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction.
   b. Maximum Operating Pressure: 0.5 psig (3.45 kPa) **OR** 7 psig (48 kPa) **OR** 60 psig (414 kPa), **as directed**.
   c. Cast-aluminum body with stainless-steel internal parts.
   d. Nitrile-rubber, reset-stem o-ring seal.
   e. Valve position, open or closed, indicator.
   f. Composition valve seat with clapper held by spring or magnet locking mechanism.
   g. Level indicator.
   h. End Connections: Threaded for valves NPS 2 (DN 50) and smaller; flanged for valves NPS 2-1/2 (DN 65) and larger.

G. Pressure Regulators
1. General Requirements:
   a. Single stage and suitable for natural gas.
   b. Steel jacket and corrosion-resistant components.
   c. Elevation compensator.
   d. End Connections: Threaded for regulators NPS 2 (DN 50) and smaller; flanged for regulators NPS 2-1/2 (DN 65) and larger.
2. Service Pressure Regulators: Comply with ANSI Z21.80.
   a. Body and Diaphragm Case: Cast iron or die-cast aluminum.
   b. Springs: Zinc-plated steel; interchangeable.
   c. Diaphragm Plate: Zinc-plated steel.
   d. Seat Disc: Nitrile rubber resistant to gas impurities, abrasion, and deformation at the valve port.
   e. Orifice: Aluminum; interchangeable.
   f. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
   g. Single-port, self-contained regulator with orifice no larger than required at maximum pressure inlet, and no pressure sensing piping external to the regulator.
   h. Pressure regulator shall maintain discharge pressure setting downstream, and not exceed 150 percent of design discharge pressure at shutoff.
   i. Overpressure Protection Device: Factory mounted on pressure regulator.

j. Atmospheric Vent: Factory- or field-installed, stainless-steel screen in opening if not connected to vent piping.
k. Maximum Inlet Pressure: 100 psig (690 kPa).

3. Line Pressure Regulators: Comply with ANSI Z21.80.
   a. Body and Diaphragm Case: Cast iron or die-cast aluminum.
   b. Springs: Zinc-plated steel; interchangeable.
   c. Diaphragm Plate: Zinc-plated steel.
   d. Seat Disc: Nitrile rubber resistant to gas impurities, abrasion, and deformation at the valve port.
   e. Orifice: Aluminum; interchangeable.
   f. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
   g. Single-port, self-contained regulator with orifice no larger than required at maximum pressure inlet, and no pressure sensing piping external to the regulator.
   h. Pressure regulator shall maintain discharge pressure setting downstream, and not exceed 150 percent of design discharge pressure at shutoff.
   i. Overpressure Protection Device: Factory mounted on pressure regulator.
   j. Atmospheric Vent: Factory- or field-installed, stainless-steel screen in opening if not connected to vent piping.
   k. Maximum Inlet Pressure: 2 psig (13.8 kPa) **OR** 5 psig (34.5 kPa) **OR** 10 psig (69 kPa), **as directed**.
4. Appliance Pressure Regulators: Comply with ANSI Z21.18.
   a. Body and Diaphragm Case: Die-cast aluminum.
   b. Springs: Zinc-plated steel; interchangeable.
   c. Diaphragm Plate: Zinc-plated steel.
   d. Seat Disc: Nitrile rubber.
   e. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
   f. Factory-Applied Finish: Minimum three-layer polyester and polyurethane paint finish.
   g. Regulator may include vent limiting device, instead of vent connection, if approved by authorities having jurisdiction.
   h. Maximum Inlet Pressure: 1 psig (6.9 kPa) **OR** 2 psig (13.8 kPa) **OR** 5 psig (34.5 kPa), **as directed**.

H. Service Meters
1. Diaphragm-Type Service Meters: Comply with ANSI B109.1 **OR** ANSI B109.2, **as directed**.
   a. Case: Die-cast aluminum.
   b. Connections: Steel threads.
   c. Diaphragm: Synthetic fabric.
   d. Diaphragm Support Bearings: Self-lubricating.
   e. Compensation: Continuous temperature and pressure, **as directed**.
   f. Meter Index: Cubic feet **OR** Liters **OR** Cubic feet and liters, **as directed**.
   g. Meter Case and Index: Tamper resistant.
   h. Remote meter reader compatible.
   i. Maximum Inlet Pressure: 100 psig (690 kPa).
   j. Pressure Loss: Maximum 0.5-inch wg (124 Pa) **OR** 2.0-inch wg (498 Pa), **as directed**.
   k. Accuracy: Maximum plus or minus 1.0 percent.
2. Rotary-Type Service Meters: Comply with ANSI B109.3.
   a. Case: Extruded aluminum.
   b. Connection: Flange.
   c. Impellers: Polished aluminum.
   d. Rotor Bearings: Self-lubricating.
   e. Compensation: Continuous temperature and pressure, **as directed**.
   f. Meter Index: Cubic feet **OR** Liters **OR** Cubic feet and liters, **as directed**.
   g. Tamper resistant.
   h. Remote meter reader compatible.
   i. Maximum Inlet Pressure: 100 psig (690 kPa).
   j. Accuracy: Maximum plus or minus 2.0 percent.

3. Turbine Meters: Comply with ASME MFC-4M.
   a. Housing: Cast iron or welded steel.
   b. Connection Threads or Flanges: Steel.
   c. Turbine: Aluminum or plastic.
   d. Turbine Bearings: Self-lubricating.
   e. Compensation: Continuous temperature and pressure, **as directed**.
   f. Meter Index: Cubic feet **OR** Liters **OR** Cubic feet and liters, **as directed**.
   g. Tamper resistant.
   h. Remote meter reader compatible.
   i. Maximum Inlet Pressure: 100 psig (690 kPa).
   j. Accuracy: Maximum plus or minus 2.0 percent.
4. Service-Meter Bars:
   a. Malleable- or cast-iron frame for supporting service meter.
   b. Include offset swivel pipes, meter nuts with o-ring seal, and factory- or field-installed dielectric unions.
   c. Omit meter offset swivel pipes if service-meter bar dimensions match service-meter connections.
5. Service-Meter Bypass Fittings:
   a. Ferrous, tee, pipe fitting with capped side inlet for temporary natural-gas supply.
   b. Integral ball-check bypass valve.

I. Dielectric Fittings
1. Dielectric Unions:
   a. Minimum Operating-Pressure Rating: 150 psig (1034 kPa).
   b. Combination fitting of copper alloy and ferrous materials.
   c. Insulating materials suitable for natural gas.
   d. Combination fitting of copper alloy and ferrous materials with threaded, brazed-joint, plain, or welded end connections that match piping system materials.
2. Dielectric Flanges:
   a. Minimum Operating-Pressure Rating: 150 psig (1034 kPa).
   b. Combination fitting of copper alloy and ferrous materials.
   c. Insulating materials suitable for natural gas.
   d. Combination fitting of copper alloy and ferrous materials with threaded, brazed-joint, plain, or welded end connections that match piping system materials.
3. Dielectric-Flange Kits:
   a. Minimum Operating-Pressure Rating: 150 psig (1034 kPa).
   b. Companion-flange assembly for field assembly.
   c. Include flanges, full-face- or ring-type neoprene or phenolic gasket, phenolic or PE bolt sleeves, phenolic washers, and steel backing washers.
   d. Insulating materials suitable for natural gas.
   e. Combination fitting of copper alloy and ferrous materials with threaded, brazed-joint, plain, or welded end connections that match piping system materials.

J. Sleeves
1. Steel Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, galvanized steel, plain ends.
2. Cast-Iron Pipe Sleeves: Cast or fabricated "wall pipe," equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop, unless otherwise indicated.

K. Mechanical Sleeve Seals
1. Description: Modular sealing element unit, designed for field assembly, to fill annular space between pipe and sleeve.
   a. Sealing Elements: EPDM **OR** NBR, **as directed**, interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe and sleeve.
   b. Pressure Plates: Plastic **OR** Carbon steel **OR** Stainless steel, **as directed**.

c. Connecting Bolts and Nuts: Carbon steel with corrosion-resistant coating **OR** Stainless steel, **as directed**, of length required to secure pressure plates to sealing elements. Include one nut and bolt for each sealing element.

L. Escutcheons
1. General Requirements for Escutcheons: Manufactured wall and ceiling escutcheons and floor plates, with ID to fit around pipe or tube, and OD that completely covers opening.
2. One-Piece, Deep-Pattern Escutcheons: Deep-drawn, box-shaped brass with polished chrome-plated finish.
3. One-Piece, Cast-Brass Escutcheons: With set screw.
   a. Finish: Polished chrome-plated **OR** Rough brass, **as directed**.
4. Split-Casting, Cast-Brass Escutcheons: With concealed hinge and set screw.
   a. Finish: Polished chrome-plated **OR** Rough brass, **as directed**.
5. One-Piece, Stamped-Steel Escutcheons: With set screw **OR** spring clips, **as directed**, and chrome-plated finish.
6. Split-Plate, Stamped-Steel Escutcheons: With concealed **OR** exposed-rivet, **as directed**, hinge, set screw **OR** spring clips, **as directed**, and chrome-plated finish.
7. One-Piece, Floor-Plate Escutcheons: Cast-iron floor plate.
8. Split-Casting, Floor-Plate Escutcheons: Cast brass with concealed hinge and set screw.

M. Grout
1. Description: ASTM C 1107, Grade B, nonshrink and nonmetallic, dry hydraulic-cement grout.
   a. Characteristics: Post-hardening, volume adjusting, nonstaining, noncorrosive, nongaseous, and recommended for interior and exterior applications.
   b. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.
   c. Packaging: Premixed and factory packaged.

N. Labeling And Identifying
1. Detectable Warning Tape: Acid- and alkali-resistant, PE film warning tape manufactured for marking and identifying underground utilities, a minimum of 6 inches (150 mm) wide and 4 mils (0.1 mm) thick, continuously inscribed with a description of utility, with metallic core encased in a protective jacket for corrosion protection, detectable by metal detector when tape is buried up to 30 inches (750 mm) deep; colored yellow.

1.3 EXECUTION

A. Preparation
1. Close equipment shutoff valves before turning off natural gas to premises or piping section.
2. Inspect natural-gas piping according to NFPA 54 **OR** the International Fuel Gas Code, **as directed**, to determine that natural-gas utilization devices are turned off in piping section affected.
3. Comply with NFPA 54 **OR** the International Fuel Gas Code, **as directed**, requirements for prevention of accidental ignition.

B. Outdoor Piping Installation
1. Comply with NFPA 54 **OR** the International Fuel Gas Code, **as directed**, for installation and purging of natural-gas piping.
2. Install underground, natural-gas piping buried at least 36 inches (900 mm) below finished grade. Comply with requirements in Division 31 Section "Earth Moving" for excavating, trenching, and backfilling.
   a. If natural-gas piping is installed less than 36 inches (900 mm) below finished grade, install it in containment conduit.
3. Install underground, PE, natural-gas piping according to ASTM D 2774.
4. Steel Piping with Protective Coating:
   a. Apply joint cover kits to pipe after joining to cover, seal, and protect joints.

b. Repair damage to PE coating on pipe as recommended in writing by protective coating manufacturer.
OR
Replace pipe having damaged PE coating with new pipe.

5. Copper Tubing with Protective Coating:
   a. Apply joint cover kits over tubing to cover, seal, and protect joints.
   b. Repair damage to PE coating on pipe as recommended in writing by protective coating manufacturer.
6. Install fittings for changes in direction and branch connections.
7. Aboveground, Exterior-Wall Pipe Penetrations: Seal penetrations using sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch (25-mm) annular clear space between pipe and sleeve for installing mechanical sleeve seals.
   a. Install steel pipe for sleeves smaller than 6 inches (150 mm) in diameter.
   b. Install cast-iron "wall pipes" for sleeves 6 inches (150 mm) and larger in diameter.
8. Underground, Exterior-Wall Pipe Penetrations: Install cast-iron "wall pipes" for sleeves. Seal pipe penetrations using mechanical sleeve seals. Select sleeve size to allow for 1-inch (25-mm) annular clear space between pipe and sleeve for installing mechanical sleeve seals.
9. Mechanical Sleeve Seal Installation: Select type and number of sealing elements required for pipe material and size. Position pipe in center of sleeve. Assemble mechanical sleeve seals and install in annular space between pipe and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.
10. Install pressure gage downstream **OR** upstream and downstream, **as directed**, from each service regulator. Pressure gages are specified in Division 23 Section "Meters And Gages For Hvac Piping".

C. Indoor Piping Installation
1. Comply with NFPA 54 **OR** the International Fuel Gas Code, **as directed**, for installation and purging of natural-gas piping.
2. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements are used to size pipe and calculate friction loss, expansion, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.
3. Arrange for pipe spaces, chases, slots, sleeves, and openings in building structure during progress of construction, to allow for mechanical installations.
4. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.
5. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
6. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
7. Locate valves for easy access.
8. Install natural-gas piping at uniform grade of 2 percent down toward drip and sediment traps.
9. Install piping free of sags and bends.
10. Install fittings for changes in direction and branch connections.
11. Install escutcheons at penetrations of interior walls, ceilings, and floors.
    a. New Piping:
       1) Piping with Fitting or Sleeve Protruding from Wall: One-piece, deep-pattern type.
       2) Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, cast-brass type with polished chrome-plated finish.
          OR
          Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, stamped-steel type.
       3) Piping at Ceiling Penetrations in Finished Spaces: One-piece **OR** Split-casting, **as directed**, cast-brass type with polished chrome-plated finish.
          OR

Piping at Ceiling Penetrations in Finished Spaces: One-piece, stamped-steel type **OR** Split-plate, stamped-steel type with concealed hinge, **as directed**, and set screw.

4) Piping in Unfinished Service Spaces: One-piece, cast-brass type with polished chrome-plated **OR** rough-brass, **as directed**, finish.
OR
Piping in Unfinished Service Spaces: One-piece, stamped-steel type with set screw **OR** spring clips, **as directed**.

5) Piping in Equipment Rooms: One-piece, cast-brass type.

Piping in Equipment Rooms: One-piece, stamped-steel type with set screw **OR** spring clips, **as directed**.

6) Piping at Floor Penetrations in Equipment Rooms: One-piece, floor-plate type.

b. Existing Piping:

1) Piping at Wall and Floor Penetrations in Finished Spaces: Split-casting, cast-brass type with chrome-plated finish.
OR
Piping at Wall and Floor Penetrations in Finished Spaces: Split-plate, stamped-steel type with concealed hinge and spring clips.

2) Piping at Ceiling Penetrations in Finished Spaces: Split-casting, cast-brass type with chrome-plated finish.
OR
Piping at Ceiling Penetrations in Finished Spaces: Split-plate, stamped-steel type with concealed hinge and set screw.

3) Piping in Unfinished Service Spaces: Split-casting, cast-brass type with polished chrome-plated **OR** rough-brass, **as directed**, finish.
OR
Piping in Unfinished Service Spaces: Split-plate, stamped-steel type with concealed **OR** exposed-rivet, **as directed**, hinge and set screw or spring clips.

4) Piping in Equipment Rooms: Split-casting, cast-brass type.
OR
Piping in Equipment Rooms: Split-plate, stamped-steel type with set screw or spring clips.

5) Piping at Floor Penetrations in Equipment Rooms: Split-casting, floor-plate type.

12. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with requirements in Division 07 Section "Penetration Firestopping".
13. Verify final equipment locations for roughing-in.
14. Comply with requirements in Sections specifying gas-fired appliances and equipment for roughing-in requirements.
15. Drips and Sediment Traps: Install drips at points where condensate may collect, including service-meter outlets. Locate where accessible to permit cleaning and emptying. Do not install where condensate is subject to freezing.
    a. Construct drips and sediment traps using tee fitting with bottom outlet plugged or capped. Use nipple a minimum length of 3 pipe diameters, but not less than 3 inches (75 mm) long and same size as connected pipe. Install with space below bottom of drip to remove plug or cap.
16. Extend relief vent connections for service regulators, line regulators, and overpressure protection devices to outdoors and terminate with weatherproof vent cap.
17. Conceal pipe installations in walls, pipe spaces, utility spaces, above ceilings, below grade or floors, and in floor channels unless indicated to be exposed to view.
18. Concealed Location Installations: Except as specified below, install concealed natural-gas piping and piping installed under the building in containment conduit constructed of steel pipe with welded joints as described in Part 2. Install a vent pipe from containment conduit to outdoors and terminate with weatherproof vent cap.

a. Above Accessible Ceilings: Natural-gas piping, fittings, valves, and regulators may be installed in accessible spaces without containment conduit.
b. In Floors: Install natural-gas piping with welded or brazed joints and protective coating in cast-in-place concrete floors. Cover piping to be cast in concrete slabs with minimum of 1-1/2 inches (38 mm) of concrete. Piping may not be in physical contact with other metallic structures such as reinforcing rods or electrically neutral conductors. Do not embed piping in concrete slabs containing quick-set additives or cinder aggregate.
c. In Floor Channels: Install natural-gas piping in floor channels. Channels must have cover and be open to space above cover for ventilation.
d. In Walls or Partitions: Protect tubing installed inside partitions or hollow walls from physical damage using steel striker barriers at rigid supports.
   1) Exception: Tubing passing through partitions or walls does not require striker barriers.
e. Prohibited Locations:
   1) Do not install natural-gas piping in or through circulating air ducts, clothes or trash chutes, chimneys or gas vents (flues), ventilating ducts, or dumbwaiter or elevator shafts.
   2) Do not install natural-gas piping in solid walls or partitions.

19. Use eccentric reducer fittings to make reductions in pipe sizes. Install fittings with level side down.
20. Connect branch piping from top or side of horizontal piping.
21. Install unions in pipes NPS 2 (DN 50) and smaller, adjacent to each valve, at final connection to each piece of equipment. Unions are not required at flanged connections.
22. Do not use natural-gas piping as grounding electrode.
23. Install strainer on inlet of each line-pressure regulator and automatic or electrically operated valve.
24. Install pressure gage downstream **OR** upstream and downstream, **as directed**, from each line regulator. Pressure gages are specified in Division 23 Section "Meters And Gages For Hvac Piping".

D. Service-Meter Assembly Installation
1. Install service-meter assemblies aboveground, on concrete bases.
2. Install metal shutoff valves upstream from service regulators. Shutoff valves are not required at second regulators if two regulators are installed in series.
3. Install strainer on inlet of service-pressure regulator and meter set.
4. Install service regulators mounted outside with vent outlet horizontal or facing down. Install screen in vent outlet if not integral with service regulator.
5. Install metal shutoff valves upstream from service meters. Install dielectric fittings downstream from service meters.
6. Install service meters downstream from pressure regulators.
7. Install metal bollards to protect meter assemblies. Comply with requirements in Division 05 Section "Metal Fabrications" for pipe bollards.

E. Valve Installation
1. Install manual gas shutoff valve for each gas appliance ahead of corrugated stainless-steel tubing, aluminum, or copper connector.
2. Install underground valves with valve boxes.
3. Install regulators and overpressure protection devices with maintenance access space adequate for servicing and testing.
4. Install earthquake valves aboveground outside buildings according to listing.
5. Install anode for metallic valves in underground PE piping.

F. Piping Joint Construction
1. Ream ends of pipes and tubes and remove burrs.
2. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

3. Threaded Joints:
   a. Thread pipe with tapered pipe threads complying with ASME B1.20.1.
   b. Cut threads full and clean using sharp dies.
   c. Ream threaded pipe ends to remove burrs and restore full inside diameter of pipe.
   d. Apply appropriate tape or thread compound to external pipe threads unless dryseal threading is specified.
   e. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
4. Welded Joints:
   a. Construct joints according to AWS D10.12/D10.12M, using qualified processes and welding operators.
   b. Bevel plain ends of steel pipe.
   c. Patch factory-applied protective coating as recommended by manufacturer at field welds and where damage to coating occurs during construction.
5. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter.
6. Flanged Joints: Install gasket material, size, type, and thickness appropriate for natural-gas service. Install gasket concentrically positioned.
7. Flared Joints: Cut tubing with roll cutting tool. Flare tube end with tool to result in flare dimensions complying with SAE J513. Tighten finger tight, then use wrench. Do not overtighten.
8. PE Piping Heat-Fusion Joints: Clean and dry joining surfaces by wiping with clean cloth or paper towels. Join according to ASTM D 2657.
   a. Plain-End Pipe and Fittings: Use butt fusion.
   b. Plain-End Pipe and Socket Fittings: Use socket fusion.

G. Hanger And Support Installation
1. Install seismic restraints on piping. Comply with requirements for seismic-restraint devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
2. Comply with requirements for pipe hangers and supports specified in Division 23 Section "Hangers And Supports For Hvac Piping And Equipment".
3. Install hangers for horizontal steel piping with the following maximum spacing and minimum rod sizes:
   a. NPS 1 (DN 25) and Smaller: Maximum span, 96 inches (2438 mm); minimum rod size, 3/8 inch (10 mm).
   b. NPS 1-1/4 (DN 32): Maximum span, 108 inches (2743 mm); minimum rod size, 3/8 inch (10 mm).
   c. NPS 1-1/2 and NPS 2 (DN 40 and DN 50): Maximum span, 108 inches (2743 mm); minimum rod size, 3/8 inch (10 mm).
   d. NPS 2-1/2 to NPS 3-1/2 (DN 65 to DN 90): Maximum span, 10 feet (3 m); minimum rod size, 1/2 inch (13 mm).
   e. NPS 4 (DN 100) and Larger: Maximum span, 10 feet (3 m); minimum rod size, 5/8 inch (15.8 mm).
4. Install hangers for horizontal drawn-temper copper tubing with the following maximum spacing and minimum rod sizes:
   a. NPS 3/8 (DN 10): Maximum span, 48 inches (1220 mm); minimum rod size, 3/8 inch (10 mm).
   b. NPS 1/2 and NPS 5/8 (DN 15 and DN 18): Maximum span, 72 inches (1830 mm); minimum rod size, 3/8 inch (10 mm).
   c. NPS 3/4 and NPS 7/8 (DN 20 and DN 22): Maximum span, 84 inches (2134 mm); minimum rod size, 3/8 inch (10 mm).
   d. NPS 1 (DN 25): Maximum span, 96 inches (2440 mm); minimum rod size, 3/8 inch (10 mm).
5. Install hangers for horizontal, corrugated stainless-steel tubing with the following maximum spacing and minimum rod sizes:

a. NPS 3/8 (DN 10): Maximum span, 48 inches (1220 mm); minimum rod size, 3/8 inch (10 mm).
b. NPS 1/2 (DN 15): Maximum span, 72 inches (1830 mm); minimum rod size, 3/8 inch (10 mm).
c. NPS 3/4 (DN 20) and Larger: Maximum span, 96 inches (2440 mm); minimum rod size, 3/8 inch (10 mm).

H. Connections
1. Connect to utility's gas main according to utility's procedures and requirements.
2. Install natural-gas piping electrically continuous, and bonded to gas appliance equipment grounding conductor of the circuit powering the appliance according to NFPA 70.
3. Install piping adjacent to appliances to allow service and maintenance of appliances.
4. Connect piping to appliances using manual gas shutoff valves and unions. Install valve within 72 inches (1800 mm) of each gas-fired appliance and equipment. Install union between valve and appliances or equipment.
5. Sediment Traps: Install tee fitting with capped nipple in bottom to form drip, as close as practical to inlet of each appliance.

I. Labeling And Identifying
1. Comply with requirements in Division 23 Section "Identification For Hvac Piping And Equipment" for piping and valve identification.
OR
Install detectable warning tape directly above gas piping, 12 inches (300 mm) below finished grade, except 6 inches (150 mm) below subgrade under pavements and slabs.

J. Painting
1. Comply with requirements in Division 07 for painting interior and exterior natural-gas piping.
2. Paint exposed, exterior metal piping, valves, service regulators, service meters and meter bars, earthquake valves, and piping specialties, except components, with factory-applied paint or protective coating.
a. Alkyd System: MPI EXT 5.1D.
1) Prime Coat: Alkyd anticorrosive metal primer.
2) Intermediate Coat (for a Premium Grade system): Exterior alkyd enamel matching topcoat.
3) Topcoat: Exterior alkyd enamel (flat) **OR** (semigloss) **OR** (gloss), **as directed**.
4) Color: Gray, **unless directed otherwise**.
3. Paint exposed, interior metal piping, valves, service regulators, service meters and meter bars, earthquake valves, and piping specialties, except components, with factory-applied paint or protective coating.
a. Latex Over Alkyd Primer System: MPI INT 5.1Q.
1) Prime Coat: Alkyd anticorrosive **OR** Quick-drying alkyd, **as directed**, metal primer.
2) Intermediate Coat (for a Premium Grade system): Interior latex matching topcoat.
3) Topcoat: Interior latex (flat) **OR** (low sheen) **OR** (eggshell) **OR** (satin) **OR** (semigloss) **OR** (gloss), **as directed**.
4) Color: Gray, **unless directed otherwise**.
b. Alkyd System: MPI INT 5.1E.
1) Prime Coat: Alkyd anticorrosive **OR** Quick-drying alkyd, **as directed**, metal primer.
2) Intermediate Coat (for a Premium Grade system): Interior alkyd matching topcoat.
3) Topcoat: Interior alkyd (flat) **OR** (eggshell) **OR** (semigloss) **OR** (gloss), **as directed**.
4) Color: Gray, **unless directed otherwise**.
4. Damage and Touchup: Repair marred and damaged factory-applied finishes with materials and by procedures to match original factory finish.

K. Concrete Bases
1. Concrete Bases: Anchor equipment to concrete base according to seismic codes at Project.

a. Construct concrete bases of dimensions indicated, but not less than 4 inches (100 mm) larger in both directions than supported unit.
b. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of the base.
c. Install epoxy-coated anchor bolts for supported equipment that extend through concrete base, and anchor into structural concrete floor.
d. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
e. Install anchor bolts to elevations required for proper attachment to supported equipment.
f. Use 3000-psig (20.7-MPa), **unless directed otherwise**, 28-day, compressive-strength concrete and reinforcement as specified in Division 03 Section "Cast-in-place Concrete".

L. Field Quality Control
1. Perform tests and inspections.
2. Tests and Inspections:
a. Test, inspect, and purge natural gas according to NFPA 54 **OR** the International Fuel Gas Code, **as directed**, and authorities having jurisdiction.
3. Natural-gas piping will be considered defective if it does not pass tests and inspections.
4. Prepare test and inspection reports.

M. Outdoor Piping Schedule
1. Underground natural-gas piping shall be one of the following:
a. PE pipe and fittings joined by heat fusion, or mechanical couplings; service-line risers with tracer wire terminated in an accessible location.
b. Steel pipe with wrought-steel fittings and welded joints, or mechanical couplings. Coat pipe and fittings with protective coating for steel piping.
c. Annealed **OR** Drawn, **as directed**,-temper copper tube with wrought-copper fittings and brazed joints. Coat pipe and fittings with protective coating for copper tubing.
2. Aboveground natural-gas piping shall be one of the following:
a. Steel pipe with malleable-iron fittings and threaded joints.
b. Steel pipe with wrought-steel fittings and welded joints.
c. Annealed **OR** Drawn, **as directed**,-temper copper tube with wrought-copper fittings and brazed joints.
3. Branch Piping in Cast-in-Place Concrete to Single Appliance: Annealed-temper copper tube with wrought-copper fittings and brazed **OR** flared, **as directed**, joints. Install piping embedded in concrete with no joints in concrete.
4. Containment Conduit: Steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.

N. Indoor Piping Schedule For System Pressures Less Than 0.5 psig (3.45 kPa)
1. Aboveground, branch piping NPS 1 (DN 25) and smaller shall be one of the following:
a. Corrugated stainless-steel tubing with mechanical fittings having socket or threaded ends to match adjacent piping.
b. Annealed-temper, tin-lined copper tube with flared joints and fittings.
c. Annealed-temper, copper tube with wrought-copper fittings and brazed **OR** flared, **as directed**, joints.
d. Aluminum tube with flared fittings and joints.
e. Steel pipe with malleable-iron fittings and threaded joints.
2. Aboveground, distribution piping shall be one of the following:
a. Steel pipe with malleable-iron fittings and threaded joints.
b. Steel pipe with wrought-steel fittings and welded joints.
c. Drawn-temper copper tube with wrought-copper fittings and brazed joints.
3. Underground, below building, piping shall be one of the following:
a. Steel pipe with malleable-iron fittings and threaded joints.
b. Steel pipe with wrought-steel fittings and welded joints.

4. Containment Conduit: Steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.
5. Containment Conduit Vent Piping: Steel pipe with malleable-iron fittings and threaded or wrought-steel fittings with welded joints. Coat underground pipe and fittings with protective coating for steel piping.

O. Indoor Piping Schedule For System Pressures More Than 0.5 psig (3.45 kPa) And Less Than 5 psig (34.5 kPa)
1. Aboveground, branch piping NPS 1 (DN 25) and smaller shall be one of the following:
   a. Corrugated stainless-steel tubing with mechanical fittings having socket or threaded ends to match adjacent piping.
   b. Annealed-temper, tin-lined copper tube with flared joints and fittings.
   c. Annealed-temper, copper tube with wrought-copper fittings and brazed **OR** flared, **as directed**, joints.
   d. Aluminum tube with flared fittings and joints.
   e. Steel pipe with malleable-iron fittings and threaded joints.
2. Aboveground, distribution piping shall be one of the following:
   a. Steel pipe with malleable-iron fittings and threaded joints.
   b. Steel pipe with steel welding fittings and welded joints.
   c. Drawn-temper copper tube with wrought-copper fittings and brazed joints.
3. Underground, below building, piping shall be one of the following:
   a. Steel pipe with malleable-iron fittings and threaded joints.
   b. Steel pipe with wrought-steel fittings and welded joints.
4. Containment Conduit: Steel pipe with wrought-steel fittings and welded joints. Coat underground pipe and fittings with protective coating for steel piping.
5. Containment Conduit Vent Piping: Steel pipe with malleable-iron fittings and threaded or wrought-steel fittings with welded joints. Coat underground pipe and fittings with protective coating for steel piping.

P. Indoor Piping Schedule For System Pressures More Than 5 psig (34.5 kPa)
1. Aboveground Piping: Maximum operating pressure more than 5 psig (34.5 kPa).
2. Aboveground, Branch Piping: Steel pipe with steel welding fittings and welded joints.
3. Aboveground, distribution piping shall be one of the following:
   a. Steel pipe with steel welding fittings and welded joints.
   b. Drawn-temper copper tube with wrought-copper fittings and brazed joints.
4. Underground, below building, piping shall be one of the following:
   a. Steel pipe with malleable-iron fittings and threaded joints.
   b. Steel pipe with wrought-steel fittings and welded joints.
5. Containment Conduit: Steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.
6. Containment Conduit Vent Piping: Steel pipe with malleable-iron fittings and threaded or wrought-steel fittings with welded joints. Coat underground pipe and fittings with protective coating for steel piping.

Q. Underground Manual Gas Shutoff Valve Schedule
1. Connections to Existing Gas Piping: Use valve and fitting assemblies made for tapping utility's gas mains and listed by an NRTL.
2. Underground:
   a. PE valves.
   b. NPS 2 (DN 50) and Smaller: Bronze plug valves.
   c. NPS 2-1/2 (DN 65) and Larger: Cast-iron, lubricated **OR** nonlubricated, **as directed**, plug valves.

R. Aboveground Manual Gas Shutoff Valve Schedule
1. Valves for pipe sizes NPS 2 (DN 50) and smaller at service meter shall be one of the following:

a. One-piece, bronze ball valve with bronze trim.
b. Two-piece, full **OR** regular, **as directed**,-port, bronze ball valves with bronze trim.
c. Bronze plug valve.

2. Valves for pipe sizes NPS 2-1/2 (DN 65) and larger at service meter shall be one of the following:
   a. Two-piece, full **OR** regular, **as directed**,-port, bronze ball valves with bronze trim.
   b. Bronze plug valve.
   c. Cast-iron, nonlubricated plug valve.
3. Distribution piping valves for pipe sizes NPS 2 (DN 50) and smaller shall be one of the following:
   a. One-piece, bronze ball valve with bronze trim.
   b. Two-piece, full **OR** regular, **as directed**,-port, bronze ball valves with bronze trim.
   c. Bronze plug valve.
4. Distribution piping valves for pipe sizes NPS 2-1/2 (DN 65) and larger shall be one of the following:
   a. Two-piece, full **OR** regular, **as directed**,-port, bronze ball valves with bronze trim.
   b. Bronze plug valve.
   c. Cast-iron, nonlubricated **OR** lubricated, **as directed**, plug valve.
5. Valves in branch piping for single appliance shall be one of the following:
   a. One-piece, bronze ball valve with bronze trim.
   b. Two-piece, full **OR** regular, **as directed**,-port, bronze ball valves with bronze trim.
   c. Bronze plug valve.

END OF SECTION 23 11 23 00b

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SECTION 23 11 23 00c - FACILITY LIQUEFIED-PETROLEUM GAS PIPING

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for facility liquid-petroleum gas piping. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Pipes, tubes, and fittings.
b. Piping specialties.
c. Piping and tubing joining materials.
d. Valves.
e. Pressure regulators.
f. Service meters.
g. Storage containers.
h. Transport truck unloading facility specialties.
i. Pumps.
j. Vaporizers.
k. Air mixers.
l. Mechanical sleeve seals.
m. Grout.
n. Concrete bases.

C. Definitions
1. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct shafts, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspaces, and tunnels.
2. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.
3. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.
4. LPG: Liquefied-petroleum gas.

D. Performance Requirements
1. Minimum Operating-Pressure Ratings:
a. For Piping Containing Only Vapor:
1) Piping and Valves: 125 psig (862 kPa) unless otherwise indicated.
b. For Piping Containing Liquid:
1) Piping between Shutoff Valves: 350 psig (2413 kPa) unless otherwise indicated.
2) Piping Other Than Above: 250 psig (1723 kPa) unless otherwise indicated.
3) Valves and Fittings: 250 psig (1723 kPa) unless otherwise indicated.
c. Minimum Operating Pressure of Service Meter: 5 psig (34.5 kPa) **OR** 10 psig (69 kPa) **OR** 20 psig (138 kPa) **OR** 65 psig (450 kPa), **as directed**.
2. LPG System Pressure within Buildings: One pressure range. 0.5 psig (3.45 kPa) or less **OR** More than 0.5 psig (3.45 kPa) but not more than 2 psig (13.8 kPa) **OR** More than 2 psig (13.8 kPa) but not more than 5 psig (34.5 kPa), **as directed**.
OR
LPG System Pressures within Buildings: Two pressure ranges. Primary pressure is more than 0.5 psig (3.45 kPa) but not more than 2 psig (13.8 kPa) and is reduced to secondary pressure of 0.5 psig (3.45 kPa) or less.

OR

LPG System Pressures within Buildings: Two pressure ranges. Primary pressure is more than 2 psig (13.8 kPa) but not more than 5 psig (34.5 kPa) and is reduced to secondary pressure of more than 0.5 psig (3.45 kPa) but not more than 2 psig (13.8 kPa).

OR

LPG System Pressures within Buildings: Three pressure ranges. Primary pressure is more than 2 psig (13.8 kPa) but not more than 5 psig (34.5 kPa) and is reduced to secondary pressures of more than 0.5 psig (3.45 kPa) but not more than 2 psig (13.8 kPa) and is reduced again to pressures of 0.5 psig (3.45 kPa) or less.

3. Delegated Design: Design restraints and anchors for LPG piping and equipment, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
4. Seismic Performance: Vaporizers and storage container supports shall withstand the effects of earthquake motions determined according to SEI/ASCE 7.
   a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."

E. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings: For facility LPG piping layout. Include plans, piping layout and elevations, sections, and details for fabrication of pipe anchors, hangers, supports for multiple pipes, alignment guides, expansion joints and loops, and attachments of the same to building structure. Detail location of anchors, alignment guides, and expansion joints and loops.
3. Delegated-Design Submittal: For LPG piping and equipment indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
   a. Detail fabrication and assembly of seismic restraints.
   b. Design Calculations: Calculate requirements for selecting seismic restraints.
4. Seismic Qualification Certificates: Submit certification that vaporizer, air mixer, storage container supports, accessories, and components will withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment". Include the following:
   a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
   c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
5. Welding certificates.
6. Field quality-control reports.
7. Operation and maintenance data.

F. Quality Assurance
1. Steel Support Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
2. Pipe Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.
3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

G. Delivery, Storage, And Handling
1. Handling Flammable Liquids: Remove and dispose of liquids from existing LPG piping according to requirements of authorities having jurisdiction.
2. Deliver pipes and tubes with factory-applied end caps. Maintain end caps through shipping, storage, and handling to prevent pipe end damage and to prevent entrance of dirt, debris, and moisture.

3. Store pipes and tubes with protective PE coating to avoid damaging coating and protect from direct sunlight.
4. Protect stored PE pipes and valves from direct sunlight.

H. Project Conditions
1. Interruption of Existing LPG Service: Do not interrupt LPG service to facilities occupied by the Owner or others unless permitted under the following conditions and then only after arranging to provide purging and startup of LPG supply according to requirements indicated:
   a. Notify the Owner no fewer than two days in advance of proposed interruption of LPG service.
   b. Do not proceed with interruption of LPG service without the Owner's written permission.

1.2 PRODUCTS

A. Pipes, Tubes, And Fittings
1. Steel Pipe: ASTM A 53/A 53M, black steel, Schedules 40 and 80, Type E or S, Grade B.
   a. Malleable-Iron Threaded Fittings: ASME B16.3, Class 150, standard pattern.
   b. Wrought-Steel Welding Fittings: ASTM A 234/A 234M for butt welding and socket welding.
   c. Unions: ASME B16.39, Class 150, malleable iron with brass-to-iron seat, ground joint, and threaded ends.
   d. Forged-Steel Flanges and Flanged Fittings: ASME B16.5, minimum Class 150, including bolts, nuts, and gaskets of the following material group, end connections, and facings:
      1) Material Group: 1.1.
      2) End Connections: Threaded or butt welding to match pipe.
      3) Lapped Face: Not permitted underground.
      4) Gasket Materials: ASME B16.20, metallic, flat, asbestos free, aluminum o-rings, and spiral-wound metal gaskets.
      5) Bolts and Nuts: ASME B18.2.1, carbon steel aboveground, and stainless steel underground.
   e. Protective Coating for Underground Piping: Factory-applied, three-layer coating of epoxy, adhesive, and PE.
      1) Joint Cover Kits: Epoxy paint, adhesive, and heat-shrink PE sleeves.
   f. Mechanical Couplings:
      1) Stainless-steel **OR** Steel, **as directed**, flanges and tube with epoxy finish.
      2) Buna-nitrile seals.
      3) Stainless-steel **OR** Steel, **as directed**, bolts, washers, and nuts.
      4) Coupling shall be capable of joining PE pipe to PE pipe, steel pipe to PE pipe, or steel pipe to steel pipe.
      5) Steel body couplings installed underground on plastic pipe shall be factory equipped with anode.
2. Corrugated, Stainless-Steel Tubing: Comply with ANSI/IAS LC 1.
   a. Tubing: ASTM A 240/A 240M, corrugated, Series 300 stainless steel.
   b. Coating: PE with flame retardant.
      1) Surface-Burning Characteristics: As determined by testing identical products according to ASTM E 84 by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
         a) Flame-Spread Index: 25 or less.
         b) Smoke-Developed Index: 50 **OR** 450, **as directed**, or less.
   c. Fittings: Copper-alloy mechanical fittings with ends made to fit and listed for use with corrugated stainless-steel tubing and capable of metal-to-metal seal without gaskets. Include brazing socket or threaded ends complying with ASME B1.20.1.
   d. Striker Plates: Steel, designed to protect tubing from penetrations.
   e. Manifolds: Malleable iron or steel with factory-applied protective coating. Threaded connections shall comply with ASME B1.20.1 for pipe inlet and corrugated tubing outlets.
   f. Operating-Pressure Rating: 5 psig (34.5 kPa).

3. Aluminum Tubing: Comply with ASTM B 210 and ASTM B 241/B 241M.
   a. Aluminum Alloy: Alloy 5456 is prohibited.
   b. Protective Coating: Factory-applied coating capable of resisting corrosion on tubing in contact with masonry, plaster, insulation, water, detergents, and sewerage.
   c. Flare Fittings: Comply with ASME B16.26 and SAE J513.
      1) Copper-alloy fittings.
      2) Metal-to-metal compression seal without gasket.
      3) Dryseal threads shall comply with ASME B1.20.3.
4. Drawn-Temper Copper Tube: Comply with ASTM B 88, Type K (ASTM B 88M, Type A) **OR** ASTM B 88, Type L (ASTM B 88M, Type B) **OR** ASTM B 837, Type G, **as directed**.
   a. Copper Fittings: ASME B16.22, wrought copper, and streamlined pattern.
   b. Bronze Flanges and Flanged Fittings: ASME B16.24, Class 150.
      1) Gasket Material: ASME B16.20, metallic, flat, asbestos free, aluminum o-rings, and spiral-wound metal gaskets.
      2) Bolts and Nuts: ASME B18.2.1, carbon steel or stainless steel.
   c. Protective Coating for Underground Tubing: Factory-applied, extruded PE a minimum of 0.022 inch (0.56 mm) thick.
5. Annealed-Temper Copper Tube: Comply with ASTM B 88, Type K (ASTM B 88M, Type A) **OR** ASTM B 88, Type L (ASTM B 88M, Type B) **OR** ASTM B 837, Type G, **as directed**.
   a. Copper Fittings: ASME B16.22, wrought copper, and streamlined pattern.
   b. Flare Fittings: Comply with ASME B16.26 and SAE J513.
      1) Copper fittings with long nuts.
      2) Metal-to-metal compression seal without gasket.
      3) Dryseal threads complying with ASME B1.20.3.
   c. Protective Coating for Underground Tubing: Factory-applied, extruded PE a minimum of 0.022 inch (0.56 mm) thick.
6. Tin-Lined Copper Tube: ASTM B 280, seamless, annealed, with interior tin-plated lining.
   a. Flare Fittings: Comply with ASME B16.26 and SAE J513.
      1) Copper fittings with long nuts.
      2) Metal-to-metal compression seal without gasket.
      3) Dryseal threads complying with ASME B1.20.3.
7. PE Pipe: ASTM D 2513, SDR 11.
   a. PE Fittings: ASTM D 2683, socket-fusion type or ASTM D 3261, butt-fusion type with dimensions matching PE pipe.
   b. PE Transition Fittings: Factory-fabricated fittings with PE pipe complying with ASTM D 2513, SDR 11; and steel pipe complying with ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.
   c. Anodeless Service-Line Risers: Factory fabricated and leak tested.
      1) Underground Portion: PE pipe complying with ASTM D 2513, SDR 11 inlet.
      2) Casing: Steel pipe complying with ASTM A 53/A 53M, Schedule 40, black steel, Type E or S, Grade B with corrosion-protective coating covering. Vent casing aboveground, **as directed**.
      3) Aboveground Portion: PE transition fitting.
      4) Outlet shall be threaded or flanged or suitable for welded connection.
      5) Tracer wire connection.
      6) Ultraviolet shield.
      7) Stake supports with factory finish to match steel pipe casing or carrier pipe.
   d. Transition Service-Line Risers: Factory fabricated and leak tested.
      1) Underground Portion: PE pipe complying with ASTM D 2513, SDR 11 inlet connected to steel pipe complying with ASTM A 53/A 53M, Schedule 40, Type E or S, Grade B, with corrosion-protective coating for aboveground outlet.
      2) Outlet shall be threaded or flanged or suitable for welded connection.
      3) Bridging sleeve over mechanical coupling.
      4) Factory-connected anode.
      5) Tracer wire connection.

6) Ultraviolet shield.
7) Stake supports with factory finish to match steel pipe casing or carrier pipe.

e. Plastic Mechanical Couplings, NPS 1-1/2 (DN 40) and Smaller: Capable of joining PE pipe to PE pipe.
1) PE body with molded-in, stainless-steel support ring.
2) Buna-nitrile seals.
3) Acetal collets.
4) Electro-zinc-plated steel stiffener.

f. Plastic Mechanical Couplings, NPS 2 (DN 50) and Larger: Capable of joining PE pipe to PE pipe, steel pipe to PE pipe, or steel pipe to steel pipe.
1) Fiber-reinforced plastic body.
2) PE body tube.
3) Buna-nitrile seals.
4) Acetal collets.
5) Stainless-steel bolts, nuts, and washers.

8. Steel Mechanical Couplings: Capable of joining plain-end PE pipe to PE pipe, steel pipe to PE pipe, or steel pipe to steel pipe.
1) Stainless-steel **OR** Steel, **as directed**, flanges and tube with epoxy finish.
2) Buna-nitrile seals.
3) Stainless-steel **OR** Steel, **as directed**, bolts, washers, and nuts.
4) Factory-installed anode for steel-body couplings installed underground.

B. Piping Specialties
1. Flexible Piping Joints:
a. Approved for LPG service.
b. Stainless-steel bellows with woven, flexible, bronze, wire-reinforcing protective jacket.
c. Minimum working pressure of 250 psig (1723 kPa) and 250 deg F (121 deg C) operating temperature.
d. Flanged- or threaded-end connections to match equipment connected and shall be capable of minimum 3/4-inch (20-mm) misalignment.
e. Maximum 36-inch (914-mm) length for liquid LPG lines.
2. Appliance Flexible Connectors:
a. Indoor, Fixed-Appliance Flexible Connectors: Comply with ANSI Z21.24.
b. Indoor, Movable-Appliance Flexible Connectors: Comply with ANSI Z21.69.
c. Outdoor, Appliance Flexible Connectors: Comply with ANSI Z21.75.
d. Corrugated stainless-steel tubing with polymer coating.
e. Operating-Pressure Rating: 0.5 psig (3.45 kPa).
f. End Fittings: Zinc-coated steel.
g. Threaded Ends: Comply with ASME B1.20.1.
h. Maximum Length: 72 inches (1830 mm).
3. Quick-Disconnect Devices: Comply with ANSI Z21.41.
a. Copper-alloy convenience outlet and matching plug connector.
b. Nitrile seals.
c. Hand operated with automatic shutoff when disconnected.
d. For indoor or outdoor applications.
e. Adjustable, retractable restraining cable.
4. Y-Pattern Strainers:
a. Body: ASTM A 126, Class B, cast iron with bolted cover and bottom drain connection.
b. End Connections: Threaded ends for NPS 2 (DN 50) and smaller; flanged ends for NPS 2-1/2 (DN 65) and larger.
c. Strainer Screen: 40 **OR** 60, **as directed**,-mesh startup strainer and perforated stainless-steel basket with 50 percent free area.
d. CWP Rating: 125 psig (862 kPa).
5. Basket Strainers:

a. Body: ASTM A 126, Class B, high-tensile cast iron with bolted cover and bottom drain connection.
b. End Connections: Threaded ends for NPS 2 (DN 50) and smaller; flanged ends for NPS 2-1/2 (DN 65) and larger.
c. Strainer Screen: 40 **OR** 60, **as directed**,-mesh startup strainer and perforated stainless-steel basket with 50 percent free area.
d. CWP Rating: 125 psig (862 kPa).

6. T-Pattern Strainers:
   a. Body: Ductile or malleable iron with removable access coupling and end cap for strainer maintenance.
   b. End Connections: Grooved ends.
   c. Strainer Screen: 40 **OR** 60, **as directed**,-mesh startup strainer and perforated stainless-steel basket with 57 percent free area.
   d. CWP Rating: 750 psig (5170 kPa).
7. Weatherproof Vent Cap: Cast- or malleable-iron increaser fitting with corrosion-resistant wire screen, with free area at least equal to cross-sectional area of connecting pipe and threaded-end connection.

C. Joining Materials
1. Joint Compound and Tape: Suitable for LPG.
2. Welding Filler Metals: Comply with AWS D10.12/D10.12M for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.
3. Brazing Filler Metals: Alloy with melting point greater than 1000 deg F (540 deg C) complying with AWS A5.8/A5.8M.

D. Manual Gas Shutoff Valves
1. See "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles for where each valve type is applied in various services.
2. Metallic Valves, NPS 2 (DN 50) and Smaller for Liquid Service: Comply with ASME B16.33 and UL 842.
   a. CWP Rating: 250 psig (1723 kPa).
   b. Threaded Ends: Comply with ASME B1.20.1.
   c. Socket ends for brazed joints.
   d. Tamperproof Feature: Locking feature for valves indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
   e. Listing by CSA or agency acceptable to authorities having jurisdiction for valves 1 inch (25 mm) and smaller.
   f. Valves 1-1/4 inch (32 mm) and larger shall be suitable for LPG service, with "WOG" indicated on valve body.
3. General Requirements for Metallic Valves, NPS 2 (DN 50) and Smaller for Vapor Service: Comply with ASME B16.33.
   a. CWP Rating: 125 psig (862 kPa).
   b. Threaded Ends: Comply with ASME B1.20.1.
   c. Dryseal Threads on Flare Ends: Comply with ASME B1.20.3.
   d. Tamperproof Feature: Locking feature for valves indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
   e. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction for valves 1 inch (25 mm) and smaller.
   f. Service Mark: Valves 1-1/4 inch (32 mm) to NPS 2 (DN 50) shall have initials "WOG" permanently marked on valve body.
4. General Requirements for Metallic Valves, NPS 2-1/2 (DN 65) and Larger: Comply with ASME B16.38.
   a. CWP Rating: 125 psig (862 kPa).
   b. Flanged Ends: Comply with ASME B16.5 for steel flanges.

c. Tamperproof Feature: Locking feature for valves indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
d. Service Mark: Initials "WOG" shall be permanently marked on valve body.

5. One-Piece, Bronze Ball Valve with Bronze Trim: MSS SP-110.
   a. Body: Bronze, complying with ASTM B 584.
   b. Ball: Chrome-plated brass.
   c. Stem: Bronze; blowout proof.
   d. Seats: Reinforced TFE; blowout proof.
   e. Packing: Separate packnut with adjustable-stem packing threaded ends.
   f. Ends: Threaded, flared, or socket as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
   g. CWP Rating: 600 psig (4143 kPa).
   h. Listing: Valves NPS 1 (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
   i. Service: Suitable for LPG service with "WOG" indicated on valve body.
6. Two-Piece, Full-Port, Bronze Ball Valves with Bronze Trim: MSS SP-110.
   a. Body: Bronze, complying with ASTM B 584.
   b. Ball: Chrome-plated bronze.
   c. Stem: Bronze; blowout proof.
   d. Seats: Reinforced TFE; blowout proof.
   e. Packing: Threaded-body packnut design with adjustable-stem packing.
   f. Ends: Threaded, flared, or socket as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
   g. CWP Rating: 600 psig (4143 kPa).
   h. Listing: Valves NPS 1 (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
   i. Service: Suitable for LPG service with "WOG" indicated on valve body.
7. Two-Piece, Regular-Port Bronze Ball Valves with Bronze Trim: MSS SP-110.
   a. Body: Bronze, complying with ASTM B 584.
   b. Ball: Chrome-plated bronze
   c. Stem: Bronze; blowout proof.
   d. Seats: Reinforced TFE.
   e. Packing: Threaded-body packnut design with adjustable-stem packing.
   f. Ends: Threaded, flared, or socket as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
   g. CWP Rating: 600 psig (4140 kPa).
   h. Listing: Valves NPS 1 (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
   i. Service: Suitable for LPG service with "WOG" indicated on valve body.
8. Bronze Plug Valves: MSS SP-78.
   a. Body: Bronze, complying with ASTM B 584.
   b. Plug: Bronze.
   c. Ends: Threaded, socket, or flanged as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
   d. Operator: Square head or lug type with tamperproof feature where indicated.
   e. Pressure Class: 125 psig (862 kPa).
   f. Listing: Valves NPS 1 (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
   g. Service: Suitable for LPG service with "WOG" indicated on valve body.
9. Cast-Iron, Nonlubricated Plug Valves: MSS SP-78.
   a. Body: Cast iron, complying with ASTM A 126, Class B.
   b. Plug: Bronze or nickel-plated cast iron.
   c. Seat: Coated with thermoplastic.
   d. Stem Seal: Compatible with LPG.
   e. Ends: Threaded or flanged as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.

f. Operator: Square head or lug type with tamperproof feature where indicated.
g. Pressure Class: 125 psig (862 kPa).
h. Listing: Valves NPS 1 (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
i. Service: Suitable for LPG service with "WOG" indicated on valve body.

10. Cast-Iron, Lubricated Plug Valves: MSS SP-78.
    a. Body: Cast iron, complying with ASTM A 126 Class B.
    b. Plug: Bronze or nickel-plated cast iron.
    c. Seat: Coated with thermoplastic.
    d. Stem Seal: Compatible with LPG.
    e. Ends: Threaded or flanged as indicated in "Underground Manual Gas Shutoff Valve Schedule" and "Aboveground Manual Gas Shutoff Valve Schedule" Articles.
    f. Operator: Square head or lug type with tamperproof feature where indicated.
    g. Pressure Class: 125 psig (862 kPa).
    h. Listing: Valves NPS 1 (DN 25) and smaller shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction.
    i. Service: Suitable for LPG service with "WOG" indicated on valve body.
11. PE Ball Valves: Comply with ASME B16.40.
    a. Body: PE.
    b. Ball: PE.
    c. Stem: Acetal.
    d. Seats and Seals: Nitrile.
    e. Ends: Plain or fusible to match piping.
    f. CWP Rating: 80 psig (552 kPa).
    g. Operating Temperature: Minus 20 to plus 140 deg F (Minus 29 to plus 60 deg C).
    h. Operator: Nut or flat head for key operation.
    i. Include plastic valve extension.
    j. Include tamperproof locking feature for valves where indicated on Drawings.
12. Valve Boxes:
    a. Cast-iron, two-section box.
    b. Top section with cover with "GAS" lettering.
    c. Bottom section with base to fit over valve and barrel a minimum of 5 inches (125 mm) in diameter.
    d. Adjustable cast-iron extensions of length required for depth of bury.
    e. Include tee-handle, steel operating wrench with socket end fitting valve nut or flat head and with stem of length required to operate valve.

E. Motorized Gas Valves
1. Hydrostatic Relief Valves: Comply with NFPA 58.
    a. Operating Pressure: 350 psig (2413 kPa).
    b. Body: Brass.
    c. Spring: Stainless steel.
    d. Disc and Seat: Nitrile.
    e. Brass body and stainless-steel, spring-operated valve with resilient rubber disc seat and protective cap.
    f. Factory set and tested.
    g. Listing: Valves listed and labeled by an NRTL acceptable to authorities having jurisdiction.
    h. Valve shall reseat after relieving pressure.
2. Automatic Gas Valves: Comply with ANSI Z21.21.
    a. Body: Brass or aluminum.
    b. Seats and Disc: Nitrile rubber.
    c. Springs and Valve Trim: Stainless steel.
    d. Normally closed.
    e. Visual position indicator.

f. Electrical **OR** Mechanical, **as directed**, operator for actuation by appliance automatic shutoff device.

3. Electrically Operated Valves: Comply with UL 429.
   a. Pilot operated.
   b. Body: Brass or aluminum.
   c. Seats and Disc: Nitrile rubber.
   d. Springs and Valve Trim: Stainless steel.
   e. 120-V ac, 60 Hz, Class B, continuous-duty molded coil, replaceable.
   f. NEMA ICS 6, Type 4, coil enclosure.
   g. Normally closed.
   h. Visual position indicator.

F. Earthquake Valves
1. Earthquake Valves: Comply with ASCE 25.
   a. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction.
   b. Maximum Operating Pressure: 5 psig (34.5 kPa).
   c. Cast-aluminum body with nickel-plated chrome steel internal parts.
   d. Nitrile-rubber valve washer.
   e. Sight windows for visual indication of valve position.
   f. Threaded-end connections complying with ASME B1.20.1.
2. Earthquake Valves: Comply with ASCE 25.
   a. Listing: Listed and labeled by an NRTL acceptable to authorities having jurisdiction.
   b. Maximum Operating Pressure: 0.5 psig (3.45 kPa) **OR** 7 psig (48 kPa) **OR** 60 psig (414 kPa), **as directed**.
   c. Cast-aluminum body with stainless-steel internal parts.
   d. Nitrile-rubber, reset-stem o-ring seal.
   e. Valve position, open or closed, indicator.
   f. Composition valve seat with clapper held by spring or magnet locking mechanism.
   g. Level indicator.
   h. End Connections: Threaded for valves NPS 2 (DN 50) and smaller; flanged for valves NPS 2-1/2 (DN 65) and larger.

G. Pressure Regulators
1. General Requirements:
   a. Single stage and suitable for LPG.
   b. Steel jacket and corrosion-resistant components.
   c. Elevation compensator.
   d. End Connections: Threaded for regulators NPS 2 (DN 50) and smaller; flanged for regulators NPS 2-1/2 (DN 65) and larger.
2. Service Pressure Regulators: Comply with ANSI Z21.80.
   a. Body and Diaphragm Case: Cast iron or die-cast aluminum.
   b. Springs: Zinc-plated steel; interchangeable.
   c. Diaphragm Plate: Zinc-plated steel.
   d. Seat Disc: Nitrile rubber resistant to gas impurities, abrasion, and deformation at the valve port.
   e. Orifice: Aluminum; interchangeable.
   f. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
   g. Single-port, self-contained regulator with orifice no larger than required at maximum pressure inlet and no pressure sensing piping external to the regulator.
   h. Pressure regulator shall maintain discharge pressure setting downstream and not exceed 150 percent of design discharge pressure at shutoff.
   i. Overpressure Protection Device: Factory mounted on pressure regulator.
   j. Atmospheric Vent: Factory- or field-installed, stainless-steel screen in opening if not connected to vent piping.
   k. Maximum Inlet Pressure: 100 psig (690 kPa).
3. Line Pressure Regulators: Comply with ANSI Z21.80.

a. Body and Diaphragm Case: Cast iron or die-cast aluminum.
b. Springs: Zinc-plated steel; interchangeable.
c. Diaphragm Plate: Zinc-plated steel.
d. Seat Disc: Nitrile rubber resistant to gas impurities, abrasion, and deformation at the valve port.
e. Orifice: Aluminum; interchangeable.
f. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
g. Single-port, self-contained regulator with orifice no larger than required at maximum pressure inlet and no pressure sensing piping external to the regulator.
h. Pressure regulator shall maintain discharge pressure setting downstream and not exceed 150 percent of design discharge pressure at shutoff.
i. Overpressure Protection Device: Factory mounted on pressure regulator.
j. Atmospheric Vent: Factory- or field-installed, stainless-steel screen in opening if not connected to vent piping.
k. Maximum Inlet Pressure: 2 psig (13.8 kPa) **OR** 5 psig (34.5 kPa) **OR** 10 psig (69 kPa), **as directed**.

4. Appliance Pressure Regulators: Comply with ANSI Z21.18.
   a. Body and Diaphragm Case: Die-cast aluminum.
   b. Springs: Zinc-plated steel; interchangeable.
   c. Diaphragm Plate: Zinc-plated steel.
   d. Seat Disc: Nitrile rubber.
   e. Seal Plug: Ultraviolet-stabilized, mineral-filled nylon.
   f. Factory-Applied Finish: Minimum three-layer polyester and polyurethane paint finish.
   g. Regulator may include vent limiting device, instead of vent connection, if approved by authorities having jurisdiction.
   h. Maximum Inlet Pressure: 1 psig (6.9 kPa) **OR** 2 psig (13.8 kPa) **OR** 5 psig (34.5 kPa-), **as directed**.

H. Service Meters
1. Diaphragm-Type Service Meters: Comply with ANSI B109.1 **OR** ANSI B109.2, **as directed**.
   a. Case: Die-cast aluminum.
   b. Connections: Steel threads.
   c. Diaphragm: Synthetic fabric.
   d. Diaphragm Support Bearings: Self-lubricating.
   e. Compensation: Continuous temperature and pressure, **as directed**.
   f. Meter Index: Cubic feet **OR** Liters **OR** Cubic feet and liters, **as directed**.
   g. Meter Case and Index: Tamper resistant.
   h. Remote meter reader compatible.
   i. Maximum Inlet Pressure: 100 psig (690 kPa).
   j. Pressure Loss: Maximum 0.5-inch wg (124 Pa) **OR** 2.0-inch wg (498 Pa), **as directed**.
   k. Accuracy: Maximum plus or minus 1.0 percent.
2. Rotary-Type Service Meters: Comply with ANSI B109.3.
   a. Case: Extruded aluminum.
   b. Connection: Flange.
   c. Impellers: Polished aluminum.
   d. Rotor Bearings: Self-lubricating.
   e. Compensation: Continuous temperature and pressure, **as directed**.
   f. Meter Index: Cubic feet **OR** Liters **OR** Cubic feet and liters, **as directed**.
   g. Tamper resistant.
   h. Remote meter reader compatible.
   i. Maximum Inlet Pressure: 100 psig (690 kPa).
   j. Accuracy: Maximum plus or minus 2.0 percent.
3. Turbine Meters: Comply with ASME MFC-4M.
   a. Housing: Cast iron or welded steel.
   b. Connection Threads or Flanges: Steel.

c. Turbine: Aluminum or plastic.
d. Turbine Bearings: Self-lubricating.
e. Compensation: Continuous temperature and pressure, **as directed**.
f. Meter Index: Cubic feet **OR** Liters **OR** Cubic feet and liters, **as directed**.
g. Tamper resistant.
h. Remote meter reader compatible.
i. Maximum Inlet Pressure: 100 psig (690 kPa).
j. Accuracy: Maximum plus or minus 2.0 percent.

4. Service-Meter Bars:
   a. Malleable- or cast-iron frame for supporting service meter.
   b. Include offset swivel pipes, meter nuts with o-ring seal, and factory- or field-installed dielectric unions.
   c. Omit meter offset swivel pipes if service-meter bar dimensions match service-meter connections.
5. Service-Meter Bypass Fittings:
   a. Ferrous, tee, pipe fitting with capped side inlet for temporary LPG supply.
   b. Integral ball-check bypass valve.

I. Dielectric Fittings
1. Dielectric Unions:
   a. Minimum Operating-Pressure Rating: 150 psig (1034 kPa).
   b. Combination fitting of copper alloy and ferrous materials.
   c. Insulating materials suitable for LPG.
   d. Combination fitting of copper alloy and ferrous materials with threaded, brazed-joint, plain, or welded end connections that match piping system materials.
2. Dielectric Flanges:
   a. Minimum Operating-Pressure Rating: 150 psig (1034 kPa).
   b. Combination fitting of copper alloy and ferrous materials.
   c. Insulating materials suitable for LPG.
   d. Combination fitting of copper alloy and ferrous materials with threaded, brazed-joint, plain, or welded end connections that match piping system materials.
3. Dielectric-Flange Kits:
   a. Minimum Operating-Pressure Rating: 150 psig (1034 kPa).
   b. Companion-flange assembly for field assembly.
   c. Include flanges, full-face- or ring-type neoprene or phenolic gasket, phenolic or PE bolt sleeves, phenolic washers, and steel backing washers.
   d. Insulating materials suitable for LPG.
   e. Combination fitting of copper alloy and ferrous materials with threaded, brazed-joint, plain, or welded end connections that match piping system materials.

J. Storage Containers
1. Description: Factory fabricated, complying with requirements in NFPA 58 and ASME Boiler and Pressure Vessel Code and bearing the ASME label. Tanks shall be rated for 250-psig (1723-kPa) minimum working pressure.
   a. Liquid outlet and vapor inlet and outlet connections shall have shutoff valves with excess-flow safety shutoff valves and bypass and back-pressure check valves with smaller than 0.039-inch (1-mm) drill-size hole to equalize pressure. Liquid-fill connection shall have backflow check valve.
      1) Connections: Color-code and tag valves to indicate type.
         a) Liquid fill and outlet, red.
         b) Vapor inlet and outlet, yellow.
   b. Level gage shall indicate current level of liquid in the container. Gages shall also indicate storage container contents; e.g., "Butane," "50-50 LPG Mix," or "Propane."
   c. Pressure relief valves, type and number as required by NFPA 58, connected to vapor space and having discharge piping same size as relief-valve outlet and long enough to extend at least 84 inches (2130 mm) directly overhead. Identify relief valves as follows:

1) Discharge pressure in psig (kPa).
2) Rate of discharge for standard air in cfm (L/s).
3) Manufacturer's name.
4) Catalog or model number.

d. Container pressure gage.
e. For outdoor installation, exposed metal surfaces mechanically cleaned, primed, and painted for resistance to corrosion.
f. Ladders for access to valves more than 72 inches (1830 mm) aboveground.
g. Stainless-Steel Nameplate: Attach to aboveground storage container or to adjacent structure for underground storage container.
1) Name and address of supplier or trade name of container.
2) Water capacity in gallons and liters.
3) Design pressure in psig (kPa).
4) Statement, "This container shall not contain a product having a vapor pressure in excess of <**Insert maximum pressure in psig (kPa) at 100 deg F (37.8 deg C)**>."
5) Outside surface area in sq. ft. (sq. m).
6) Year of manufacture.
7) Shell thickness in inches (mm).
8) Overall length in feet (m).
9) OD in feet (m).
10) Manufacturer's serial number.
11) ASME Code label.

h. Felt support pads and two concrete or painted-steel saddles per storage container. Corrosion protection required at container-to-felt contact.
i. Tie straps for each saddle.
j. Straps and anchors for tie-down slab.
k. Asphalt-based coating for corrosion protection.
l. Container connections and valves protected in manway at top of storage container.
m. Manway equipped with ventilation louvers.

K. Transport Truck Unloading Facility
1. Description: Comply with requirements in NFPA 58.
a. Support structure consisting of a minimum 6-inch (150-mm) steel channel or 6-by-4-inch (150-by-100-mm) rectangular steel tubing, a minimum of 36 inches (914 mm) above and below grade.
b. Liquid-fill and vapor-return, quick-disconnect fittings.
c. Liquid and vapor shutoff valves with hydrostatic relief valves mounted between the quick-disconnect fittings and shutoff valves.
d. Excess-flow safety shutoff valve in vapor-return line.
e. Backflow check valve in liquid-fill line.
f. Remote emergency shutoff valve station with underground cable to the vapor emergency shutoff valve.

L. Pumps
1. Description: Factory-assembled and -tested, duplex, positive-displacement, belt drive.
2. Pump Construction:
a. Casing: Ductile-iron casing with threaded gage tappings at inlet and outlet.
b. Internal Pressure Relief Valve: For pump protection in addition to the external pressure relief valves.
c. Impeller: Carbon or composite vane in cast-iron rotor.
d. Pump Shaft: Carbon steel.
e. Seal: Mechanical with Buna-N o-ring.
f. Pump Bearings: Ball bearings with grease fittings.
g. Baseplate: Bent carbon-steel channel or structural channel.

3. Motor: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
   b. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 22.
   c. Motor Speeds: Single.
   d. Bearings: Permanently lubricated **OR** Grease-lubricated, **as directed**, ball bearings.
   e. Class I, Division 1, Group D requirements per NFPA 70.
4. Factory-Installed Piping and Specialties:
   a. Pipe: ASTM A 53/A 53M, Type E or S, Grade B; Schedule 40 black steel with welded fittings and joints or Schedule 80 for threaded malleable-iron fittings and joints.
   b. Piping Specialties for Each Pump:
      1) Bypass valve.
      2) Isolation valves.
      3) Unions for each connection.
      4) Check valve.
      5) Basket strainer.
      6) Pressure gages for suction and discharge connections.
      7) Hydrostatic relief valve.
      8) Pilot-operated, pressure-regulating valve.
5. Braided-jacket flexible connectors for suction and discharge connections.
6. Pump and Piping Finish: For outdoor installation, exposed metal surfaces mechanically cleaned, primed, and painted for resistance to corrosion.
7. Controls:
   a. Explosion-proof controls enclosure.
   b. Magnetic starter package with automatic alternator.
   c. Pressure-activated start and stop.
   d. Lag pump starts if lead pump fails.
   e. Audible and visual indication of pump failure.

M. Vaporizers
1. Description: Factory-fabricated, -assembled, and -tested vaporizer with heat exchanger sealed pressure-tight, built on a steel base; including insulated jacket, flue-gas vent, liquid fuel supply and vapor connections, and controls. Assembly shall be FMG labeled and comply with NFPA 58 and NFPA 70.
2. Fabricate base and attachment to vaporizers with reinforcement strong enough to resist vaporizer movement during a seismic event when steel base is anchored to a concrete base.
3. Casing:
   a. Mineral-fiber insulation, a minimum of 2 inches (50 mm) thick, surrounding the heat exchanger.
   b. Integral one-piece skid with forklift access holes.
   c. Lifting lugs on top of vaporizer.
   d. Flue rain cap and bird screen.
   e. Sheet metal jacket with screw-fastened closures and baked-enamel **OR** powder-coat, **as directed**, protective finish.
   f. Mounting base to secure boiler to concrete base.
   g. Control Compartment Enclosure: NEMA 250, Type 4, enclosure housing control panels for LPG-fired vaporizers. Explosion-proof control compartment construction required for electric vaporizers.
4. LPG Liquid and Vapor Circuit Specialties:
   a. Y-type strainer with drain valve at inlet.
   b. Vaporizer coil safety pressure relief valve.
   c. Vaporizer coil blowdown valve.
   d. Vapor outlet isolation valve.

e. Pressure gages, a minimum of 2-1/2 inches (63 mm) in diameter, at liquid inlet and vapor discharge. Gages shall have operating-temperature ranges so normal operating range is at approximately 50 percent of full range.
f. Inlet safety solenoid valve to close with off-normal operation alarm.
g. Backflow check valve in bypass around inlet safety solenoid valve.
h. Liquid carryover or float-type safety shutoff switch.
i. LPG Vapor Filter: Steel shell designed and manufactured per ASME Boiler and Pressure Vessel Code, Section VIII, Division 1; factory mounted on vaporizer discharge. Shells larger than 5 inches (125 mm) shall be ASME "U" stamped. Fill with stainless-steel, woven-mesh coalescing element to remove 99 percent of particles larger than 10 microns. 250-psig (1723-kPa) minimum working pressure. Finish with corrosion-resistant coating for an exterior application. Include factory-mounted and -piped, differential pressure gage with gage cocks in and out, and minimum NPS 3/4 (DN 20) full-port, ball-type drain valve.

5. Direct-Type, Direct-Fired Heat Exchanger:
   a. Description: ASME-rated and -stamped, LPG, vaporizer coil contained in an enclosure insulated with at least 2-inch- (50-mm-) thick, mineral-fiber board enclosure with a burner.
   b. Burner Tubes and Orifices: Stainless steel.
      1) Gas Train: Control devices and burner control sequence shall be FMG labeled. Include shutoff valve, high- and low-pressure safety switches, pressure regulator, and main- and pilot-control valves.
      2) Pilot: Standing pilot with 100 percent main-valve and pilot safety shutoff.
   c. Burner Operating Controls:
      1) Controls shall maintain safe operating conditions. Mechanical burner safety controls limit operation of the burner.
      2) High-Pressure Cutoff: Manual reset stops burner if operating conditions rise above maximum design pressure.
      3) Operating Vapor-Pressure Control: Factory piped and mounted to control burner.
6. Indirect-Type, Direct-Fired Heat Exchanger:
   a. Description: ASME-rated and -stamped, LPG, vaporizer vessel with a replaceable, immersion-type, electric heating element.
   b. Heating Element Operating Controls:
      1) Operating controls shall maintain safe operating conditions. Safety controls limit operation of the element. Microprocessor-based control system integrates safety and operating controls, **as directed**.
      2) Operating Vapor-Pressure Control: Factory wired and mounted to control heating element.
      3) High-Pressure Cutoff: Manual reset stops burner if operating conditions rise above maximum design pressure.
      4) Alarm Bell and Rotary Beacon: Factory mounted on control panel with silence switch; shall sound alarm for out-of-normal conditions.
      5) Control Transformer: 115-V maximum control voltage.
7. Direct-Type, Water-Bath Heat Exchanger:
   a. Description: Straight, steel fire tubes welded into steel headers with ASME-rated and -stamped, helical, LPG, vaporizer coil submerged in water bath. Include the following:
      1) Water bath filled with water/glycol solution designed to prevent freezing at minus 30 deg F (minus 34 deg C).
      2) Water-bath, high- and low-level sight glasses.
      3) Low-water cutoff to stop burner and annunciate alarm.
      4) Water/glycol fill and vent fitting.
      5) Minimum NPS 3/4 (DN 20) hose-end drain valves.
      6) Operating high- and low-limit aquastat controllers.
      7) Water-bath temperature gage; a minimum of 2-1/2 inches (63 mm) in diameter. Gages shall have operating-temperature ranges so normal operating range is at approximately 50 percent of full range.
   b. Burner Tubes and Orifices: Stainless steel.

1) Gas Train: Control devices and burner modulation control sequence shall be FMG labeled. Include shutoff valve, high- and low-pressure safety switches, pressure regulator, and main- and pilot-control valves.
2) Pilot: Intermittent-electric-spark **OR** Hot-surface, **as directed**, pilot ignition with 100 percent main-valve and pilot safety shutoff with electronic supervision of burner flame.

c. Burner Operating Controls:
1) Operating controls shall maintain safe operating conditions. Safety controls limit operation of the burner. Microprocessor-based control system integrates safety and operating controls, **as directed**.
2) Operating Water-Bath Temperature Control: Factory wired and mounted to control burner.
3) High-Temperature and High-Pressure Cutoff: Manual reset stops burner if operating conditions rise above maximum design temperature or vapor pressure.
4) Alarm Bell and Rotary Beacon: Factory mounted on control panel with silence switch; shall sound alarm for out-of-normal conditions.
5) Control Transformer: 115-V maximum control voltage.

8. Indirect-Type, Water-Bath Heat Exchanger:
a. Description: Immersion-type, electric heating element with ASME-rated and -stamped, helical, LPG, vaporizer coil submerged in water bath. Include the following:
1) Water bath filled with water/glycol solution designed to prevent freezing at minus 30 deg F (minus 34 deg C).
2) Water-bath, high- and low-level sight glasses.
3) Low-water cutoff to stop electric heater and annunciate alarm.
4) Water/glycol fill and vent fitting.
5) Minimum NPS 3/4 (DN 20) hose-end drain valves.
6) Operating high- and low-limit aquastat controllers.
7) Water-bath temperature gage; a minimum of 2-1/2 inches (63 mm) in diameter. Gages shall have operating-temperature ranges so normal operating range is at approximately 50 percent of full range.

b. Electric Heater Operating Controls:
1) Controls shall maintain safe operating conditions. Safety controls limit operation of the electric element. Microprocessor-based control system integrates safety and operating controls, **as directed**.
2) Operating Water-Bath Temperature Control: Factory wired and mounted to control burner.
3) High-Temperature and High-Pressure Cutoff: Manual reset stops burner if operating conditions rise above maximum design temperature or pressure.
4) Alarm Bell and Rotary Beacon: Factory mounted on control panel with silence switch; shall sound alarm for out-of-normal conditions.
5) Control Transformer: 115-V maximum control voltage.

9. Building Management System Interface: Factory-installed hardware and software to enable building management system to monitor and control set points and display vaporizer status and alarms.

N. Air Mixers
1. Description: Factory-fabricated, -assembled, -calibrated, and -tested, blower-assisted, **as directed**, air mixer with surge tank, built on a steel base; including vapor supply and discharge connections, and controls. Assembly shall be FMG labeled and comply with NFPA 58 and NFPA 70.
2. Fabricate base and attachment to mixers with reinforcement strong enough to resist air mixer movement during a seismic event when steel base is anchored to a concrete base.
3. Mounting Skid, Panels, and Surge Tank:
a. Integral one-piece skid with forklift access holes.
b. Lifting lugs on top of air mixer.
c. Baked-enamel **OR** Powder-coat, **as directed**, protective finish.

d. Mounting base to secure boiler to concrete base.
e. Control Compartment Enclosure: NEMA 250, Type 4, enclosure housing control panels.
f. ASME-stamped surge tank with venturi, isolation valves, excess-flow safeties, and safety relief valves.

4. Blower: Positive-displacement, rotary-lobe type.
   a. Motor: Single speed, with permanently lubricated **OR** grease-lubricated, **as directed**, ball bearings. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
5. LPG Circuit Specialties:
   a. Venturi solenoid valves.
   b. Venturi nozzles, minimum of 3, for minimum of 10:1 turndown capacity.
   c. Venturi silencers.
   d. Mist filter and strainer with pressure differential gage, and blowdown ball valve.
   e. Inlet and outlet isolation valves.
   f. Pressure gages, a minimum of 2-1/2 inches (63 mm) in diameter, at inlet and discharge. Gages shall have operating-temperature ranges so normal operating range is at approximately 50 percent of full range.
6. Air-Mixer Controls:
   a. Controls shall maintain safe operating conditions. The following safety controls limit the operation of the air mixer. All safety controls are manual reset.
      1) Low-inlet-vapor pressure.
      2) High- or low-discharge pressure.
   b. Alarm Bell and Rotary Beacon: Factory mounted on control panel with silence switch; shall sound alarm for out-of-normal conditions.
   c. Control Transformer: 115-V maximum control voltage.
7. Mount on common skid with vaporizer.

O. Sleeves
1. Steel Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, galvanized steel, plain ends.
2. Cast-Iron Pipe Sleeves: Cast or fabricated "wall pipe," equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop, unless otherwise indicated.

P. Mechanical Sleeve Seals
1. Description: Modular sealing element unit, designed for field assembly, to fill annular space between pipe and sleeve.
   a. Sealing Elements: EPDM **OR** NBR, **as directed**, interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe and sleeve.
   b. Pressure Plates: Plastic **OR** Carbon steel **OR** Stainless steel, **as directed**.
   c. Connecting Bolts and Nuts: Carbon steel with corrosion-resistant coating **OR** Stainless steel, **as directed**, of length required to secure pressure plates to sealing elements. Include one nut and bolt for each sealing element.

Q. Escutcheons
1. General Requirements for Escutcheons: Manufactured wall and ceiling escutcheons and floor plates, with ID to fit around pipe or tube, and OD that completely covers opening.
2. One-Piece, Deep-Pattern Escutcheons: Deep-drawn brass with polished chrome-plated finish.
3. One-Piece, Cast-Brass Escutcheons: With set screw.
   a. Finish: Polished chrome-plated **OR** Rough brass, **as directed**.
4. Split-Casting, Cast-Brass Escutcheons: With concealed hinge and set screw.
   a. Finish: Polished chrome-plated **OR** Rough brass, **as directed**.
5. One-Piece, Stamped-Steel Escutcheons: With set screw **OR** spring clips, **as directed**, and chrome-plated finish.
6. Split-Plate, Stamped-Steel Escutcheons: With concealed **OR** exposed-rivet, **as directed**, hinge, set screw **OR** spring clips, **as directed**, and chrome-plated finish.

7. One-Piece, Floor-Plate Escutcheons: Cast-iron floor plate.
8. Split-Casting, Floor-Plate Escutcheons: Cast brass with concealed hinge and set screw.

R. Grout
1. Description: ASTM C 1107, Grade B, nonshrink and nonmetallic, dry hydraulic-cement grout.
   a. Characteristics: Post-hardening, volume adjusting, nonstaining, noncorrosive, nongaseous, and recommended for interior and exterior applications.
   b. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.
   c. Packaging: Premixed and factory packaged.

S. Labeling And Identifying
1. Detectable Warning Tape: Acid- and alkali-resistant PE film warning tape manufactured for marking and identifying underground utilities, a minimum of 6 inches (150 mm) wide and 4 mils (0.1 mm) thick, continuously inscribed with a description of utility, with metallic core encased in a protective jacket for corrosion protection, detectable by metal detector when tape is buried up to 30 inches (750 mm) deep; colored yellow.

1.3 EXECUTION

A. Earthwork
1. Comply with requirements in Division 31 Section "Earth Moving" for excavating, trenching, and backfilling.

B. Preparation
1. Close equipment shutoff valves before turning off LPG to premises or piping section.
2. Inspect LPG piping according to NFPA 58 and NFPA 54 **OR** the International Fuel Gas Code, **as directed**, to determine that LPG utilization devices are turned off in piping section affected.
3. Comply with NFPA 58 and NFPA 54 **OR** the International Fuel Gas Code, **as directed**, requirements for prevention of accidental ignition.

C. Outdoor Piping Installation
1. Comply with NFPA 58 and NFPA 54 **OR** the International Fuel Gas Code, **as directed**, requirements for installation and purging of LPG piping.
2. Install underground, LPG piping buried at least 36 inches (900 mm) below finished grade. Comply with requirements in Division 31 Section "Earth Moving" for excavating, trenching, and backfilling.
   a. If LPG piping is installed less than 36 inches (914 mm) below finished grade, install it in containment conduit.
3. Install underground, PE, LPG piping according to ASTM D 2774.
4. Steel Piping with Protective Coating:
   a. Apply joint cover kits to pipe after joining to cover, seal, and protect joints.
   b. Repair damage to PE coating on pipe as recommended in writing by protective coating manufacturer.
      OR
      Replace pipe having damaged PE coating with new pipe.
5. Copper Tubing with Protective Coating:
   a. Apply joint cover kits over tubing to cover, seal, and protect joints.
   b. Repair damage to PE coating on pipe as recommended in writing by protective coating manufacturer.
6. Install fittings for changes in direction and branch connections.
7. Joints for connection to inlets and outlets on vaporizers, air mixers, regulators, and valves may be flanged or threaded to match the equipment.
8. Aboveground, Exterior-Wall Pipe Penetrations: Seal penetrations using sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch (25-mm) annular clear space between pipe and sleeve for installing mechanical sleeve seals.

a. Install steel pipe for sleeves smaller than 6 inches (150 mm) in diameter.
b. Install cast-iron "wall pipes" for sleeves 6 inches (150 mm) and larger in diameter.

9. Underground, Exterior-Wall Pipe Penetrations: Install cast-iron "wall pipes" for sleeves. Seal pipe penetrations using mechanical sleeve seals. Select sleeve size to allow for 1-inch (25-mm) annular clear space between pipe and sleeve for installing mechanical sleeve seals.
10. Mechanical Sleeve Seal Installation: Select type and number of sealing elements required for pipe material and size. Position pipe in center of sleeve. Assemble mechanical sleeve seals and install in annular space between pipe and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.
11. Install pressure gage downstream **OR** upstream and downstream, **as directed**, from each service regulator. Pressure gages are specified in Division 23 Section "Meters And Gages For Hvac Piping".

D. Indoor Piping Installation

1. Comply with NFPA 54 **OR** the International Fuel Gas Code, **as directed**, for installation and purging of LPG piping.
2. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.
3. Arrange for pipe spaces, chases, slots, sleeves, and openings in building structure during progress of construction, to allow for mechanical installations.
4. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.
5. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
6. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
7. Locate valves for easy access.
8. Install LPG piping at uniform grade of 2 percent down toward drip and sediment traps.
9. Install piping free of sags and bends.
10. Install fittings for changes in direction and branch connections.
11. Install escutcheons for penetrations of interior walls, ceilings, and floors.
    a. New Piping:
        1) Piping with Fitting or Sleeve Protruding from Wall: One-piece, deep-pattern type.
        2) Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, cast-brass type with polished chrome-plated finish.
           OR
           Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, stamped-steel type.
        3) Piping at Ceiling Penetrations in Finished Spaces: One-piece **OR** Split-casting, **as directed**, cast-brass type with polished chrome-plated finish.
           OR
           Piping at Ceiling Penetrations in Finished Spaces: One-piece, stamped-steel type **OR** Split-plate, stamped-steel type with concealed hinge, **as directed**, and set screw.
        4) Piping in Unfinished Service Spaces: One-piece, cast-brass type with polished chrome-plated **OR** rough-brass, **as directed**, finish.
           OR
           Piping in Unfinished Service Spaces: One-piece, stamped-steel type with set screw **OR** spring clips, **as directed**.
        5) Piping in Equipment Rooms: One-piece, cast-brass type.
           OR
           Piping in Equipment Rooms: One-piece, stamped-steel type with set screw **OR** spring clips, **as directed**.

6) Piping at Floor Penetrations in Equipment Rooms: One-piece, floor-plate type.

b. Existing Piping:

1) Piping at Wall and Floor Penetrations in Finished Spaces: Split-casting, cast-brass type with chrome-plated finish.

OR

Piping at Wall and Floor Penetrations in Finished Spaces: Split-plate, stamped-steel type with concealed hinge and spring clips.

2) Piping at Ceiling Penetrations in Finished Spaces: Split-casting, cast-brass type with chrome-plated finish.

OR

Piping at Ceiling Penetrations in Finished Spaces: Split-plate, stamped-steel type with concealed hinge and set screw.

3) Piping in Unfinished Service Spaces: Split-casting, cast-brass type with polished chrome-plated **OR** rough-brass, **as directed**, finish.

OR

Piping in Unfinished Service Spaces: Split-plate, stamped-steel type with concealed **OR** exposed-rivet, **as directed**, hinge and set screw or spring clips.

4) Piping in Equipment Rooms: Split-casting, cast-brass type.

OR

Piping in Equipment Rooms: Split-plate, stamped-steel type with set screw or spring clips.

5) Piping at Floor Penetrations in Equipment Rooms: Split-casting, floor-plate type.

12. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with requirements in Division 07 Section "Penetration Firestopping" for materials.
13. Verify final equipment locations for roughing-in.
14. Comply with requirements in Sections specifying gas-fired appliances and equipment for roughing-in requirements.
15. Drips and Sediment Traps: Install drips at points where condensate may collect, including service-meter outlets. Locate where readily accessible to permit cleaning and emptying. Do not install where condensate is subject to freezing.
    a. Construct drips and sediment traps using tee fitting with bottom outlet plugged or capped. Use nipple a minimum length of 3 pipe diameters, but not less than 3 inches (75 mm) long and same size as connected pipe. Install with space below bottom of drip to remove plug or cap.
16. Extend relief vent connections for service regulators, line regulators, and overpressure protection devices to outdoors and terminate with weatherproof vent cap.
17. Conceal pipe installations in walls, pipe spaces, utility spaces, above ceilings, below grade or floors, and in floor channels unless indicated to be exposed to view.
18. Concealed Location Installations: Except as specified below, install concealed LPG piping and piping installed under the building in containment conduit constructed of steel pipe with welded joints as described in Part 2. Install a vent pipe from containment conduit to outdoors and terminate with weatherproof vent cap.
    a. Above Accessible Ceilings: LPG piping, fittings, valves, and regulators may be installed in accessible spaces without containment conduit.
    b. In Floors: Install LPG piping with welded or brazed joints and protective coating in cast-in-place concrete floors. Cover piping to be cast in concrete slabs with minimum of 1-1/2 inches (38 mm) of concrete. Piping may not be in physical contact with other metallic structures such as reinforcing rods or electrically neutral conductors. Do not embed piping in concrete slabs containing quick-set additives or cinder aggregate.
    c. In Floor Channels: Install LPG piping in floor channels. Channels must have cover and be open to space above cover for ventilation.
    d. In Walls or Partitions: Protect tubing installed inside partitions or hollow walls from physical damage using steel striker barriers at rigid supports.
        1) Exception: Tubing passing through partitions or walls does not require striker barriers.

e. Prohibited Locations:
   1) Do not install LPG piping in or through circulating air ducts, clothes or trash chutes, chimneys or gas vents (flues), ventilating ducts, or dumbwaiter or elevator shafts.
   2) Do not install LPG piping in solid walls or partitions.

19. Use eccentric reducer fittings to make reductions in pipe sizes. Install fittings with level side down.
20. Connect branch piping from top or side of horizontal piping.
21. Install unions in pipes NPS 2 (DN 50) and smaller, adjacent to each valve, at final connection to each piece of equipment. Unions are not required at flanged connections.
22. Do not use LPG piping as grounding electrode.
23. Install strainer on inlet of each line-pressure regulator and automatic or electrically operated valve.
24. Install pressure gage downstream **OR** upstream and downstream, **as directed**, from each line regulator. Pressure gages are specified in Division 23 Section "Meters And Gages For Hvac Piping".

E. Service-Meter Assembly Installation
1. Install service-meter assemblies aboveground, on concrete bases, **as directed**.
2. Install metal shutoff valves upstream from service regulators. Shutoff valves are not required at second regulators if two regulators are installed in series.
3. Install strainer on inlet of service-pressure regulator and meter set.
4. Install service regulators mounted outside with vent outlet horizontal or facing down. Install screen in vent outlet if not integral with service regulator.
5. Install metal shutoff valves upstream from service meters. Install dielectric fittings downstream from service meters.
6. Install service meters downstream from pressure regulators.
7. Install metal bollards to protect meter assemblies. Comply with requirements in Division 05 Section "Metal Fabrications" for pipe bollards.

F. Valve Installation
1. Install manual gas shutoff valve for each gas appliance ahead of corrugated stainless-steel tubing, aluminum, or copper connector.
2. Install underground valves with valve boxes.
3. Install regulators and overpressure protection devices with maintenance access space adequate for servicing and testing.
4. Install earthquake valves aboveground outside buildings according to listing.
5. Install anode for metallic valves in underground PE piping.

G. Piping Joint Construction
1. Ream ends of pipes and tubes and remove burrs.
2. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
3. Threaded Joints:
   a. Thread pipe with tapered pipe threads complying with ASME B1.20.1.
   b. Cut threads full and clean using sharp dies.
   c. Ream threaded pipe ends to remove burrs and restore full ID of pipe.
   d. Apply appropriate tape or thread compound to external pipe threads unless dryseal threading is specified.
   e. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
4. Welded Joints:
   a. Construct joints according to AWS D10.12/D10.12M, using qualified processes and welding operators.
   b. Bevel plain ends of steel pipe.
   c. Patch factory-applied protective coating as recommended by manufacturer at field welds and where damage to coating occurs during construction.

5. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," Ch. 22, "Pipe and Tube."
6. Flanged Joints: Install gasket material, size, type, and thickness appropriate for LPG service. Install gasket concentrically positioned.
7. Flared Joints: Cut tubing with roll cutting tool. Flare tube end with tool to result in flare dimensions complying with SAE J513. Tighten finger tight, then use wrench. Do not overtighten.
8. PE Piping Heat-Fusion Joints: Clean and dry joining surfaces by wiping with clean cloth or paper towels. Join according to ASTM D 2657.
   a. Plain-End Pipe and Fittings: Use butt fusion.
   b. Plain-End Pipe and Socket Fittings: Use socket fusion.

H. Hanger And Support Installation
1. Install seismic restraints on piping. Comply with requirements for seismic-restraint devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
2. Comply with requirements for pipe hangers and supports specified in Division 23 Section "Hangers And Supports For Hvac Piping And Equipment".
3. Install hangers for horizontal steel piping with the following maximum spacing and minimum rod sizes:
   a. NPS 1 (DN 25) and Smaller: Maximum span, 96 inches (2438 mm); minimum rod size, 3/8 inch (10 mm).
   b. NPS 1-1/4 (DN 32): Maximum span, 108 inches (2743 mm); minimum rod size, 3/8 inch (10 mm).
   c. NPS 1-1/2 and NPS 2 (DN 40 and DN 50): Maximum span, 108 inches (2743 mm); minimum rod size, 3/8 inch (10 mm).
   d. NPS 2-1/2 to NPS 3-1/2 (DN 65 to DN 90): Maximum span, 10 feet (3 m); minimum rod size, 1/2 inch (13 mm).
   e. NPS 4 (DN 100) and Larger: Maximum span, 10 feet (3 m); minimum rod size, 5/8 inch (16 mm).
4. Install hangers for horizontal, drawn-temper copper tubing with the following maximum spacing and minimum rod sizes:
   a. NPS 3/8 (DN 10): Maximum span, 48 inches (1220 mm); minimum rod size, 3/8 inch (10 mm).
   b. NPS 1/2 and NPS 5/8 (DN 15 and DN 18): Maximum span, 72 inches (1830 mm); minimum rod size, 3/8 inch (10 mm).
   c. NPS 3/4 and NPS 7/8 (DN 20 and DN 22): Maximum span, 84 inches (2134 mm); minimum rod size, 3/8 inch (10 mm).
   d. NPS 1 (DN 25): Maximum span, 96 inches (2440 mm); minimum rod size, 3/8 inch (10 mm).
5. Install hangers for horizontal, corrugated stainless-steel tubing with the following maximum spacing and minimum rod sizes:
   a. NPS 3/8 (DN 10): Maximum span, 48 inches (1220 mm); minimum rod size, 3/8 inch (10 mm).
   b. NPS 1/2 (DN 15): Maximum span, 72 inches (1830 mm); minimum rod size, 3/8 inch (10 mm).
   c. NPS 3/4 (DN 20) and Larger: Maximum span, 96 inches (2440 mm); minimum rod, 3/8 inch (10 mm).

I. Connections
1. Connect to utility's gas main according to utility's procedures and requirements.
2. Install LPG piping electrically continuous, and bonded to gas appliance equipment grounding conductor of the circuit powering the appliance according to NFPA 70.
3. Install piping adjacent to appliances to allow service and maintenance of appliances.
4. Connect piping to appliances using manual gas shutoff valves and unions. Install valve within 72 inches (1830 mm) of each gas-fired appliances and equipment. Install union between valve and appliances or equipment.

5. Sediment Traps: Install tee fitting with capped nipple in bottom to form drip, as close as practical to inlet of each appliance.

J. Transport Truck Unloading Facility
1. Install transport truck unloading in a cast-in-place concrete base, 48 inches (1220 mm) square by 36 inches (914 mm) deep. Set top of concrete base at least 6 inches (150 mm) above finished grade.
2. Install remote emergency shutoff station with cable release in an accessible location, a minimum of 25 feet (7.6 m) and a maximum of 100 feet (30 m) away from transport truck unloading.
3. Install at least two 6-inch- (150-mm-) diameter metal bollards set in and filled with concrete on both sides of transport truck unloading. Bollard length shall be at least 48 inches (1220 mm) above and below grade, with concrete encasement a minimum of 12 inches (305 mm) in diameter.

K. Storage Container Installation
1. Fill storage container to at least 80 percent capacity with butane **OR** propane, **as directed**.
2. Install piping connections with swing joints or flexible connectors to allow for storage container settlement and for thermal expansion and contraction.
3. Ground containers according to NFPA 780. Grounding is specified in Division 26 Section "Lightning Protection For Structures".
4. Set storage containers in felt pads on concrete or steel saddles. Install corrosion protection at container-to-felt contact.
5. Install tie-downs over storage containers on saddles with proper tension.
6. Set concrete saddles on dowels set in concrete base. Anchor steel saddles to concrete base.
7. Set storage container on concrete ballast base large enough to offset buoyancy of empty storage container immersed in water.
8. Install tie-down straps over container anchored in ballast base and repair damaged coating.
9. Backfill with a minimum coverage for underground or mounded storage containers according to NFPA 58.
10. Backfill with pea gravel as required in Division 31 Section "Earth Moving".
11. Install cathodic protection for storage container. Cathodic protection is specified in Division 26 Section "Cathodic Protection".

L. Pump Installation
1. Install pumps with access space for periodic maintenance including removal of motors, impellers, and accessories.
2. Set pumps on and anchored to concrete base.
3. Install suction piping with minimum fittings and change of direction.
4. Connect liquid suction to container, supply to vaporizer, and return line to container.

M. Vaporizer Installation
1. Install vaporizer with access space for periodic maintenance.
2. Set vaporizers on and anchor to concrete base.
3. Connect liquid line from pump set, and vapor supply to distribution piping.
4. Install backup connection from vapor space of container to inlet of pressure-regulating valve at vaporizer discharge to bypass the vaporizer during maintenance. Install shutoff valves to change source from vaporizer to storage container.

N. Air Mixer With Vaporizer Installation
1. Install air mixer with vaporizer with access space for periodic maintenance.
2. Set air mixer with vaporizer on and anchor to concrete base.
3. Connect liquid line from pump set, and mixed gas supply to distribution piping.
4. Install backup connection from vapor space of container to inlet of pressure-regulating valve at vaporizer discharge to bypass vaporizer during maintenance. Install shutoff valves to change source from vaporizer to storage container.

5. Replace filters at Final Completion if air mixer was operated during construction.

O. Labeling And Identifying
1. Comply with requirements in Division 23 Section "Identification For Hvac Piping And Equipment" for piping and valve identification.
OR
Install detectable warning tape directly above gas piping, 12 inches (305 mm) below finished grade, except 6 inches (150 mm) below subgrade under pavements and slabs.

P. Painting
1. Comply with requirements in Division 07 for painting interior and exterior LPG piping.
2. Paint exposed, exterior metal piping, valves, service regulators, service meters and meter bars, earthquake valves, and piping specialties, except components with factory-applied paint or protective coating.
   a. Alkyd System: MPI EXT 5.1D.
      1) Prime Coat: Alkyd anticorrosive metal primer.
      2) Intermediate Coat (for a Premium Grade system): Exterior alkyd enamel matching topcoat.
      3) Topcoat: Exterior alkyd enamel (flat) **OR** (semigloss) **OR** (gloss), **as directed**.
      4) Color: Gray, **unless directed otherwise**.
3. Paint exposed, interior metal piping, valves, service regulators, service meters and meter bars, earthquake valves, and piping specialties, except components with factory-applied paint or protective coating.
   a. Latex Over Alkyd Primer System: MPI INT 5.1Q.
      1) Prime Coat: Alkyd anticorrosive **OR** Quick-drying alkyd, **as directed**, metal primer.
      2) Intermediate Coat (for a Premium Grade system): Interior latex matching topcoat.
      3) Topcoat: Interior latex (flat) **OR** (low sheen) **OR** (eggshell) **OR** (satin) **OR** (semigloss) **OR** (gloss), **as directed**.
      4) Color: Gray, **unless directed otherwise**.
   b. Alkyd System: MPI INT 5.1E.
      1) Prime Coat: Alkyd anticorrosive **OR** Quick-drying alkyd, **as directed**, metal primer.
      2) Intermediate Coat (for a Premium Grade system): Interior alkyd matching topcoat.
      3) Topcoat: Interior alkyd (flat) **OR** (eggshell) **OR** (semigloss) **OR** (gloss), **as directed**.
      4) Color: Gray, **unless directed otherwise**.
4. Damage and Touchup: Repair marred and damaged factory-applied finishes with materials and by procedures to match original factory finish.

Q. Concrete Bases
1. Concrete Bases: Anchor equipment to concrete base according to seismic codes at Project.
   a. Construct concrete bases of dimensions indicated, but not less than 4 inches (100 mm) larger in both directions than supported unit.
   b. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (451-mm) centers around the full perimeter of the base.
   c. Install epoxy-coated anchor bolts for supported equipment that extend through concrete base, and anchor into structural concrete floor.
   d. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   e. Install anchor bolts to elevations required for proper attachment to supported equipment.
   f. Use 3000-psig (20.7-MPa), **unless directed otherwise**, 28-day, compressive-strength concrete and reinforcement as specified in Division 03 Section "Cast-in-place Concrete".

R. Field Quality Control
1. Perform tests and inspections.
2. Tests and Inspections:

a. Test, inspect, and purge LPG according to NFPA 58 and NFPA 54 **OR** the International Fuel Gas Code, **as directed**, and requirements of authorities having jurisdiction.

3. LPG piping will be considered defective if it does not pass tests and inspections.
4. Prepare test and inspection reports.

S. Outdoor Piping Schedule

1. Underground LPG liquid piping shall be one of the following:
   a. Schedule 40 steel pipe with wrought-steel fittings and welded joints, or mechanical couplings. Coat pipe and fittings with protective coating for steel piping.
   b. Annealed **OR** Drawn, **as directed**,-temper copper tube, Type K (Type A) **OR** Type L (Type B), **as directed**, with wrought-copper fittings and brazed joints. Coat pipe and fittings with protective coating for copper tubing.
2. Aboveground LPG liquid piping shall be one of the following:
   a. NPS 2 (DN 50) and Smaller: Schedule 40 **OR** Schedule 80, **as directed**, steel pipe, malleable-iron threaded fittings and threaded and seal welded, **as directed**, joints. Coat pipe and fittings with protective coating for steel piping.
   b. NPS 2-1/2 (DN 65) and Larger: Schedule 40, steel pipe with wrought-steel fittings and welded joints, or mechanical couplings. Coat pipe and fittings with protective coating for steel piping.
   c. Annealed **OR** Drawn, **as directed**,-temper copper tube, Type L (Type B), with wrought-copper fittings and brazed joints. Coat pipe and fittings with protective coating for copper tubing.
3. Underground LPG vapor piping shall be one of the following:
   a. PE pipe and fittings joined by heat-fusion, or mechanical couplings; service-line risers with tracer wire terminated in an accessible location.
   b. Schedule 40, steel pipe with wrought-steel fittings and welded joints, or mechanical couplings. Coat pipe and fittings with protective coating for steel piping.
   c. Annealed **OR** Drawn, **as directed**,-temper copper tube, Type L (Type B) with wrought-copper fittings and brazed joints. Coat pipe and fittings with protective coating for copper tubing.
4. Aboveground LPG vapor piping shall be one of the following:
   a. Schedule 40, steel pipe with malleable-iron fittings and threaded joints.
   b. Schedule 40, steel pipe with wrought-steel fittings and welded joints, or mechanical couplings.
   c. Annealed **OR** Drawn, **as directed**,-temper copper tube, Type L (Type B), with wrought-copper fittings and brazed joints. Coat pipe and fittings with protective coating for copper tubing.
5. Branch Piping in Cast-in-Place Concrete to Single Appliance: Annealed-temper copper, with wrought-copper fittings and brazed **OR** flared, **as directed**, joints. Install piping embedded in concrete with no joints in concrete.
6. Containment Conduit: Schedule 40, steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.

T. Indoor Piping Schedule For System Pressures Less Than 0.5 psig (3.45 kPa)

1. Aboveground, branch piping NPS 1 (DN 25) and smaller shall be one of the following:
   a. Corrugated stainless-steel tubing with mechanical fittings having socket or threaded ends to match adjacent piping.
   b. Annealed-temper, tin-lined copper tube with flared joints and fittings.
   c. Annealed-temper copper tube with wrought-copper fittings and brazed **OR** flared, **as directed**, joints.
   d. Aluminum tube with flared fittings and joints.
   e. Schedule 40, steel pipe with malleable-iron fittings and threaded joints.
2. Aboveground, distribution piping shall be one of the following:
   a. Schedule 40, steel pipe with malleable-iron fittings and threaded joints.
   b. Schedule 40, steel pipe with wrought-steel fittings and welded joints.

c. Drawn-temper copper tube, Type L (Type B) with wrought-copper fittings and brazed joints.

3. Underground, below building, piping shall be one of the following:
   a. Schedule 40, steel pipe with malleable-iron fittings and threaded joints.
   b. Schedule 40, steel pipe with wrought-steel fittings and welded joints.
4. Containment Conduit: Schedule 40, steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.
5. Containment Conduit Vent Piping: Schedule 40, steel pipe with malleable-iron fittings and threaded or wrought-steel fittings with welded joints. Coat underground pipe and fittings with protective coating for steel piping.

U. Indoor Piping Schedule For System Pressures More Than 0.5 psig (3.45 kPa) And Less Than 5 psig (34.5 kPa)
1. Aboveground, branch piping NPS 1 (DN 25) and smaller shall be one of the following:
   a. Corrugated stainless-steel tubing with mechanical fittings having socket or threaded ends to match adjacent piping.
   b. Annealed-temper, tin-lined copper tube with flared joints and fittings.
   c. Annealed-temper copper tube, Type L (Type B) with wrought-copper fittings and brazed **OR** flared, **as directed**, joints.
   d. Aluminum tube with flared fittings and joints.
   e. Schedule 40, steel pipe with malleable-iron fittings and threaded joints.
2. Aboveground, distribution piping shall be one of the following:
   a. Schedule 40, steel pipe with malleable-iron fittings and threaded joints.
   b. Schedule 40, steel pipe with steel welding fittings and welded joints.
   c. Drawn-temper copper tube, Type L (Type B) **OR** Type G, **as directed**, with wrought-copper fittings and brazed joints.
3. Underground, below building, piping shall be one of the following:
   a. Schedule 40, steel pipe with malleable-iron fittings and threaded joints.
   b. Schedule 40, steel pipe with wrought-steel fittings and welded joints.
4. Containment Conduit: Schedule 40, steel pipe with wrought-steel fittings and welded joints. Coat underground pipe and fittings with protective coating for steel piping.
5. Containment Conduit Vent Piping: Schedule 40, steel pipe with malleable-iron fittings and threaded or wrought-steel fittings with welded joints. Coat underground pipe and fittings with protective coating for steel piping.

V. Indoor Piping Schedule For System Pressures More Than 5 psig (34.5 kPa)
1. Aboveground Piping: Maximum operating pressure more than 5 psig (34.5 kPa).
2. Aboveground, Branch Piping: Schedule 40, steel pipe with steel welding fittings and welded joints.
3. Aboveground, distribution piping shall be one of the following:
   a. Schedule 40, steel pipe with steel welding fittings and welded joints.
   b. Drawn-temper copper tube, Type L (Type B) **OR** Type G, **as directed**, with wrought-copper fittings and brazed joints.
4. Underground, below building, piping shall be one of the following:
   a. Schedule 40, steel pipe with malleable-iron fittings and threaded joints.
   b. Schedule 40, steel pipe with wrought-steel fittings and welded joints.
5. Containment Conduit: Schedule 40, steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.
6. Containment Conduit Vent Piping: Schedule 40, steel pipe with malleable-iron fittings and threaded or wrought-steel fittings with welded joints. Coat underground pipe and fittings with protective coating for steel piping.

W. Underground Manual Gas Shutoff Valve Schedule
1. Connections to Existing Gas Piping: Use valve and fitting assemblies made for tapping utility's gas mains and listed by an NRTL.
2. Underground Vapor Piping:
   a. PE valves.

b. NPS 2 (DN 50) and Smaller: Bronze, lubricated **OR** nonlubricated, **as directed**, plug valves.
c. NPS 2-1/2 (DN 65) and Larger: Cast-iron, lubricated **OR** nonlubricated, **as directed**, plug valves.

X. Aboveground Manual Gas Shutoff Valve Schedule
1. Aboveground Liquid Piping:
   a. Two-piece, full **OR** regular, **as directed**,-port, bronze ball valves with bronze trim.
2. Valves for pipe NPS 2 (DN 50) and smaller at service meter shall be one of the following:
   a. One-piece, bronze ball valve with bronze trim.
   b. Two-piece, full **OR** regular, **as directed**,-port, bronze ball valves with bronze trim.
   c. Bronze plug valve.
3. Valves for pipe NPS 2-1/2 (DN 65) and larger at service meter shall be one of the following:
   a. Two-piece, full **OR** regular, **as directed**,-port, bronze ball valves with bronze trim.
   b. Bronze plug valve.
   c. Cast-iron, nonlubricated plug valve.
4. Distribution piping valves for pipe NPS 2 (DN 50) and smaller shall be one of the following:
   a. One-piece, bronze ball valve with bronze trim.
   b. Two-piece, full **OR** regular, **as directed**,-port, bronze ball valves with bronze trim.
   c. Bronze plug valve.
5. Distribution piping valves for pipe NPS 2-1/2 (DN 65) and larger shall be one of the following:
   a. Two-piece, full **OR** regular, **as directed**,-port, bronze ball valves with bronze trim.
   b. Bronze plug valve.
   c. Cast-iron, nonlubricated **OR** lubricated, **as directed**, plug valve.
6. Valves in branch piping for single appliance shall be one of the following:
   a. One-piece, bronze ball valve with bronze trim.
   b. Two-piece, full **OR** regular, **as directed**,-port, bronze ball valves with bronze trim.
   c. Bronze plug valve.

END OF SECTION 23 11 23 00c

Task	Specification	Specification Description
23 11 23 00	22 05 23 00	Piped Utilities Basic Materials And Methods
23 11 23 00	22 11 23 39	Water Supply Wells
23 11 23 00	22 05 76 00	Sanitary Sewerage
23 11 23 00	07 63 00 00	Common Work Results for Fire Suppression
23 11 23 00	07 63 00 00a	Common Work Results for Plumbing
23 11 23 00	07 63 00 00b	Common Work Results for HVAC
23 12 13 00	22 05 23 00	Piped Utilities Basic Materials And Methods
23 12 23 00	22 05 23 00	Piped Utilities Basic Materials And Methods
23 13 13 13	22 05 23 00	Piped Utilities Basic Materials And Methods
23 13 13 13	22 12 23 26	Underground Storage Tanks
23 13 13 23	22 05 23 00	Piped Utilities Basic Materials And Methods
23 13 13 23	22 12 23 26	Underground Storage Tanks
23 13 23 16	22 05 23 00	Piped Utilities Basic Materials And Methods
23 13 23 26	22 05 23 00	Piped Utilities Basic Materials And Methods
23 13 33 00	22 05 23 00	Piped Utilities Basic Materials And Methods
23 13 33 00	22 12 23 26	Underground Storage Tanks

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SECTION 23 21 13 23 - FACILITY FUEL-OIL PIPING

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for facility fuel-oil piping. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes fuel-oil, fuel-oil and diesel-fuel-oil, and diesel-fuel-oil distribution systems and the following:
   a. Pipes, tubes, and fittings.
   b. Piping and tubing joining materials.
   c. Piping specialties.
   d. Valves.
   e. Vertical, steel, fuel-oil ASTs.
   f. Horizontal, steel, fuel-oil ASTs.
   g. Containment-dike, steel, fuel-oil ASTs.
   h. Insulated, steel, fuel-oil ASTs.
   i. Concrete-vaulted, steel, fuel-oil ASTs.
   j. Steel, fuel-oil USTs with STI-P3.
   k. Composite, steel, fuel-oil USTs.
   l. Jacketed, steel, fuel-oil USTs.
   m. FRP fuel-oil USTs.
   n. Fuel-oil AST accessories.
   o. Fuel-oil UST accessories.
   p. Fuel-oil storage tank piping specialties.
   q. Fuel-oil storage tank pumps.
   r. Fuel-transfer pumps.
   s. Fuel maintenance system.
   t. Liquid-level gage system.
   u. Leak-detection and monitoring system.
   v. Mechanical sleeve seals.
   w. Grout.
   x. Concrete bases.

C. Definitions
1. AST: Aboveground storage tank.
2. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.
3. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.
4. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct shafts, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspaces, and tunnels.
5. FPM: Vinylidene fluoride-hexafluoropropylene copolymer rubber.
6. FRP: Glass-fiber-reinforced plastic.
7. UST: Underground storage tank.

D. Performance Requirements
1. Maximum Operating-Pressure Ratings: 3-psig (21-kPa) fuel-oil supply pressure at oil-fired appliances.

2. Delegated Design: Design restraint and anchors for fuel-oil piping, ASTs, and equipment, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
3. Seismic Performance: Factory-installed support attachments for AST shall withstand the effects of earthquake motions determined according to SEI/ASCE 7.
   a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event, **as directed**."

E. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings: For facility fuel-oil piping layout. Include plans, piping layout and elevations, sections, and details for fabrication of pipe anchors, hangers, supports for multiple pipes, alignment guides, expansion joints and loops, and attachments of the same to building structure. Detail location of anchors, alignment guides, and expansion joints and loops.
3. Delegated-Design Submittal: For fuel-oil piping and equipment indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
   a. Detail fabrication and assembly of anchors and seismic restraints.
   b. Design Calculations: Calculate requirements for selecting seismic restraints.
   c. Detail fabrication and assembly of pipe anchors, hangers, supports for multiple pipes, and attachments of the same to building structure.
4. Seismic Qualification Certificates: For ASTs, accessories, and components, from manufacturer.
   a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
   c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
5. Brazing certificates.
6. Welding certificates.
7. Field quality-control reports.
8. Operation and Maintenance Data.
9. Warranty: Sample of special warranty.

F. Quality Assurance
1. Brazing: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX.
2. Steel Support Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
3. Pipe Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.
4. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
5. Comply with ASME B31.9, "Building Services Piping," for fuel-oil piping materials, installation, testing, and inspecting.
6. Comply with requirements of the EPA and of state and local authorities having jurisdiction. Include recording of fuel-oil storage tanks and monitoring of tanks and piping.

G. Delivery, Storage, And Handling
1. Lift and support fuel-oil storage tanks only at designated lifting or supporting points, as shown on Shop Drawings. Do not move or lift tanks unless empty.
2. Deliver pipes and tubes with factory-applied end caps. Maintain end caps through shipping, storage, and handling to prevent pipe end damage and to prevent entrance of dirt, debris, and moisture.

3. Store pipes and tubes with protective PE coating to avoid damaging the coating and to protect from direct sunlight.
4. Store PE pipes and valves protected from direct sunlight.

H. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of fuel-oil storage tanks and flexible, double-containment piping and related equipment that fail in materials or workmanship within specified warranty period.
   a. Storage Tanks:
      1) Failures include, but are not limited to, the following when used for storage of fuel oil at temperatures not exceeding 150 deg F (66 deg C):
         a) Structural failures including cracking, breakup, and collapse.
         b) Corrosion failure including external and internal corrosion of steel tanks.
      2) Warranty Period: 30 years from date of Final Completion.
   b. Flexible, Double-Containment Piping and Related Equipment:
      1) Failures due to defective materials or workmanship for materials installed together, including piping, dispenser sumps, entry boots, and sump mounting adapters.
      2) Warranty Period: 10 **OR** 30, **as directed**, years from date of Final Completion.

1.2 PRODUCTS

A. Pipes, Tubes, And Fittings
1. See Part 1.3 piping schedule articles for where pipes, tubes, fittings, and joining materials are applied in various services.
2. Steel Pipe: ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.
   a. Malleable-Iron Threaded Fittings: ASME B16.3, Class 150, standard pattern.
   b. Wrought-Steel Welding Fittings: ASTM A 234/A 234M, for butt and socket welding.
   c. Unions: ASME B16.39, Class 150, malleable iron with brass-to-iron seat, ground joint, and threaded ends.
   d. Forged-Steel Flanges and Flanged Fittings: ASME B16.5, minimum Class 150, including bolts, nuts, and gaskets of the following material group, end connections, and facings:
      1) Material Group: 1.1.
      2) End Connections: Threaded or butt welding to match pipe.
      3) Lapped Face: Not permitted underground.
      4) Gasket Materials: Asbestos free, ASME B16.20 metallic, or ASME B16.21 nonmetallic, gaskets compatible with fuel oil.
      5) Bolts and Nuts: ASME B18.2.1, cadmium-plated steel.
   e. Protective Coating for Underground Piping: Factory-applied, three-layer coating of epoxy, adhesive, and PE.
      1) Joint Cover Kits: Epoxy paint, adhesive, and heat-shrink PE sleeves.
3. Drawn-Temper Copper Tube: Comply with ASTM B 88, Type K (ASTM B 88M, Type A) **OR** ASTM B 88, Type L (ASTM B 88M, Type B), **as directed**.
   a. Copper Fittings: ASME B16.22, wrought copper, streamlined pattern.
   b. Bronze Flanges and Flanged Fittings: ASME B16.24, Class 150.
      1) Gasket Material: Asbestos free, ASME B16.20, metallic, or ASME B16.21 nonmetallic, gaskets compatible with fuel oil.
      2) Bolts and Nuts: ASME B18.2.1, cadmium-plated steel.
4. Annealed-Temper Copper Tube: Comply with ASTM B 88, Type K (ASTM B 88M, Type A) **OR** ASTM B 88, Type L (ASTM B 88M, Type B), **as directed**.
   a. Copper Fittings: ASME B16.22, wrought copper, streamlined pattern.
   b. Flare Fittings: Comply with ASME B16.26 and SAE J513.
      1) Copper fittings with long nuts.
      2) Metal-to-metal compression seal without gasket.
      3) Dryseal threads complying with ASME B1.20.3.

B. Double-Containment Pipe And Fittings
1. Flexible, Double-Containment Piping: Comply with UL 971.
a. Pipe Materials: PVDF complying with ASTM D 3222 for carrier pipe with mechanical couplings to seal carrier, and PE pipe complying with ASTM D 4976 for containment piping.
b. Fiberglass **OR** PE, **as directed**, sumps.
c. Watertight sump entry boots, pipe adapters with test ports and tubes, coaxial fittings, and couplings.
d. Minimum Operating Pressure Rating: 10 psig (69 kPa).
e. Plastic to Steel Pipe Transition Fittings: Factory-fabricated fittings with plastic end matching or compatible with carrier piping, and steel pipe end complying with ASTM A 53/A 53M, black steel, Schedule 40, Type E or S, Grade B.
f. Include design and fabrication of double-containment pipe and fitting assemblies with provision for field installation of cable leak-detection system in annular space between carrier and containment piping.
2. Rigid, Double-Containment Piping: Comply with UL 971.
a. RTRP: ASTM D 2996 or ASTM D 2997 carrier and containment piping and mechanical couplings to seal carrier and containment piping or individually bonded joints.
1) Minimum Operating-Pressure Rating for RTRP NPS 2 and NPS 3 (DN 50 and DN 80): 150 psig (1035 kPa).
2) Minimum Operating-Pressure Rating for RTRP NPS 4 and NPS 6 (DN 100 and DN 150): 125 psig (860 kPa). Compliance with UL 971 is not required for NPS 6 (DN 150) and larger piping.
3) Fittings: RTRF complying with ASTM D 2996 or ASTM D 2997, and made by RTRP manufacturer; watertight sump entry boots, termination, or other end fittings.
b. Include design and fabrication of double-containment pipe and fitting assemblies with provision for field installation of cable leak-detection system in annular space between carrier and containment piping.

C. Piping Specialties
1. Flexible Connectors: Comply with UL 567.
a. Metallic Connectors:
1) Listed and labeled for aboveground and underground applications by an NRTL acceptable to authorities having jurisdiction.
2) Stainless-steel bellows with woven, flexible, bronze or stainless-steel, wire-reinforcing protective jacket.
3) Minimum Operating Pressure: 150 psig (1035 kPa).
4) End Connections: Socket, flanged, or threaded end to match connected piping.
5) Maximum Length: 30 inches (762 mm).
6) Swivel end, 50-psig (345-kPa) maximum operating pressure.
7) Factory-furnished anode.
b. Nonmetallic Connectors:
1) Listed and labeled for underground applications by an NRTL acceptable to authorities having jurisdiction.
2) PFTE bellows with woven, flexible, bronze or stainless-steel, wire-reinforcing protective jacket.
3) Minimum Operating Pressure: 150 psig (1035 kPa).
4) End Connections: Socket, flanged, or threaded end to match connected piping.
5) Maximum Length: 30 inches (762 mm).
6) Swivel end, 50-psig (345-kPa) maximum operating pressure.
7) Factory-furnished anode.
2. Y-Pattern Strainers:
a. Body: ASTM A 126, Class B, cast iron with bolted cover and bottom drain connection.
b. End Connections: Threaded ends for NPS 2 (DN 50) and smaller; flanged ends for NPS 2-1/2 (DN 65) and larger.

c. Strainer Screen: 60 **OR** 80, **as directed**,-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.
d. CWP Rating: 125 psig (860 kPa).

3. Basket Strainers:
a. Body: ASTM A 126, Class B, high-tensile cast iron with bolted cover and bottom drain connection.
b. End Connections: Threaded ends for NPS 2 (DN 50) and smaller; flanged ends for NPS 2-1/2 (DN 65) and larger.
c. Strainer Screen: 60 **OR** 80, **as directed**,-mesh startup strainer, and perforated stainless-steel basket with 50 percent free area.
d. CWP Rating: 125 psig (860 kPa).

4. T-Pattern Strainers:
a. Body: Ductile or malleable iron with removable access coupling and end cap for strainer maintenance.
b. End Connections: Grooved ends.
c. Strainer Screen: 60 **OR** 80, **as directed**,-mesh startup strainer, and perforated stainless-steel basket with 57 percent free area.
d. CWP Rating: 750 psig (5170 kPa).

5. Manual Air Vents:
a. Body: Bronze.
b. Internal Parts: Nonferrous.
c. Operator: Screwdriver or thumbscrew.
d. Inlet Connection: NPS 1/2 (DN 15).
e. Discharge Connection: NPS 1/8 (DN 6).
f. CWP Rating: 150 psig (1035 kPa).
g. Maximum Operating Temperature: 225 deg F (107 deg C).

D. Joining Materials
1. Joint Compound and Tape: Suitable for fuel oil.
2. Welding Filler Metals: Comply with AWS D10.12/D10.12M for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.
3. Brazing Filler Metals: Alloy with melting point greater than 1000 deg F (540 deg C) complying with AWS A5.8/A5.8M. Brazing alloys containing more than 0.05 percent phosphorus are prohibited.
4. Bonding Adhesive for Fiberglass Piping: As recommended by fiberglass piping manufacturer.

E. Manual Fuel-Oil Shutoff Valves
1. See valve schedule in Part 1.3 for where each valve type is applied in various services.
2. General Requirements for Metallic Valves, NPS 2 (DN 50) and Smaller for Liquid Service: Comply with UL 842.
a. CWP Rating: 125 psig (860 kPa).
b. Threaded Ends: Comply with ASME B1.20.1.
c. Dryseal Threads on Flare Ends: Comply with ASME B1.20.3.
d. Tamperproof Feature: Locking feature for valves indicated in the valve schedule.
e. Service Mark: Initials "WOG" shall be permanently marked on valve body.

3. General Requirements for Metallic Valves, NPS 2-1/2 (DN 65) and Larger: Comply with UL 842.
a. CWP Rating: 125 psig (860 kPa).
b. Flanged Ends: Comply with ASME B16.5 for steel flanges.
c. Tamperproof Feature: Locking feature for valves indicated in the valve schedule.
d. Service Mark: Initials "WOG" shall be permanently marked on valve body.

4. One-Piece, Bronze Ball Valve with Bronze Trim: MSS SP-110.
a. Body: Bronze, complying with ASTM B 584.
b. Ball: Chrome-plated brass.
c. Stem: Bronze; blowout proof.
d. Seats: Reinforced TFE; blowout proof.
e. Packing: Separate packnut with adjustable-stem packing threaded ends.

f. Ends: Threaded, flared, or socket as indicated in the valve schedule.
g. CWP Rating: 600 psig (4140 kPa).
h. Service Mark: Initials "WOG" shall be permanently marked on valve body.

5. Two-Piece, Full-Port, Bronze Ball Valves with Bronze Trim: MSS SP-110.
   a. Body: Bronze, complying with ASTM B 584.
   b. Ball: Chrome-plated bronze.
   c. Stem: Bronze; blowout proof.
   d. Seats: Reinforced TFE; blowout proof.
   e. Packing: Threaded-body packnut design with adjustable-stem packing.
   f. Ends: Threaded, flared, or socket as indicated in the valve schedule.
   g. CWP Rating: 600 psig (4140 kPa).
   h. Service Mark: Initials "WOG" shall be permanently marked on valve body.
6. Two-Piece, Regular-Port Bronze Ball Valves with Bronze Trim: MSS SP-110.
   a. Body: Bronze, complying with ASTM B 584.
   b. Ball: Chrome-plated bronze.
   c. Stem: Bronze; blowout proof.
   d. Seats: Reinforced TFE.
   e. Packing: Threaded-body packnut design with adjustable-stem packing.
   f. Ends: Threaded, flared, or socket as indicated in the valve schedule.
   g. CWP Rating: 600 psig (4140 kPa).
   h. Service Mark: Initials "WOG" shall be permanently marked on valve body.

F. Specialty Valves
1. Pressure Relief Valves: Comply with UL 842.
   a. Listed and labeled for fuel-oil service by an NRTL acceptable to authorities having jurisdiction.
   b. Body: Brass, bronze, or cast steel.
   c. Springs: Stainless steel, interchangeable.
   d. Seat and Seal: Nitrile rubber.
   e. Orifice: Stainless steel, interchangeable.
   f. Factory-Applied Finish: Baked enamel.
   g. Maximum Inlet Pressure: 150 psig (1035 kPa).
   h. Relief Pressure Setting: 60 psig (414 kPa).
2. Oil Safety Valves: Comply with UL 842.
   a. Listed and labeled for fuel-oil service by an NRTL acceptable to authorities having jurisdiction.
   b. Body: Brass, bronze, or cast steel.
   c. Springs: Stainless steel.
   d. Seat and Diaphragm: Nitrile rubber.
   e. Orifice: Stainless steel, interchangeable.
   f. Factory-Applied Finish: Baked enamel.
   g. Manual override port.
   h. Maximum Inlet Pressure: 60 psig (414 kPa).
   i. Maximum Outlet Pressure: 3 psig (21 kPa).
3. Emergency Shutoff Valves: Comply with UL 842.
   a. Listed and labeled for fuel-oil service by an NRTL acceptable to authorities having jurisdiction.
   b. Single **OR** Double, **as directed**, poppet valve.
   c. Body: ASTM A 126, cast iron.
   d. Disk: FPM.
   e. Poppet Spring: Stainless steel.
   f. Stem: Plated brass.
   g. O-Ring: FPM.
   h. Packing Nut: PTFE-coated brass.
   i. Fusible link to close valve at 165 deg F (74 deg C).

j. Thermal relief to vent line pressure buildup due to fire.
k. Air test port.
l. Maximum Operating Pressure: 0.5 psig (3.45 kPa).

4. Mechanical Leak Detector: Comply with UL 842.
   a. Listed and labeled for fuel-oil service by an NRTL acceptable to authorities having jurisdiction.
   b. Body: ASTM A 126, cast iron.
   c. O-Rings: Elastomeric compatible with fuel oil.
   d. Piston and Stem Seals: PTFE.
   e. Stem and Spring: Stainless steel.
   f. Piston Cylinder: Burnished brass.
   g. Indicated Leak Rate: Maximum 3 gph (3 mL/s) at 10 psig (69 kPa).
   h. Leak Indication: Reduced flow.

G. Vertical, Steel, Fuel-Oil AST
1. Description:
   a. UL 142, single-wall, vertical, steel tank.
   b. UL 142 and STI F921, **as directed**, double-wall, vertical, steel tank; with primary- and secondary-containment walls and interstitial space.
2. Construction: Fabricated with welded, carbon steel suitable for operation at atmospheric pressure and for storing fuel oil with specific gravity up to 1.1 and maintained temperature up to 150 deg F (66 deg C).

H. Horizontal, Steel, Fuel-Oil AST
1. Description:
   a. UL 142, single-wall, horizontal, steel tank.
   b. UL 142 and STI F921, **as directed**, double-wall, horizontal, steel tank; with primary- and secondary-containment walls and interstitial space.
2. Construction: Fabricated with welded, carbon steel; suitable for operation at atmospheric pressure and for storing fuel oil with specific gravity up to 1.1 and with maintained temperature up to 150 deg F (66 deg C).
3. Supports:
   a. Manufacturer's standard structural steel welded to tank.
   b. Manufacturer's standard type and number, steel or cast-iron cradles, for field installation.

I. Containment-Dike, Steel, Fuel-Oil AST
1. Description: UL 142 and STI F911, single-wall, horizontal, steel tank; with open or enclosed **OR** enclosed, **as directed**, secondary-containment dike with capacity greater than tank capacity.
2. Construction: Fabricated with welded, carbon steel; suitable for operation at atmospheric pressure and for storing fuel oil with specific gravity up to 1.1 and with maintained temperature up to 150 deg F (66 deg C).

J. Insulated, Steel, Fuel-Oil AST
1. Description: UL 142 and UL 2085 **OR** UL 142, UL 2085, and STI F941, **as directed**, thermally insulated and fire-resistant, double-wall, horizontal, steel tank; with primary- and secondary-containment walls and insulation and with interstitial space.
2. Construction: Fabricated with welded, carbon steel and insulation; suitable for operation at atmospheric pressure and for storing fuel oil with specific gravity up to 1.1 and with test temperature according to UL 2085.

K. Concrete-Vaulted, Steel, Fuel-Oil AST
1. Description: UL 142 and UL 2085 **OR** UL 142, UL 2085, and STI F941, **as directed**; thermally insulated, fire-resistant and protected, double-wall, horizontal, steel tank; with primary- and secondary-containment walls and insulation and with interstitial space.

2. Construction: Fabricated with welded, carbon steel and insulation and encased in concrete that will protect from bullets; suitable for operation at atmospheric pressure and for storing fuel oil with specific gravity up to 1.1 and with test temperature according to UL 2085.

L. Steel, Fuel-Oil UST With STI-P3
1. Description: UL 58 and STI P3, double-wall, horizontal, steel tank; with cathodic protection and electrical isolation.
   a. Containment Method: STI-P3, Type I, with primary and secondary walls in contact **OR** Type II, with interstitial space, **as directed**.
2. Construction: Fabricated with welded steel; suitable for operation at atmospheric pressure and for storing liquids with specific gravity up to 1.1; fabricated for the following loads:
   a. Depth of Bury: 3 feet (1 m) from top of tank to finished surface.
   b. External Hydrostatic Pressure: To withstand general buckling with safety factor of 2:1 if hole is fully flooded.
   c. Surface Loads: AASHTO's "Specifications for Highway Bridges," H-20 axle loads of 32,000 lb (14 515 kg).
3. Corrosion-Protection System: Protect tank and factory-installed piping by engineered and installed corrosion-protection system according to STI P3, with means of monitoring cathodic protection.

M. Composite, Steel, Fuel-Oil UST
1. Description: UL 58, double-wall, horizontal, composite tank; with coating complying with UL 1746 and STI F894.
   a. Containment Method: STI F894, Type I, with primary and secondary walls in contact **OR** Type II, with interstitial space, **as directed**.
2. Construction: Fabricated with welded steel and factory coating according to UL 1746 and STI F894; suitable for operation at atmospheric pressure and for storing liquids with specific gravity up to 1.1; fabricated for the following loads:
   a. Depth of Bury: 3 feet (1 m) from top of tank to finished surface.
   b. External Hydrostatic Pressure: To withstand general buckling with safety factor of 2:1 if hole is fully flooded.
   c. Surface Loads: AASHTO's "Specifications for Highway Bridges," H-20 axle loads of 32,000 lb (14 515 kg).

N. Jacketed, Steel, Fuel-Oil UST
1. Description: Jacketed, horizontal, steel tank; complying with UL 58, and with plastic or fiberglass jacket and corrosion-protection system according to UL 1746 and STI F922, **as directed**.
2. Construction: Tank fabricated with welded carbon steel, and jacket fabricated with plastic or fiberglass and vacuum-sealed interstitial space; suitable for operation at atmospheric pressure and with integral leak-detection device. Tank fabricated for the following loads:
   a. Depth of Bury: 3 feet (1 m) from top of tank to finished surface.
   b. External Hydrostatic Pressure: To withstand general buckling with safety factor of 2:1 if hole is fully flooded.
   c. Surface Loads: AASHTO's "Specifications for Highway Bridges," H-20 axle loads of 32,000 lb (14 515 kg).

O. FRP Fuel-Oil UST
1. Description: Horizontal, FRP UST; UL 1316, double wall, with interstitial space and integral, hydrostatic, leak-detection and monitoring system, **as directed**.
2. Construction: Fabricated with fiberglass-reinforced polyester resins; suitable for operation at atmospheric pressure; fabricated for the following loads:
   a. Depth of Bury: 3 feet (1 m) from top of tank to finished surface.
   b. External Hydrostatic Pressure: To withstand general buckling with safety factor of 2:1 if hole is fully flooded.

c. Surface Loads: AASHTO's "Specifications for Highway Bridges," H-20 axle loads of 32,000 lb (14 515 kg).

P. Shop Painting Of AST
1. Apply manufacturer's standard prime coat to exterior steel surface of AST and supports.
2. Prepare exterior steel surface of AST and tank supports.
3. Shop Cleaning: After fabrication, blast clean according to SSPC-SP 6/NACE No. 3 **OR** SSPC-SP 10/NACE No. 2, **as directed**.
4. After cleaning, remove dust or residue from cleaned surfaces.
5. If surface develops rust before prime coat is applied, repeat surface preparation.
6. Apply manufacturer's standard prime coat to shop-cleaned, dry surface same day as surface preparation.
7. Apply manufacturer's standard two-component, epoxy finish coats.

Q. Fuel-Oil AST Accessories
1. Tank Manholes (for horizontal tanks and some vertical tanks): 22-inch- (560-mm-) minimum diameter; bolted, flanged, and gasketed; centered on top of tank.
2. Tank Manholes (for vertical tanks): 22-inch- (560-mm-) minimum diameter; bolted, flanged, and gasketed; on top and at side of tank.
3. For Horizontal Tanks: Threaded pipe connection fittings on top of tank, for fill, supply, return, vent, sounding, and gaging. Include cast-iron plugs for shipping.
4. For Vertical Tanks: Threaded pipe connection fittings on top or sides of tank as indicated, for fill, supply, return, vent, sounding, and gaging. Include cast-iron plugs for shipping.
5. Striker Plates: Inside tank, on bottom below fill, vent, sounding, gage, and other tube openings.
6. Lifting Lugs: For handling and installation.
7. Ladders (for horizontal tanks and some vertical tanks): Carbon-steel ladder inside tank, anchored to top and bottom, and located as indicated. Include reinforcement of tank at bottom of ladder.
8. Ladders (for vertical tanks): Carbon-steel ladder outside tank, anchored to top and side wall. Comply with requirements in Division 05 Section "Metal Fabrications" for exterior steel ladder.
   a. Cage: Include welded steel cage around ladders for tanks 20 feet (6 m) high or higher.
9. Supply Tube: Extension of supply piping fitting into tank, terminating 6 inches (150 mm) above tank bottom and cut at a 45-degree angle (1:1 slope).
10. Sounding and Gage Tubes: Extension of fitting into tank, terminating 6 inches (150 mm) above tank bottom and cut at a 45-degree angle (1:1 slope).

R. Fuel-Oil UST Accessories
1. Tank Manholes: 22-inch- (560-mm-) minimum diameter; bolted, flanged, and gasketed, with extension collar; for access to inside of tank.
2. Steel Tank Masonry Supports: Two 6-by-6-by-3/8-inch (150-by-150-by-10-mm) steel angles, 72 inches (1800 mm) long, located longitudinally on tank on each side of manholes and continuously welded in place.
3. Threaded pipe connection fittings on top of tank for fill, supply, return, vent, sounding, and gaging, in locations and of sizes indicated. Include cast-iron plugs for shipping.
4. Striker Plates: Inside tank, on bottom below fill, vent, sounding, gage, and other tube openings.
5. Lifting Lugs: For handling and installation.
6. Ladders: Carbon-steel ladder inside tank, anchored to top and bottom. Include reinforcement of tank at bottom of ladder.
7. Supply Tube: Extension of supply piping fitting into tank, terminating 6 inches (150 mm) above tank bottom and cut at a 45-degree angle (1:1 slope).
8. Sounding and Gage Tubes: Extension of fitting into tank, terminating 6 inches (150 mm) above tank bottom and cut at a 45-degree angle (1:1 slope).
9. Containment Sumps: Fiberglass **OR** PE, **as directed**, with sump base, add-on extension pieces as required, sump top, lid, and gasket-seal joints. Include sump entry boots for pipe penetrations through sidewalls.

10. Sump Entry Boots: Two-part pipe fitting for field assembly and of size required to fit over pipe. Include gaskets shaped to fit sump sidewall, sleeves, seals, and clamps as required for liquid-tight pipe penetrations.
11. Anchor Straps: Storage tank manufacturer's standard anchoring system, with straps, strap-insulating material, cables and turnbuckles, of strength at least one and one-half times maximum uplift force of empty tank without backfill in place.
12. Filter Mat: Geotextile woven or spun filter fabric, in 1 or more layers, for minimum total weight of 3 oz./sq. yd. (101.7 g/sq. m).
13. Overfill Prevention Valves: Factory fabricated or shop or field assembled from manufacturer's standard components. Include drop tube, cap, fill nozzle adaptor, check valve mechanism or other devices, and vent if required to restrict flow at 95 percent of tank capacity and to provide complete shutoff of filling at 98 **OR** 99, **as directed**, percent of tank capacity.

S. Fuel-Oil Storage Tank Piping Specialties
1. Fitting Materials: Cast iron, malleable iron, brass, or corrosion-resistant metal; suitable for fuel-oil service.
   a. Surface, Flush-Mounted Fittings: Waterproof and suitable for truck traffic.
   b. Aboveground-Mounted Fittings: Weatherproof.
2. Spill-Containment Fill Boxes: Flush mounting, with drainage feature to drain oil into tank, threaded fill-pipe connection, and wrench operation.
3. Fill Boxes: Flush mounting, with threaded fill-pipe connection and wrench operation.
4. Locking Fill Boxes: Flush mounting, with locking-type inner fill cap for standard padlock and threaded fill-pipe connection.
5. Supply and Sounding Drop Tubes: Fuel-oil supply piping or fitting, inside tank, terminating 6 inches (150 mm) above bottom of tank, and with end cut at a 45-degree angle (1:1 slope).
6. Pipe Adapters and Extensions: Compatible with piping and fittings.
7. Suction Strainers and Check Valves: Bronze or corrosion-resistant metal components.
8. Foot Valves and Antisiphon Valves: Poppet-type, bronze or corrosion-resistant metal components.
9. Weatherproof Vent Cap: Cast- or malleable-iron increaser fitting with corrosion-resistant wire screen, with free area at least equal to cross-sectional area of connecting pipe and threaded-end connection.
10. Metal Manholes: 22-inch- (560-mm-) minimum diameter frame and cover. Furnish manhole units of adequate size for access to fittings if size is not indicated.
11. Monitoring Well Caps: Locking pipe plug and manhole.

T. Submersible Fuel-Oil Pumps
1. Description: Comply with UL 79, UL 87, and UL 343.
   a. Listed and labeled for fuel-oil service by an NRTL acceptable to authorities having jurisdiction.
   b. Impeller: Turbine.
   c. Housing and Volute: Cast iron.
   d. Bearings: Bronze, self-lubricating.
   e. Seals: Mechanical.
   f. Shaft: Polished steel.
   g. Suspension Piping: Telescoping to accommodate tank diameter and depth of bury.
   h. Base: Steel.
   i. Pressure Relief: Built in.
   j. Discharge Check Valve: Built in.
   k. Drive: Direct, close coupled.
2. Controls: Pump controller panel complying with UL 353 and UL 508C and with interlock and terminals for connections to fuel-oil-burning equipment **OR** diesel-driven fire pumps **OR** diesel-driven emergency generators **OR** diesel-fuel-oil dispenser, **as directed**.
   a. Run pumps to maintain minimum manifold pressure with outdoor-air temperature less than 60 deg F (16 deg C).

b. Run pumps on seven-day schedule.
c. Stage pumps on pressure at a common supply manifold.
d. Alternate pumps to equalize run time.
e. Alarm motor failure.
f. Manual reset dry-run protection. Stop pumps if fuel level falls below pump suction.
g. Deenergize and alarm pump locked rotor condition.
h. Alarm open circuit, high and low voltage.
i. Indicating lights for power on, run, and off normal conditions.
j. Interface with automatic control system is specified in Division 23 Section "Instrumentation And Control For Hvac" to control and indicate the following:
1) Start/stop pump set when required by schedule, fuel-fired appliance operation, day tank level control, or weather conditions.
2) Operating status.
3) Alarm off-normal status.

3. Motor: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
b. Thermal-Overload Protection: Motor-winding temperature sensor.
c. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 22.

U. Simplex Fuel-Oil Transfer Pumps
1. Description: Comply with UL 343, and HI M109.
a. Listed and labeled for fuel-oil service by an NRTL acceptable to authorities having jurisdiction.
b. Type: Positive-displacement, rotary type.
c. Impeller: Steel gear with crescent **OR** Carbon vane, **as directed**.
d. Housing: Cast-iron foot mounted.
e. Bearings: Bronze, self-lubricating.
f. Shaft: Polished steel.
g. Seals: Mechanical.
h. Base: Steel.
i. Pressure Relief: Built in.
j. Discharge Check Valve: Built in.
2. Drive: V-belt with guard; gear reducer; or direct, close coupled **OR** V-belt with guard **OR** Gear reducer **OR** Direct, close coupled, **as directed**.
3. Controls:
a. Run pump to maintain minimum manifold pressure with outdoor-air temperature less than 60 deg F (16 deg C).
b. Run pump on seven-day schedule.
c. Alarm motor failure.
d. Manual reset dry-run protection. Stop pump if fuel level falls below pump suction.
e. Deenergize and alarm pump locked rotor condition.
f. Alarm open circuit, high and low voltage.
g. Indicating lights for power on, run, and off normal conditions.
h. Interface with automatic control system is specified in Division 23 Section "Instrumentation And Control For Hvac" to control and indicate the following:
1) Start/stop pump set when required by schedule, fuel-fired appliance operation, day tank level control, or weather conditions.
2) Operating status.
3) Alarm off-normal status.
4. Motor: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".

a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
b. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 22.

V. Duplex **OR** Triplex, **as directed**, Fuel-Oil Transfer Pump Sets
1. Description: Comply with HI M109.
a. Listed and labeled for fuel-oil service by an NRTL acceptable to authorities having jurisdiction.
b. Type: Positive-displacement, rotary type.
c. Impeller: Steel gear with crescent **OR** Carbon vane, **as directed**.
d. Housing: Cast-iron foot mounted.
e. Bearings: Bronze, self-lubricating.
f. Shaft: Polished steel.
g. Seals: Mechanical.
h. Base: Steel.
i. Pressure Relief: Built in.
j. Discharge Check Valve: Built in.
2. Drive: V-belt with guard, gear reducer, or direct close coupled **OR** V-belt with guard **OR** Gear reducer **OR** Direct close coupled, **as directed**.
3. Controls:
a. Run pumps to maintain minimum manifold pressure with outdoor-air temperature less than 60 deg F (16 deg C).
b. Run pumps on seven-day schedule.
c. Stage pumps on pressure at a common supply manifold.
d. Alternate pumps to equalize run time.
e. Alarm motor failure.
f. Manual reset dry-run protection. Stop pumps if fuel level falls below pump suction.
g. Deenergize and alarm pump locked rotor condition.
h. Alarm open circuit, high and low voltage.
i. Indicating lights for power on, run, and off normal conditions.
j. Interface with automatic control system is specified in Division 23 Section "Instrumentation And Control For Hvac" to control and indicate the following:
1) Start/stop pump set when required by schedule, fuel-fired appliance operation, day tank level control, or weather conditions.
2) Operating status.
3) Alarm off-normal status.
4. Motor: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
b. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 22.
5. Piping Furnished with Pumps: Steel with ferrous fittings and threaded or welded joints.
6. Strainers Furnished with Pumps: Duplex, basket type with corrosion-resistant-metal-screen baskets.

W. Fuel Maintenance System
1. Description: Factory fabricated and wired fuel maintenance system for fuel-oil filtration; with enclosure, filter, fuel-oil pump, and controls; FMG approved, listed, and labeled by an NRTL acceptable to authorities having jurisdiction.
a. Enclosure: NEMA 250, Type 3R, painted steel containing pumps, filters, accessories, and controls. Hinged door on the front of enclosure.

b. Pump: Comply with HI M109, steel-gear-with-crescent, positive-displacement, direct-coupled, rotary-type.
c. Materials: Cast-iron housing; bronze bearings; steel shaft; mechanical seals; and built-in, pressure relief bypass valve.
d. Motor: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   1) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
   2) Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 22.
e. Piping: Steel with malleable-iron fittings and threaded joints or wrought-steel fittings and welded joints.
f. Multistage Filter: Spin-on, replaceable types.
   1) Stage 1: 100-mesh strainer.
   2) Stage 2: Centrifuge to separate particulates and water from oil.
   3) Stage 3: Coalescing water and particulate filter.
   4) Stage 4: 30-micron particulate removal.
   5) Stage 5: 10-micron particulate removal.
   6) Stage 6: Minimum 99.5 percent water removal with see-through bowl and water-sensor probe.
   7) Stage 7: 1.5 **OR** 3, **as directed**,-micron particulate removal.
g. Multiple-Tank Manifolds:
   1) Manifold fabricated of Schedule 80, black steel pipe and threaded nipples for two **OR** three **OR** four, **as directed**, tanks.
   2) Solenoid valves for supply and return piping to each tank.
   3) Strainers for each tank supply connection.
h. Programmable Logic Controller:
   1) Alarm on maximum 15-in. Hg (51-kPa) vacuum at pump suction indicating plugged filter.
   2) Alarm on high water level in filter.
   3) Alarm leak in enclosure.
   4) Touch screen; with minimum 2-line, 20-character, backlit, LCD display.
   5) Controller strip heater with thermostat.
i. Interface with automatic control system is specified in Division 23 Section "Instrumentation And Control For Hvac" to control and indicate the following:
   1) Start/stop system when required by schedule.
   2) Operating status.
   3) Alarm off-normal status.

X. Liquid-Level Gage System
1. Description: Calibrated, liquid-level gage system complying with UL 180 with floats **OR** UL 1238 with probes, **as directed**, or other sensors and remote annunciator panel.
2. Annunciator Panel: With visual and audible, high-tank-level and low-tank-level alarms, fuel indicator with registration in gallons (liters), and overfill alarm. Include gage volume range that covers fuel-oil storage capacity.
3. Controls: Electrical, operating on 120-V ac.

Y. Leak-Detection And Monitoring System
1. Cable and Sensor System: Comply with UL 1238.
   a. Calibrated, leak-detection and monitoring system with probes and other sensors and remote alarm panel for fuel-oil storage tanks and fuel-oil piping.
   b. Include fittings and devices required for testing.
   c. Controls: Electrical, operating on 120-V ac.
   d. Calibrated, liquid-level gage complying with UL 180 with floats **OR** UL 1238 with probes, **as directed,** or other sensors and remote annunciator panel.

e. Remote Annunciator Panel: With visual and audible, high-tank-level and low-tank-level alarms, fuel indicator with registration in gallons (liters), and overfill alarm. Include gage volume range that covers fuel-oil storage capacity.
f. Controls: Electrical, operating on 120-V ac.

2. Hydrostatic System: Comply with UL 1238.
   a. Calibrated, leak-detection and monitoring system with brine antifreeze solution, reservoir sensor, and electronic control panel to monitor leaks in inner and outer tank walls.
   b. Include fittings and devices required for testing.
   c. Controls: Electrical, operating on 120-V ac.
   d. Calibrated, liquid-level gage complying with UL 180 with floats **OR** UL 1238 with probes, **as directed**, or other sensors and remote annunciator panel.
   e. Remote Annunciator Panel: With visual and audible, high-tank-level and low-tank-level alarms, fuel indicator with registration in gallons (liters), and overfill alarm. Include gage volume range that covers fuel-oil storage capacity.
   f. Controls: Electrical, operating on 120-V ac.

Z. Fuel Oil
1. Fuel Oil: ASTM D 396, Grade No. 1 **OR** No. 2, **as directed**.
2. Diesel Fuel Oil: ASTM D 975, Grade Low Sulfur **OR** No. 1-D, special-purpose **OR** No. 2-D, general-purpose, **as directed**, high volatility.

AA. Sleeves
1. Steel Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, galvanized steel, plain ends.
2. Cast-Iron Pipe Sleeves: Cast or fabricated "wall pipe," equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop unless otherwise indicated.

BB. Mechanical Sleeve Seals
1. Description: Modular sealing element unit, designed for field assembly, to fill annular space between pipe and sleeve.
   a. Sealing Elements: EPDM **OR** NBR, **as directed**, interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe and sleeve.
   b. Pressure Plates: Plastic **OR** Carbon steel **OR** Stainless steel, **as directed**.
   c. Connecting Bolts and Nuts: Carbon steel with corrosion-resistant coating **OR** Stainless steel, **as directed**, of length required to secure pressure plates to sealing elements. Include one nut and bolt for each sealing element.

CC. Escutcheons
1. General Requirements for Escutcheons: Manufactured wall and ceiling escutcheons and floor plates, with ID to fit around pipe or tube and with OD that completely covers opening.
2. One-Piece, Deep-Pattern Escutcheons: Deep-drawn brass with polished chrome-plated finish.
3. One-Piece, Cast-Brass Escutcheons: With set screw.
   a. Finish: Polished chrome-plated **OR** Rough brass, **as directed**.
4. Split-Casting, Cast-Brass Escutcheons: With concealed hinge and set screw.
   a. Finish: Polished chrome-plated **OR** Rough brass, **as directed**.
5. One-Piece, Stamped-Steel Escutcheons: With set screw **OR** spring clips, **as directed**, and chrome-plated finish.
6. Split-Plate, Stamped-Steel Escutcheons: With concealed **OR** exposed-rivet, **as directed**, hinge, set screw **OR** spring clips, **as directed**, and chrome-plated finish.
7. One-Piece, Floor-Plate Escutcheons: Cast-iron floor plate.
8. Split-Casting, Floor-Plate Escutcheons: Cast brass with concealed hinge and set screw.

DD. Grout
1. Description: ASTM C 1107, Grade B, nonshrink and nonmetallic, dry hydraulic-cement grout.

a. Characteristics: Posthardening, volume adjusting, nonstaining, noncorrosive, nongaseous, and recommended for interior and exterior applications.
b. Design Mix: 5000-psi (34.5-MPa), 28-day compressive strength.
c. Packaging: Premixed and factory packaged.

EE. Labeling And Identifying
1. Detectable Warning Tape: Acid- and alkali-resistant, PE film warning tape manufactured for marking and identifying underground utilities, a minimum of 6 inches (152 mm) wide and 4 mils (0.1 mm) thick, continuously inscribed with a description of utility, with metallic core encased in a protective jacket for corrosion protection, detectable by metal detector when tape is buried up to 30 inches (762 mm) deep; colored yellow.

FF. Concrete Manholes
1. Precast Concrete Manhole Sections: ASTM C 478 (ASTM C 478M), base and concentric-cone sections with integral ladder or steps.
2. Cast-Iron Frame and Cover: Heavy-duty, water-resistant, cast-iron manhole frame, gasket, and bolted cover; 24-inch- (609-mm-) diameter, inside opening dimension; 8-inch (203-mm) frame riser height.

GG. Source Quality Control
1. Pressure test and inspect fuel-oil storage tanks, after fabrication and before shipment, according to ASME and the following:
a. Vertical **OR** Horizontal, **as directed**, Single-Wall Steel ASTs: UL 142.
b. Vertical **OR** Horizontal, **as directed**, Double-Wall Steel ASTs: UL 142, STI F921, and STI R931.
c. Horizontal, Containment-Dike, Steel ASTs: UL 142 and STI F911.
d. Horizontal, Concrete-Vaulted **OR** Concrete-Vaulted and Insulated **OR** Insulated, **as directed**, Steel ASTs: UL 142 and UL 2085.
e. Horizontal, Steel USTs with the STI-P3 Corrosion-Protection System: UL 58 and STI P3.
f. Composite **OR** Composite and Jacketed **OR** Jacketed, **as directed**, Steel USTs: UL 58.
g. FRP USTs: UL 1316.
2. Affix standards organization's code stamp.

1.3 EXECUTION

A. Earthwork
1. Comply with requirements in Division 31 Section "Earth Moving" for excavating, trenching, and backfilling.

B. Preparation
1. Close equipment shutoff valves before turning off fuel oil to premises or piping section.
2. Comply with NFPA 30 and NFPA 31 requirements for prevention of accidental ignition.

C. Outdoor Piping Installation
1. Install underground fuel-oil piping buried at least 18 inches (457 mm) below finished grade. Comply with requirements in Division 31 Section "Earth Moving" for excavating, trenching, and backfilling.
a. If fuel-oil piping is installed with less than 12 inches (305 mm) of cover to finished grade, install in containment piping.
2. Steel Piping with Protective Coating:
a. Apply joint cover kits to pipe after joining, to cover, seal, and protect joints.
b. Repair damage to PE coating on pipe as recommended in writing by protective coating manufacturer. Review protective coating damage prior to repair.
OR
Replace pipe having damaged PE coating with new pipe.

3. Install double-containment, fuel-oil pipe at a minimum slope of 1 percent downward toward fuel-oil storage tank sump.
4. Install vent pipe at a minimum slope of 2 percent downward toward fuel-oil storage tank sump.
5. Assemble and install entry boots for pipe penetrations through sump sidewalls for liquid-tight joints.
6. Install metal pipes and tubes, fittings, valves, and flexible connectors at piping connections to AST and UST.
7. Install fittings for changes in direction in rigid pipe.
8. Install system components with pressure rating equal to or greater than system operating pressure.
9. Aboveground, Exterior-Wall Pipe Penetrations: Seal penetrations using steel pipe sleeves and mechanical sleeve seals. Install sleeve size to allow for 1-inch (25-mm) annular clear space between pipe and sleeve for installing mechanical sleeve seals.
10. Underground, Exterior-Wall Pipe Penetrations: Install cast-iron "wall pipes" for sleeves. Seal pipe penetrations using mechanical sleeve seals. Select sleeve size to allow for 1-inch (25-mm) annular clear space between pipe and sleeve for installing mechanical sleeve seals.
11. Mechanical Sleeve Seal Installation: Position pipe in center of sleeve. Assemble mechanical sleeve seals and install in annular space between pipe and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.
12. Install pressure gage on suction **OR** suction and discharge, **as directed**, from each pump. Pressure gages are specified in Division 23 Section "Meters And Gages For Hvac Piping".

D. Indoor Piping Installation
1. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.
2. Arrange for pipe spaces, chases, slots, sleeves, and openings in building structure during progress of construction, to allow for mechanical installations.
3. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.
4. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.
5. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
6. Install piping free of sags and bends.
7. Install fittings for changes in direction and branch connections.
8. Install escutcheons for penetrations of walls, ceilings, and floors.
   a. New Piping:
      1) Piping with Fitting or Sleeve Protruding from Wall: One-piece, deep-pattern type.
      2) Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, cast-brass type with polished chrome-plated finish.
         OR
         Piping at Wall and Floor Penetrations in Finished Spaces: One-piece, stamped-steel type.
      3) Piping at Ceiling Penetrations in Finished Spaces: One-piece **OR** Split-casting, **as directed**, cast-brass type with polished chrome-plated finish.
         OR
         Piping at Ceiling Penetrations in Finished Spaces: One-piece, stamped-steel type **OR** Split-plate, stamped-steel type with concealed hinge, **as directed**, and set screw.
      4) Piping in Unfinished Service Spaces: One-piece, cast-brass type with polished chrome-plated **OR** rough-brass, **as directed**, finish.
         OR

Piping in Unfinished Service Spaces: One-piece, stamped-steel type with set screw **OR** spring clips, **as directed**.

5) Piping in Equipment Rooms: One-piece, cast-brass type.
OR
Piping in Equipment Rooms: One-piece, stamped-steel type with set screw **OR** spring clips, **as directed**.

6) Piping at Floor Penetrations in Equipment Rooms: One-piece, floor-plate type.

9. Existing Piping:
   1) Piping at Wall and Floor Penetrations in Finished Spaces: Split-casting, cast-brass type with chrome-plated finish.
   OR
   Piping at Wall and Floor Penetrations in Finished Spaces: Split-plate, stamped-steel type with concealed hinge and spring clips.
   2) Piping at Ceiling Penetrations in Finished Spaces: Split-casting, cast-brass type with chrome-plated finish.
   OR
   Piping at Ceiling Penetrations in Finished Spaces: Split-plate, stamped-steel type with concealed hinge and set screw.
   3) Piping in Unfinished Service Spaces: Split-casting, cast-brass type with polished chrome-plated **OR** rough-brass, **as directed**, finish.
   OR
   Piping in Unfinished Service Spaces: Split-plate, stamped-steel type with concealed **OR** exposed-rivet, **as directed**, hinge and set screw or spring clips.
   4) Piping in Equipment Rooms: Split-casting, cast-brass type.
   OR
   Piping in Equipment Rooms: Split-plate, stamped-steel type with set screw or spring clips.
   5) Piping at Floor Penetrations in Equipment Rooms: Split-casting, floor-plate type.
10. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with requirements in Division 07 Section "Penetration Firestopping".
11. Verify final equipment locations for roughing-in.
12. Comply with requirements for equipment specifications in Division 14 AND Division 21 for roughing-in requirements.
13. Conceal pipe installations in walls, pipe spaces, or utility spaces; above ceilings; below grade or floors; and in floor channels unless indicated to be exposed to view.
14. Prohibited Locations:
    a. Do not install fuel-oil piping in or through circulating air ducts, clothes or trash chutes, chimneys or gas vents (flues), ventilating ducts, or dumbwaiter or elevator shafts.
    b. Do not install fuel-oil piping in solid walls or partitions.
15. Use eccentric reducer fittings to make reductions in pipe sizes. Install fittings with level side down.
16. Connect branch piping from top or side of horizontal piping.
17. Install unions in pipes NPS 2 (DN 50) and smaller at final connection to each piece of equipment and elsewhere as indicated. Unions are not required on flanged devices.
18. Do not use fuel-oil piping as grounding electrode.
19. Install Y-pattern **OR** basket **OR** T-pattern, **as directed**, strainer on inlet side of fuel-oil pump.

E. Valve Installation
1. Install manual fuel-oil shutoff valves on branch connections to fuel-oil appliance.
2. Install valves in accessible locations.
3. Protect valves from physical damage.
4. Install metal tag attached with metal chain indicating fuel-oil piping systems.
5. Identify valves as specified in Division 23 Section "Identification For Hvac Piping And Equipment".
6. Install oil safety valves at inlet of each oil-fired appliance.

7. Install pressure relief valves in distribution piping between the supply and return lines.
8. Install one-piece, bronze ball valve with hose end connection at low points in fuel-oil piping.
9. Install manual air vents at high points in fuel-oil piping.
10. Install emergency shutoff valves at dispensers (for systems with fuel-oil or diesel-fuel-oil dispensers).

F. Piping Joint Construction
1. Ream ends of pipes and tubes and remove burrs.
2. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
3. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
   a. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
   b. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
4. Welded Joints: Construct joints according to AWS D10.12/D10.12M, using qualified processes and welding operators according to "Quality Assurance" Article.
   a. Bevel plain ends of steel pipe.
   b. Patch factory-applied protective coating as recommended by manufacturer at field welds and where damage to coating occurs during construction.
5. Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter.
6. Flanged Joints: Install gasket material, size, type, and thickness for service application. Install gasket concentrically positioned.
7. Flared Joints: Comply with SAE J513. Tighten finger tight, then use wrench according to fitting manufacturer's written recommendations. Do not overtighten.
8. Fiberglass-Bonded Joints: Prepare pipe ends and fittings, apply adhesive, and join according to pipe manufacturer's written instructions.

G. Fuel-Oil AST Installation
1. Install tank bases and supports.
2. Connect piping and vent fittings.
3. Install ground connections.
4. Install tank leak-detection and monitoring devices.
5. Install steel ASTs according to STI R912.
6. Install insulated and concrete-vaulted, steel ASTs according to STI R942.
7. Fill storage tanks with fuel oil.

H. Fuel-Oil UST Installation
1. Excavate to sufficient depth for a minimum of 3 feet (1 m) of earth cover from top of tank to finished grade. Allow for cast-in-place, concrete-ballast base plus 6 inches (150 mm) of sand or pea gravel between ballast base and tank. Extend excavation at least 12 inches (300 mm) around perimeter of tank.
2. Set tie-down eyelets for hold-down straps in concrete-ballast base and tie to reinforcing steel.
3. Place 6 inches (152 mm) of clean sand or pea gravel on top of concrete-ballast base.
4. Set tank on fill materials and install hold-down straps.
5. Connect piping.
6. Install tank leak-detection and monitoring devices.
7. Install containment sumps.
8. Backfill excavation with clean sand or pea gravel in 12-inch (305-mm) lifts and tamp backfill lift to consolidate.
9. Install filter mat between top of backfill material and earth fill.
10. Install steel USTs with the STI-P3 corrosion-protection system according to STI R821 and STI R891. Protect anodes during tank placement and backfilling operations.

11. Install composite, steel USTs according to STI R913 and STI R891.
12. Install jacketed, steel USTs according to STI R923 and STI R891.
13. Install FRP USTs with FRP hold-down straps, manhole extensions, and manhole risers.
14. Fill storage tanks with fuel oil.

I. Hanger And Support Installation
1. Pipe hanger and support and equipment support materials and installation requirements are specified in Division 23 Section "Hangers And Supports For Hvac Piping And Equipment".
2. Install hangers for horizontal steel piping with the following maximum spacing and minimum rod sizes:
   a. NPS 1-1/4 (DN 32) and Smaller: Maximum span, 84 inches (2130 mm); minimum rod size, 3/8 inch (10 mm).
   b. NPS 1-1/2 (DN 40): Maximum span, 108 inches (2740 mm); minimum rod size, 3/8 inch (10 mm).
   c. NPS 2 (DN 50): Maximum span, 10 feet (3 m); minimum rod size, 3/8 inch (10 mm).
   d. NPS 2-1/2 (DN 65): Maximum span, 11 feet (3.4 m); minimum rod size, 1/2 inch (13 mm).
   e. NPS 3 (DN 80): Maximum span, 12 feet (3.7 m); minimum rod size, 1/2 inch (13 mm).
   f. NPS 4 (DN 100): Maximum span, 13 feet (4 m); minimum rod size, 5/8 inch (16 mm).
3. Support vertical steel pipe at each floor and at spacing not greater than 15 feet (4.5 m).
4. Install hangers for horizontal, drawn-temper copper tubing with the following maximum spacing and minimum rod sizes:
   a. NPS 3/4 (DN 20) and Smaller: Maximum span, 60 inches (1524 mm); minimum rod size, 3/8 inch (10 mm).
   b. NPS 1 (DN 25): Maximum span, 72 inches (1830 mm); minimum rod size, 3/8 inch (10 mm).
   c. NPS 1-1/4 (DN 32): Maximum span, 84 inches (2130 mm); minimum rod size, 3/8 inch (10 mm).
   d. NPS 1-1/2 and NPS 2 (DN 40 and DN 50): Maximum span, 96 inches (2440 mm); minimum rod size, 3/8 inch (10 mm).
   e. NPS 2-1/2 (DN 65): Maximum span, 108 inches (2740 mm); minimum rod size, 1/2 inch (13 mm).
   f. NPS 3 (DN 80): Maximum span, 10 feet (3 m); minimum rod size, 1/2 inch (13 mm).
   g. NPS 4 (DN 100): Maximum span, 11 feet (3.4 m); minimum rod size, 5/8 inch (16 mm).
5. Support vertical copper tube at each floor and at spacing not greater than 10 feet (3 m).

J. Fuel-Oil Pump Installation
1. Submersible Pumps:
   a. Suspend pumps from supply piping and anchored to bottom of tank.
2. Transfer Pumps:
   a. Install pumps with access space for periodic maintenance including removal of motors, impellers, and accessories.
   b. Set pumps on and anchor to concrete base.
3. Install two-piece, full-port ball valves at suction and discharge of pumps.
4. Install mechanical leak-detector valves at pump discharge.
5. Install Y-pattern **OR** basket **OR** T-pattern, **as directed**, strainer on inlet side of simplex fuel-oil pumps.
6. Install check valve on discharge of simplex fuel-oil pumps.
7. Install suction piping with minimum fittings and change of direction.
8. Install vacuum and pressure gage, upstream and downstream respectively, at each pump to measure the differential pressure across the pump. Pressure gages are specified in Division 23 Section "Meters And Gages For Hvac Piping".

K. Fuel Maintenance System Installation
1. Install suction line, with foot valve, at one end of storage tank, 1 inch (25 mm) from the bottom of tank.
2. Install return line at the opposite end of storage tank from suction line.

L. Liquid-Level Gage System Installation
1. Install liquid-level gage system. Locate panel inside building where indicated.

M. Leak-Detection And Monitoring System Installation
1. Install leak-detection and monitoring system. Install alarm panel inside building where indicated.
   a. Double-Wall, Fuel-Oil Storage Tanks: Install probes **OR** Install probes or use factory-installed integral probes **OR** Use factory-installed integral probes, **as directed**, in interstitial space.
   b. Single-Wall, Fuel-Oil Storage Tanks: Install probes as indicated.
   c. Double-Containment, Fuel-Oil Piping: Install leak-detection sensor probes in fuel-oil storage tank containment sumps and at low points in piping **OR** cable probes in interstitial space of double-containment piping, **as directed**.
   d. Install liquid-level gage.

N. Connections
1. Install piping adjacent to equipment to allow service and maintenance.
2. Install unions, in piping NPS 2 (DN 50) and smaller, adjacent to each valve and at final connection to each piece of equipment having threaded pipe connection.
3. Install flanges, in piping NPS 2-1/2 (DN 65) and larger, adjacent to flanged valves and at final connection to each piece of equipment having flanged pipe connection.
4. Connect piping to equipment with ball valve and union. Install union between valve and equipment.
5. Install flexible piping connectors at final connection to burners or oil-fired appliances that must be moved for maintenance access.

O. Labeling And Identifying
1. Nameplates, pipe identification, and signs are specified in Division 23 Section "Identification For Hvac Piping And Equipment".
   OR
   Equipment Nameplates and Signs: Install engraved plastic-laminate equipment nameplates and signs on or near each service regulator, service meter, and earthquake valve.
   a. Text: In addition to identifying unit, distinguish between multiple units, inform operator of operational requirements, indicate safety and emergency precautions, and warn of hazards and improper operations.
2. Install detectable warning tape directly above fuel-oil piping, 12 inches (304 mm) below finished grade, except 6 inches (152 mm) below subgrade under pavements and slabs. Terminate tracer wire in an accessible area, and identify as "tracer wire" for future use with plastic-laminate sign.
   a. Piping: Over underground fuel-oil distribution piping.
   b. Fuel-Oil Storage Tanks: Over edges of each UST.

P. Field Painting Of AST
1. If shop painting AST, prepare and touch up damaged exterior surface of AST and supports, **as directed**, as specified in "Shop Painting of AST" Article.
2. If field painting AST, prepare exterior steel surface of AST and tank supports, **as directed**.
3. Field Cleaning: After fabrication, blast clean according to SSPC-SP 6/NACE No. 3 **OR** SSPC-SP 10/NACE No. 2, **as directed**.
4. After cleaning, remove dust or residue from cleaned surfaces.
5. If surfaces develop rust before prime coat is applied, repeat surface preparation.
6. Prepare surface of AST and supports, **as directed**, and apply painting systems according to specifications in Division 09 Section "High-performance Coatings" for severe **OR** moderate **OR** mild, **as directed**, environment high-gloss **OR** semigloss, **as directed**, finish for ferrous metal.

Q. Field Painting Of Aboveground Piping
1. Comply with requirements in Division 07 for painting interior and exterior fuel-oil piping.

2. Paint exposed, exterior metal piping, valves, and piping specialties, except components with factory-applied paint or protective coating.
   a. Alkyd System: MPI EXT 5.1D.
      1) Prime Coat: Alkyd anticorrosive metal primer.
      2) Intermediate Coat (for a Premium Grade system): Exterior alkyd enamel matching topcoat.
      3) Topcoat: Exterior alkyd enamel (flat) **OR** (semigloss) **OR** (gloss), **as directed**.
      4) Color: Gray, **as directed**.
3. Paint exposed, interior metal piping, valves, and piping specialties, except components with factory-applied paint or protective coating.
   a. Latex Over Alkyd Primer System: MPI INT 5.1Q.
      1) Prime Coat: Alkyd anticorrosive **OR** Quick-drying alkyd, **as directed**, metal primer.
      2) Intermediate Coat (for a Premium Grade system): Interior latex matching topcoat.
      3) Topcoat: Interior latex (flat) **OR** (low sheen) **OR** (eggshell) **OR** (satin) **OR** (semigloss) **OR** (gloss), **as directed**.
      4) Color: Gray, **as directed**.
   b. Alkyd System: MPI INT 5.1E.
      1) Prime Coat: Alkyd anticorrosive **OR** Quick-drying alkyd, **as directed**, metal primer.
      2) Intermediate Coat (for a Premium Grade system): Interior alkyd matching topcoat.
      3) Topcoat: Interior alkyd (flat) **OR** (eggshell) **OR** (semigloss) **OR** (gloss), **as directed**.
      4) Color: Gray, **as directed**.
4. Damage and Touchup: Repair marred and damaged factory-applied finishes with materials and by procedures to match original factory finish.

R. Concrete Bases
1. Concrete Bases: Anchor equipment to concrete base according to equipment manufacturer's written instructions and according to seismic codes at Project.
   a. Construct concrete bases of dimensions indicated, but not less than 4 inches (100 mm) larger in both directions than supported unit.
   b. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (457-mm) centers around the full perimeter of the base.
   c. Install epoxy-coated anchor bolts for supported equipment that extend through concrete base, and anchor into structural concrete floor.
   d. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   e. Install anchor bolts to elevations required for proper attachment to supported equipment.
   f. Use 3000-psig (20.7-MPa), **unless directed otherwise**, 28-day, compressive-strength concrete and reinforcement as specified in Division 03 Section "Cast-in-place Concrete".

S. Field Quality Control
1. Perform tests and inspections.
   a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
2. Tests and Inspections:
   a. Tanks: Minimum hydrostatic or compressed-air test pressures for fuel-oil storage tanks that have not been factory tested and do not bear the ASME code stamp or a listing mark acceptable to authorities having jurisdiction:
      1) Single-Wall Tanks: Minimum 3 psig (20.7 kPa) and maximum 5 psig (34.5 kPa).
      2) Double-Wall Tanks:
         a) Inner Tanks: Minimum 3 psig (20.7 kPa) and maximum 5 psig (34.5 kPa).
         b) Interstitial Space: Minimum 3 psig (20.7 kPa) and maximum 5 psig (34.5 kPa), or 5.3-in. Hg (18-kPa) vacuum.

3) Where vertical height of fill and vent pipes is such that the static head imposed on the bottom of the tank is greater than 10 psig (69 kPa), hydrostatically test the tank and fill and vent pipes to a pressure equal to the static head thus imposed.
4) Maintain the test pressure for one hour.

b. Piping: Minimum hydrostatic or pneumatic test-pressures measured at highest point in system:
1) Fuel-Oil Distribution Piping: Minimum 5 psig (34.5 kPa) for minimum 30 minutes.
2) Fuel-Oil, Double-Containment Piping:
a) Carrier Pipe: Minimum 5 psig (34.5 kPa) for minimum 30 minutes.
b) Containment Conduit: Minimum 5 psig (34.5 kPa) for minimum 60 minutes.
3) Suction Piping: Minimum 20-in. Hg (68 kPa) for minimum 30 minutes.
4) Isolate storage tanks if test pressure in piping will cause pressure in storage tanks to exceed 10 psig (69 kPa).

c. Inspect and test fuel-oil piping according to NFPA 31, "Tests of Piping" Paragraph; and according to requirements of authorities having jurisdiction.

d. Test liquid-level gage for accuracy by manually measuring fuel-oil levels at not less than three **OR** four **OR** five, **as directed**, different depths while filling tank and checking against gage indication.

e. Test leak-detection and monitoring system for accuracy by manually operating sensors and checking against alarm panel indication.

f. Start fuel-oil transfer pumps to verify for proper operation of pump and check for leaks.

g. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

h. Bleed air from fuel-oil piping using manual air vents.

3. Fuel-oil piping and equipment will be considered defective if it does not pass tests and inspections.

4. Prepare test and inspection reports.

T. Outdoor Piping Schedule

1. Underground fuel-oil piping shall be one of the following. Size indicated is carrier-pipe size.
a. Flexible, double-containment piping.
b. Rigid, double-containment piping.

2. Underground fuel-oil-tank fill and vent piping shall be one of the following:
a. NPS 2 (DN 50) and Smaller: Steel pipe, steel or malleable-iron threaded fittings, and threaded joints. Coat pipe and fittings with protective coating for steel piping.
b. NPS 2-1/2 (DN 65) and Larger: Steel pipe, steel welding fittings, and welded joints. Coat pipe and fittings with protective coating for steel piping.

3. Containment Conduit: Steel pipe with wrought-steel fittings and welded joints. Coat pipe and fittings with protective coating for steel piping.

4. Aboveground fuel-oil piping shall be one of the following:
a. NPS 2 (DN 50) and Smaller: Steel pipe, steel or malleable-iron threaded fittings, and threaded joints.
b. NPS 2-1/2 (DN 65) and Larger: Steel pipe, steel welding fittings, and welded joints.
c. Annealed **OR** Drawn, **as directed**,-temper copper tube with wrought-copper fittings and brazed joints.

U. Indoor Piping Schedule

1. Aboveground fuel-oil piping shall be one of the following:
a. NPS 1/2 (DN 15) and Smaller: Steel pipe, steel or malleable-iron threaded fittings, and threaded joints **OR** Annealed-temper copper pipe, wrought copper fittings, and brazed or flared joints, **as directed**.
b. NPS 5/8 to NPS 2 (DN 18 to DN 50): Steel pipe, steel or malleable-iron threaded fittings, and threaded joints **OR** Drawn temper copper pipe, wrought copper fittings, and brazed joints, **as directed**.

c. NPS 2-1/2 (DN 65) and Larger: Steel pipe, steel fittings, and welded or flanged joints **OR** Drawn temper copper pipe, wrought copper fittings, and brazed or flanged joints, **as directed**.
d. Steel pipe with malleable-iron fittings and threaded joints.
e. Steel pipe with wrought-steel fittings and welded joints.
f. Annealed-temper copper tube, brass fittings, and flared joints.
g. Drawn-temper copper tubing, copper fittings, and brazed joints.

V. Aboveground Manual Fuel-Oil Shutoff Valve Schedule
1. Distribution piping valves for pipe NPS 2 (DN 50) and smaller shall be one of the following:
   a. One-piece, bronze ball valve with bronze trim.
   b. Two-piece, full **OR** regular, **as directed**,-port, bronze ball valves with bronze trim.
2. Distribution piping valves for pipe NPS 2-1/2 (DN 65) and larger shall be one of the following:
   a. Two-piece, full **OR** regular, **as directed**,-port, bronze ball valves with bronze trim.
   b. Bronze, nonlubricated **OR** lubricated, **as directed**, plug valve.
3. Valves in branch piping for single appliance shall be one of the following:
   a. One-piece, bronze ball valve with bronze trim.
   b. Two-piece, full **OR** regular, **as directed**,-port, bronze ball valves with bronze trim.

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SECTION 23 21 13 23a - RADIANT HEATING PIPING

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for radiant heating piping. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes radiant heating piping, including pipes, fittings, and piping specialties.

C. Definitions
1. EPDM: Ethylene-propylene-diene terpolymer rubber.
2. PEX: Crosslinked polyethylene.
3. PEX/AL/PEX: Crosslinked polyethylene/aluminum/crosslinked polyethylene.

D. Submittals
1. Product Data: For each type of radiant heating pipe, fitting, manifold, specialty, and control.
   a. For radiant heating piping and manifolds, include pressure and temperature rating, oxygen-barrier performance, fire-performance characteristics, and water flow and pressure drop characteristics.
2. Shop Drawings: Show piping layout and details drawn to scale, including valves, manifolds, controls, and support assemblies, and their attachments to building structure.
3. Operation and Maintenance Data.

1.2 PRODUCTS

A. PEX Pipe And Fittings
1. Pipe Material: PEX plastic according to ASTM F 876.
2. Oxygen Barrier: Limit oxygen diffusion through the tube to maximum 0.10 mg per cu. m/day at 104 deg F (40 deg C) according to DIN 4726.
3. Fittings: ASTM F 1807, metal insert and copper crimp rings.
4. Pressure/Temperature Rating: Minimum 100 psig (690 kPa) and 180 deg F (82 deg C).

B. PEX/AL/PEX Pipe And Fittings
1. Pipe Material: PEX plastic bonded to the inside and outside of a welded aluminum tube according to ASTM F 1281.
2. Oxygen Barrier: Limit oxygen diffusion through the pipe to maximum 0.10 mg per cu. m/day at 104 deg F (40 deg C) according to DIN 4726.
3. Fittings: ASTM F 1974, metal insert fittings with split ring and compression nut (compression joint) or metal insert fittings with copper crimp rings (crimp joint).
4. Flame-Spread and Smoke-Developed Indexes: 25 and 50 or less, respectively, tested according to ASTM E 84.
5. Pressure/Temperature Rating: Minimum 100 psig (690 kPa) and 210 deg F (99 deg C).

C. EPDM Pipe And Fittings
1. Pipe Material: Crosslinked EPDM inner and outer tubes.
2. Wall Thickness: Minimum 0.125 inch (3.2 mm).
3. Oxygen Barrier: Ductile aluminum foil layer applied to the inner tube to limit oxygen diffusion through the pipe to maximum 0.10 mg per cu. m/day at 104 deg F (40 deg C) according to DIN 4726.

4. Reinforcing Braid: Braided-aluminum wire between the inner and outer tube.
5. Fittings: ASTM F 1807, copper with stainless-steel crimps or clamps.
6. Pressure/Temperature Rating: Minimum 100 psig (690 kPa) and 210 deg F (99 deg C).

D. Distribution Manifolds
1. Manifold: Minimum NPS 1 (DN 25), brass **OR** copper **OR** modular plastic **OR** stainless steel, **as directed**.
2. Main Shutoff Valves:
   a. Factory installed on supply and return connections.
   b. Two **OR** Three, **as directed**,-piece body.
   c. Body: Brass or bronze.
   d. Ball: Chrome-plated bronze.
   e. Seals: PTFE.
   f. CWP Rating: 150 psig (1035 kPa).
   g. Maximum Operating Temperature: 225 deg F (107 deg C).
3. Manual Air Vents:
   a. Body: Bronze.
   b. Internal Parts: Nonferrous.
   c. Operator: Key furnished with valve, or screwdriver bit.
   d. Inlet Connection: NPS 1/2 (DN 15).
   e. Discharge Connection: NPS 1/8 (DN 6).
   f. CWP Rating: 150 psig (1035 kPa).
   g. Maximum Operating Temperature: 225 deg F (107 deg C).
4. Balancing Valves:
   a. Body: Plastic or bronze, ball or plug, or globe cartridge type.
   b. Ball or Plug: Brass or stainless steel.
   c. Globe Cartridge and Washer: Brass with EPDM composition washer.
   d. Seat: PTFE.
   e. Visual Flow Indicator: Flowmeter with visible indication in a clear plastic cap at top of valve.
      OR
      Differential Pressure Gage Connections: Integral seals for portable meter to measure loss across calibrated orifice.
   f. Handle Style: Lever or knob, with memory stop to retain set position if used for shutoff.
   g. CWP Rating: Minimum 125 psig (860 kPa).
   h. Maximum Operating Temperature: 250 deg F (121 deg C).
5. Zone Control Valves:
   a. Body: Plastic or bronze, ball or plug, or globe cartridge type.
   b. Ball or Plug: Brass or stainless steel.
   c. Globe Cartridge and Washer: Brass with EPDM composition washer.
   d. Seat: PTFE.
   e. Actuator: Replaceable electric motor.
   f. CWP Rating: Minimum 125 psig (860 kPa).
   g. Maximum Operating Temperature: 250 deg F (121 deg C).
6. Thermometers:
   a. Mount on supply and return connections.
   b. Case: Dry type, metal or plastic, 2-inch (50-mm) diameter.
   c. Element: Bourdon tube or other type of pressure element.
   d. Movement: Mechanical, connecting element and pointer.
   e. Dial: Satin-faced, nonreflective aluminum with permanently etched scale markings.
   f. Pointer: Black metal.
   g. Window: Plastic.
   h. Connector: Rigid, back type.
   i. Thermal System: Liquid- or mercury-filled bulb in copper-plated steel, aluminum, or brass stem.

j. Accuracy: Plus or minus 1 percent of range or plus or minus 1 scale division to maximum of 1.5 percent of range.

7. Mounting Brackets: Copper, or plastic or copper-clad steel, where in contact with manifold.

E. Piping Specialties

1. Cable Ties:
   a. Fungus-inert, self-extinguishing, 1-piece, self-locking, Type 6/6 nylon cable ties.
   b. Minimum Width: 1/8 inch (3 mm).
   c. Tensile Strength: 20 lb (9 kg), minimum.
   d. Temperature Range: Minus 40 to plus 185 deg F (Minus 40 to plus 85 deg C).
2. Floor-Mounting Staples:
   a. Steel, with corrosion-resistant coating and smooth finish without sharp edges.
   b. Minimum Thickness: 3/32 inch (2.4 mm).
   c. Width: Minimum, wider than tubing.
3. Floor-Mounting Clamps:
   a. Two bolt, steel, with corrosion-resistant coating and smooth finish without sharp edges.
   b. Minimum Thickness: 3/32 inch (2.4 mm).
   c. Width: Minimum, wider than tubing.
4. Floor Mounting Tracks:
   a. Aluminum or plastic channel track with smooth finish, no sharp edges.
   b. Minimum Thickness: 1/16 inch (1.6 mm).
   c. Slot Width: Snap fit to hold tubing.
   d. Slot Spacing: 2-inch (50-mm) **OR** 3-inch (75-mm), **as directed**, intervals.
5. Channeled Subfloor:
   a. Plywood, APA-rated subfloor panel, composed of premium, tongue-and-groove, 7-layer, Douglas fir structural subfloor panels.
   b. Particleboard manufactured to meet Federal Housing Authority standards of less than 0.3-ppm formaldehyde.
   c. Clad panel with minimum 0.025-inch- (0.635-mm-) thick aluminum recessed in the grooves sized to maintain contact with radiant piping.
6. Modular Interlocking Blocks:
   a. Polypropylene snap-together blocks with grooves to support piping.
   b. Galvanized sheet metal or aluminum emission plates.
   c. Natural mineralboard cover panel.
7. Heat-Emission Plates:
   a. Formed aluminum suitable for radiant heating piping.
   b. Minimum Thickness: 1/16 inch (1.6 mm).
   c. Slot Width: Snap fit to maintain pressure fit on tubing.

F. Controls

1. Temperature-control devices and sequence of operations are specified in Division 23 Section(s) "Instrumentation And Control For Hvac" AND "Sequence Of Operations For Hvac Controls".
2. Wall-Mounting Thermostat:
   a. Minimum temperature range from 50 to 90 deg F (10 to 32 deg C).
   b. Manually operated with on-off switch.
   c. Day and night setback and clock program with minimum four periods per day.
   d. Operate pumps or open zone control valves if room temperature falls below the thermostat setting, and stop pumps or close zone control valves when room temperature rises above the thermostat setting.
3. Heated-Panel Thermostat:
   a. Remote bulb unit with adjustable temperature range from 50 to 90 deg F (10 to 32 deg C).
   b. Snap action; open-on-rise, single-pole switch with minimum current rating adequate for connected pump or zone control valve.
   c. Remote bulb on capillary tube, resistance temperature device, or thermistor for directly sensing radiant panel temperature.
   d. Stop pump or close zone control valves if heated-panel thermostat setting is exceeded.

e. Corrosion-resistant, waterproof control enclosure.

4. Heated-Panel Thermostat with Outdoor Temperature Reset:
   a. Remote bulb unit with adjustable temperature range from 50 to 90 deg F (10 to 32 deg C).
   b. Snap action; open-on-rise, single-pole switch with minimum current rating adequate for connected pump and zone control valve.
   c. Remote bulb on capillary tube, resistance temperature device, or thermistor for directly sensing radiant panel temperature.
   d. Remote bulb on capillary tube, resistance temperature device, or thermistor for directly sensing outdoor-air temperature.
   e. Operate zone control valves to reset supply-water temperature inversely with outdoor-air temperature as follows:
      1) Low outdoor-air temperature, zero deg F (minus 18 deg C) with high supply-water temperature 110 deg F (43 deg C).
      2) High outdoor-air temperature, 60 deg F (16 deg C) with low supply-water temperature 70 deg F (21 deg C).
   f. Corrosion-resistant, waterproof control enclosure.
5. Precipitation and Temperature Sensor:
   a. Microprocessor-based **OR** Automatic, **as directed**, control with manual on, automatic, and standby/reset switch.
   b. Precipitation and temperature sensors shall sense the surface conditions of pavement and shall be programmed to operate pump and zone control valves as follows:
      1) Temperature Span: 34 to 44 deg F (1 to 7 deg C).
      2) Adjustable Delay Off Span: 30 to 90 minutes.
      3) Start Pump or Open Zone Control Valves: Following two-minute delay if ambient temperature is below set point and precipitation is detected.
      4) Stop Pump or Close Zone Control Valves: On detection of a dry surface plus time delay.
   c. Corrosion-proof and waterproof enclosure suitable for outdoor mounting, for controls and precipitation and temperature sensors.
   d. Minimum 30-A contactor to start pump and open valves.
   e. Precipitation sensor shall be mounted in pavement.
   f. Provide relay with contacts to indicate operational status, on or off, for interface with central HVAC control system workstation.

1.3 EXECUTION

A. Applications
1. Install the following types of radiant heating piping for the applications described:
   a. Piping in Exterior Pavement: EPDM **OR** PEX **OR** PEX/AL/PEX, **as directed**.
   b. Piping in Interior Reinforced-Concrete Floors: EPDM **OR** PEX **OR** PEX/AL/PEX, **as directed**.
   c. Piping in Level Fill Concrete Floors (Not Reinforced): EPDM **OR** PEX **OR** PEX/AL/PEX, **as directed**.
   d. Piping in Ceilings: EPDM **OR** PEX **OR** PEX/AL/PEX, **as directed**.
   e. Piping in Subfloors: EPDM **OR** PEX **OR** PEX/AL/PEX, **as directed**.
   f. Piping below Wood Floors: EPDM **OR** PEX **OR** PEX/AL/PEX, **as directed**.

B. Installation
1. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems. Indicate piping locations and arrangements if such were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Shop or Coordination Drawings.
2. Install radiant heating piping continuous from the manifold through the heated panel and back to the manifold without piping joints in heated panels.

3. Connect radiant piping to manifold in a reverse-return arrangement.
4. Do not bend pipes in radii smaller than manufacturer's minimum bend radius dimensions.
5. Install manifolds in accessible locations, or install access panels to provide maintenance access as required in Division 08 Section "Access Doors And Frames".
6. Refer to Division 23 Section "Hydronic Piping" for pipes and connections to hydronic systems and for glycol-solution fill requirements.
7. Fire- and Smoke-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials according to Division 07 Section "Penetration Firestopping".
8. Piping in Exterior Pavement:
    a. Secure piping in concrete floors by attaching pipes to reinforcement using cable ties.
    b. Space cable ties a maximum of 18 inches (457 mm) o.c., and at center of turns or bends.
    c. Maintain 3-inch (75-mm) minimum cover.
    d. Install a sleeve of 3/8-inch- (9.5-mm-) thick, foam-type insulation or PE pipe around tubing and extending for a minimum of 10 inches (250 mm) on each side of slab joints to protect the tubing passing through expansion or control joints. Anchor sleeve to slab form at control joints to provide maximum clearance for saw cut.
    e. Maintain minimum 40-psig (275-kPa) pressure in piping during concrete placement and continue for 24 hours after placement.
9. Piping in Interior Reinforced-Concrete Floors:
    a. Secure piping in concrete floors by attaching pipes to reinforcement using cable ties.
    b. Space cable ties a maximum of 18 inches (457 mm) o.c., and at center of turns or bends.
    c. Maintain 2-inch (50-mm) minimum cover.
    d. Install a sleeve of 3/8-inch- (9.5-mm-) thick, foam-type insulation or PE pipe around tubing and extending for a minimum of 10 inches (250 mm) on each side of slab joints to protect the tubing passing through expansion or control joints. Anchor sleeve to slab form at control joints to provide maximum clearance for saw cut.
    e. Maintain minimum 40-psig (275-kPa) pressure in piping during concrete placement and continue for 24 hours after placement.
10. Piping in Level Fill Concrete Floors (Not Reinforced):
    a. Secure piping in concrete floors by attaching pipes to subfloor using tracks, clamps, or staples.
    b. Space tracks, clamps, or staples a maximum of 18 inches (457 mm) o.c., and at center of turns or bends.
    c. Maintain 3/4-inch (19-mm) minimum cover.
    d. Install a sleeve of 3/8-inch- (9.5-mm-) thick, foam-type insulation or PE pipe around tubing and extending for a minimum of 10 inches (250 mm) on each side of slab joints to protect the tubing passing through expansion or control joints. Anchor sleeve to slab form at control joints to provide maximum clearance for saw cut.
    e. Maintain minimum 40-psig (275-kPa) pressure in piping during the concrete pour and continue for 24 hours during curing.
11. Piping in Ceiling:
    a. Secure piping by attaching pipes to ceiling substrate using clamps or staples.
    b. Space clamps or staples a maximum of 18 inches (457 mm) o.c., and at center of turns or bends.
    c. Maintain 1-1/2-inch (38-mm) minimum plaster cover.
    d. Maintain minimum 40-psig (275-kPa) pressure in piping during the plaster application and continue for 24 hours during curing.
12. Piping in Subfloor:
    a. Secure piping by laying piping in subfloor channels or modular interlocking blocks.
    b. Use straight channel panels or blocks in the center, and curved channel panels or blocks at the ends.
    c. Finish floor with mineralboard panel cover or finished floor surface.
13. Piping below Wood Floor:
    a. Secure piping by attaching pipes to subfloor using heat-emission plates, clamps, or staples.

b. Space heat-emission plates, clamps, or staples a maximum of 4 inches (100 mm) o.c., and at center of turns or bends.
c. Install heat-emission plates on underside of wood subfloor with maximum space between plates, as noted above, to maintain pipe contact with floor.

14. Revise locations and elevations from those indicated as required to suit field conditions and ensure integrity of piping and as approved.
15. After system balancing has been completed, mark balancing valves to permanently indicate final position.
16. Perform the following adjustments before operating the system:
    a. Open valves to fully open position.
    b. Check operation of automatic valves.
    c. Set temperature controls so all zones call for full flow.
    d. Purge air from piping.
17. After the concrete or plaster heating panel has cured as recommended by concrete or plaster supplier, operate radiant heating system as follows:
    a. Start system heating at a maximum of 10 deg F (6 deg C) above the ambient radiant panel temperature, and increase 10 deg F (6 deg C) each following day until design temperature is achieved.
    b. For freeze protection, operate at a maximum of 60 deg F (16 deg C) supply-water temperature.

C. Field Quality Control
1. Prepare radiant heating piping for testing as follows:
    a. Open all isolation valves and close bypass valves.
    b. Open and verify operation of zone control valves.
    c. Flush with clean water, and clean strainers.
2. Tests and Inspections:
    a. Leak Test: After installation, charge system and test for leaks. Subject piping to hydrostatic test pressure that is not less than 1.5 times the design pressure but not more than 100 psig (690 kPa). Repair leaks and retest until no leaks exist.
    b. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
3. Remove and replace malfunctioning radiant heating piping components that do not pass tests, and retest as specified above.
4. Prepare a written report of testing.

END OF SECTION 23 21 13 23a

Task	Specification	Specification Description
23 21 13 23	22 05 23 00	Piped Utilities Basic Materials And Methods
23 21 13 23	23 11 23 00	Relief Wells
23 21 13 23	21 05 19 00	Water Distribution
23 21 13 23	23 11 23 00a	Monitoring Wells
23 21 13 23	22 11 23 39	Water Supply Wells
23 21 13 23	22 05 76 00	Sanitary Sewerage
23 21 13 23	23 05 29 00	Steam Distribution
23 21 13 23	07 63 00 00	Common Work Results for Fire Suppression
23 21 13 23	07 63 00 00a	Common Work Results for Plumbing
23 21 13 23	07 63 00 00b	Common Work Results for HVAC
23 21 13 23	22 11 16 00	Domestic Water Piping
23 21 13 23	22 11 16 00a	Sanitary Waste And Vent Piping
23 21 13 23	22 11 16 00b	Storm Drainage Piping
23 21 13 23	22 11 16 00c	Hydronic Piping
23 21 13 23	22 11 16 00d	Steam And Condensate Piping
23 21 13 23	22 11 16 00e	Refrigerant Piping
23 21 13 23	23 11 23 00b	Facility Natural-Gas Piping
23 21 13 23	23 11 23 00c	Facility Liquefied-Petroleum Gas Piping
23 21 13 23	22 11 16 00f	General-Service Compressed-Air Piping
23 21 13 23	22 11 16 00g	Compressed-Air Piping For Laboratory And Healthcare Facilities
23 21 13 23	22 11 16 00h	Vacuum Piping For Laboratory And Healthcare Facilities
23 21 13 23	22 11 16 00i	Gas Piping For Laboratory And Healthcare Facilities
23 21 16 00	01 22 16 00	No Specification Required
23 21 16 00	22 05 23 00	Piped Utilities Basic Materials And Methods
23 21 16 00	21 05 19 00	Water Distribution
23 21 16 00	23 05 29 00	Steam Distribution
23 21 16 00	22 12 23 26	Underground Storage Tanks
23 21 16 00	07 63 00 00	Common Work Results for Fire Suppression
23 21 16 00	07 63 00 00a	Common Work Results for Plumbing
23 21 16 00	07 63 00 00b	Common Work Results for HVAC
23 21 16 00	22 11 16 00c	Hydronic Piping
23 21 16 00	22 11 16 00d	Steam And Condensate Piping
23 21 16 00	22 11 16 00e	Refrigerant Piping
23 21 16 00	22 11 23 39a	Hydronic Pumps
23 21 16 00	23 21 13 23	Facility Fuel-Oil Piping
23 21 16 00	22 11 16 00f	General-Service Compressed-Air Piping
23 21 23 13	22 05 23 00	Piped Utilities Basic Materials And Methods
23 21 23 13	22 11 23 39	Water Supply Wells
23 21 23 13	22 11 23 39a	Hydronic Pumps
23 21 23 16	22 05 23 00	Piped Utilities Basic Materials And Methods
23 21 23 16	22 11 23 39	Water Supply Wells
23 21 23 16	22 11 23 39a	Hydronic Pumps

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SECTION 23 21 23 23 - ELECTRIC-DRIVE, VERTICAL-TURBINE FIRE PUMPS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for electric-drive, vertical-turbine fire pumps. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Vertical-turbine fire pumps.
b. Fire-pump accessories and specialties.
c. Flowmeter systems.

C. Performance Requirements
1. Seismic Performance: Fire pumps shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
2. Pump Equipment, Accessory, and Specialty Pressure Rating: 175 psig (1200 kPa) minimum unless higher pressure rating is indicated.

D. Submittals
1. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, performance curves, electrical characteristics, and furnished specialties and accessories.
2. Shop Drawings: For fire pumps, motor drivers, and fire-pump accessories and specialties. Include plans, elevations, sections, details, and attachments to other work.
a. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
b. Wiring Diagrams: For power, signal, and control wiring.
3. Seismic Qualification Certificates: For fire pumps, accessories, and components, from manufacturer.
a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
4. Product Certificates: For each fire pump, from manufacturer.
5. Source quality-control reports.
6. Field quality-control reports.
7. Operation and maintenance data.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. NFPA Compliance: Comply with NFPA 20, "Installation of Stationary Pumps for Fire Protection."

1.2 PRODUCTS

A. General Requirements For Vertical-Turbine Fire Pumps
   1. Description: Factory-assembled and -tested fire-pump and driver unit.
   2. Base: Fabricated and attached to fire-pump and driver unit with reinforcement to resist movement of pump during seismic events when base is anchored to building substrate.
   3. Finish: Red paint applied to factory-assembled and -tested unit before shipping.

B. Vertical-Turbine Fire Pumps
   1. Pump Head: Cast iron, for surface discharge.
      a. Discharge Outlet: With flange according to ASME B16.1 except connections may be threaded according to ASME B1.20.1, in sizes where flanges are not available.
      b. Pump Head Seal: Stuffing box and packing.
      c. Base: Cast iron or steel with hole for electrical cable.
   2. Pump:
      a. Standard: UL 448, for vertical-turbine pumps for fire service.
      b. Line Shaft: Stainless steel or steel, with corrosion-resistant shaft sleeves.
      c. Line Shaft Bearings: Rubber sleeve, water lubricated.
      d. Line Shaft: Steel.
      e. Line Shaft Bearings: Corrosion resistant, oil lubricated.
      f. Impeller Shaft: Monel metal or stainless steel.
      g. Bowl Section: Multiple cast-iron bowls with closed-type bronze or stainless-steel impellers.
      h. Column Pipe: ASTM A 53/A 53M, Schedule 40, galvanized-steel pipe with threaded ends and cast-iron or steel fittings, in sections 10 feet (3 m) or less.
      i. Suction Strainer: Cast or fabricated, bronze or stainless steel, and sized to restrict passage of 0.5-inch (12.7-mm) spheres.
   3. Driver:
      a. Standard: UL 1004A.
      b. Type: Electric motor; NEMA MG 1, polyphase Design B.
      c. Mounting: On pump head above pump.

C. Fire-Pump Accessories And Specialties
   1. Automatic Air-Release Valves: Comply with NFPA 20 for installation in fire-pump discharge piping.
   2. Relief Valves:
      a. Description: UL 1478, bronze or cast iron, spring loaded; for installation in fire-suppression water-supply piping.
   3. Outlet Fitting: Concentric tapered reducer at pump-head discharge outlet.
   4. Discharge Cone: Closed **OR** Open, **as directed**, type.
   5. Hose Valve Manifold Assembly:
      a. Standard: Comply with requirements in NFPA 20.
      b. Header Pipe: ASTM A 53/A 53M, Schedule 40, galvanized steel with ends threaded according to ASME B1.20.1.
      c. Header Pipe Fittings: ASME B16.4, galvanized cast-iron threaded fittings.
      d. Automatic Drain Valve: UL 1726.
      e. Manifold:
         1) Test Connections: Comply with UL 405 except provide outlets without clappers instead of inlets.
         2) Body: Flush type, brass or ductile iron, with number of outlets required by NFPA 20.
         3) Nipples: ASTM A 53/A 53M, Schedule 40, galvanized-steel pipe with ends threaded according to ASME B1.20.1.
         4) Adapters and Caps with Chain: Brass or bronze, with outlet threaded according to NFPA 1963 and matching local fire-department threads.
         5) Escutcheon Plate: Brass or bronze; rectangular.
         6) Hose Valves: UL 668, bronze, with outlet threaded according to NFPA 1963 and matching local fire-department threads.

7) Exposed Parts Finish: Polished **OR** Rough, **as directed**, brass, **as directed**, chrome plated, **as directed**.
8) Escutcheon Plate Marking: Equivalent to "FIRE PUMP TEST."

OR

Manifold:
1) Test Connections: Comply with UL 405 except provide outlets without clappers instead of inlets.
2) Body: Exposed type, brass, with number of outlets required by NFPA 20.
3) Escutcheon Plate: Brass or bronze; round.
4) Hose Valves: UL 668, bronze, with outlet threaded according to NFPA 1963 and matching local fire-department threads. Include caps and chains.
5) Exposed Parts Finish: Polished **OR** Rough, **as directed**, brass, **as directed**, chrome plated, **as directed**.
6) Escutcheon Plate Marking: Equivalent to "FIRE PUMP TEST."

D. Flowmeter Systems
1. Description: UL-listed or FM-Approved, fire-pump flowmeter system with capability to indicate flow to not less than 175 percent of fire-pump rated capacity.
2. Pressure Rating: 175 psig (1200 kPa) minimum **OR** 250 psig (1725 kPa), **as directed**.
3. Sensor: Annubar probe, orifice plate, or venturi unless otherwise indicated. Sensor size shall match pipe, tubing, flowmeter, and fittings.
4. Permanently Mounted Flowmeter: Compatible with flow sensor; with dial not less than 4-1/2 inches (115 mm) in diameter. Include bracket or device for wall mounting.
   a. Tubing Package: NPS 1/8 or NPS 1/4 (DN 6 or DN 10) soft copper **OR** plastic, **as directed**, tubing with copper or brass fittings and valves.

   OR

   Portable Flowmeter: Compatible with flow sensor; with dial not less than 4-1/2 inches (115 mm) in diameter and with two 12-foot- (3.7-m-) long hoses in carrying case.

E. Grout
1. Standard: ASTM C 1107, Grade B, post-hardening and volume-adjusting, dry, hydraulic-cement grout.
2. Characteristics: Nonshrink and recommended for interior and exterior applications.
3. Design Mix: 5000-psi (34-MPa), 28-day compressive strength.
4. Packaging: Premixed and factory packaged.

F. Source Quality Control
1. Testing: Test and inspect fire pumps according to UL 448 requirements for "Operation Test" and "Manufacturing and Protection Tests."
   a. Verification of Performance: Rate fire pumps according to UL 448.
2. Fire pumps will be considered defective if they do not pass tests and inspections.
3. Prepare test and inspection reports.

1.3 EXECUTION

A. Installation
1. Fire-Pump Installation Standard: Comply with NFPA 20 for installation of fire pumps, relief valves, and related components.
2. Equipment Mounting: Install fire pumps on concrete bases. Comply with requirements for concrete bases specified in Division 03 Section "Cast-in-place Concrete".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.

c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
d. Install anchor bolts to elevations required for proper attachment to supported equipment.

3. Install fire-pump discharge piping equal to or larger than size required by NFPA 20.
4. Support piping and pumps separately so weight of piping does not rest on pumps.
5. Install valves that are same size as connecting piping. Comply with requirements for fire-protection valves specified in Division 21 Section(s) "Fire-suppression Standpipes" OR "Wet-pipe Sprinkler Systems", **as directed**.
6. Install pressure gage on pump head discharge flange pressure-gage tapping. Comply with requirements for pressure gages specified in Division 21 Section(s) "Fire-suppression Standpipes" OR "Wet-pipe Sprinkler Systems", **as directed**.
7. Install flowmeters and sensors. Install flowmeter-system components and make connections according to NFPA 20 and manufacturer's written instructions.
8. Electrical Wiring: Install electrical devices furnished by equipment manufacturers but not factory mounted. Furnish copies of manufacturers' wiring diagram submittals to electrical Installer.
9. Wiring Method: Conceal conductors and cables in accessible ceilings, walls, and floors where possible.

B. Alignment
1. Align pump and driver shafts after complete unit has been leveled on concrete base, grout has set, and anchor bolts have been tightened.
2. After alignment is correct, tighten anchor bolts evenly. Fill baseplate completely with grout, with metal blocks and shims or wedges in place. Tighten anchor bolts after grout has hardened. Check alignment and make required corrections.
3. Align piping connection.
4. Align pump and driver shafts for angular and parallel alignment according to HI 2.4 and to tolerances specified by manufacturer.

C. Connections
1. Comply with requirements for piping and valves specified in Division 21 Section(s) "Fire-suppression Standpipes" OR "Wet-pipe Sprinkler Systems", **as directed**. Drawings indicate general arrangement of piping, fittings, and specialties.
2. Install piping adjacent to pumps and equipment to allow service and maintenance.
3. Connect relief-valve discharge to drainage piping or point of discharge.
4. Connect flowmeter-system meters, sensors, and valves to tubing.
5. Connect fire pumps to their controllers.

D. Identification
1. Identify system components. Comply with requirements for fire-pump marking according to NFPA 20.

E. Field Quality Control
1. Test each fire pump with its controller as a unit. Comply with requirements for electric-motor-driver fire-pump controllers specified in Division 21 Section(s) "Electric-drive, Centrifugal Fire Pumps" OR "Diesel-drive, Centrifugal Fire Pumps" OR "Electric-drive, Vertical-turbine Fire Pumps" OR "Diesel-drive, Vertical-turbine Fire Pumps"
2. Perform tests and inspections.
   a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
3. Tests and Inspections:
   a. After installing components, assemblies, and equipment including controller, test for compliance with requirements.
   b. Test according to NFPA 20 for acceptance and performance testing.

c. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
d. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
e. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

4. Components, assemblies, and equipment will be considered defective if they do not pass tests and inspections.
5. Prepare test and inspection reports.
6. Furnish fire hoses in number, size, and length required to reach storm drain or other acceptable location to dispose of fire-pump test water. Hoses are for tests only and do not convey to the Owner.

F. Startup Service
1. Perform startup service.
a. Complete installation and startup checks according to manufacturer's written instructions.

G. Demonstration
1. Train the Owner's maintenance personnel to adjust, operate, and maintain fire pumps.

END OF SECTION 23 21 23 23

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SECTION 23 21 23 23a - DIESEL-DRIVE, VERTICAL-TURBINE FIRE PUMPS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for diesel-drive, vertical-turbine fire pumps. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Vertical-turbine fire pumps.
b. Fire-pump accessories and specialties.
c. Flowmeter systems.

C. Performance Requirements
1. Seismic Performance: Fire pumps shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
2. Pump Equipment, Accessory, and Specialty Pressure Rating: 175 psig (1200 kPa) minimum unless higher pressure rating is indicated.

D. Submittals
1. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, performance curves, electrical characteristics, and furnished specialties and accessories.
2. Shop Drawings: For fire pumps, right-angle gear drives, engine drivers, and fire-pump accessories and specialties. Include plans, elevations, sections, details, and attachments to other work.
a. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
b. Wiring Diagrams: For power, signal, and control wiring.
3. Seismic Qualification Certificates: For fire pumps, accessories, and components, from manufacturer.
a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
4. Product Certificates: For each fire pump, from manufacturer.
5. Source quality-control reports.
6. Field quality-control reports.
7. Operation and maintenance data

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for location and application.
2. NFPA Compliance: Comply with NFPA 20, "Installation of Stationary Pumps for Fire Protection."

1.2 PRODUCTS

A. General Requirements For Vertical-Turbine Fire Pumps
1. Description: Factory-assembled and -tested fire pump, right-angle gear drive, and driver.
2. Base: Fabricated and attached to fire pump, right-angle gear drive, and driver with reinforcement to resist movement of pump, gear drive, and driver during seismic events when base is anchored to building substrate.
3. Finish: Red paint applied to factory-assembled and -tested unit before shipping.

B. Vertical-Turbine Fire Pumps
1. Pump Head: Cast iron, for surface discharge.
   a. Discharge Outlet: With flange according to ASME B16.1 except connections may be threaded according to ASME B1.20.1, in sizes where flanges are not available.
   b. Pump Head Seal: Stuffing box and packing.
   c. Base: Cast iron or steel with hole for electrical cable.
2. Pump:
   a. Standard: UL 448, for vertical-turbine pumps for fire service.
   b. For static water levels of 50 feet (15 m) or less and for water-lubricated bearings.
      1) Line Shaft: Stainless steel or steel, with corrosion-resistant shaft sleeves.
      2) Line Shaft Bearings: Rubber sleeve, water lubricated.
   c. For static water levels between 50 and 200 feet (15 and 61 m) and for oil-lubricated bearings.
      1) Line Shaft: Steel.
      2) Line Shaft Bearings: Corrosion resistant, oil lubricated.
   d. Impeller Shaft: Monel metal or stainless steel.
   e. Bowl Section: Multiple cast-iron bowls with closed-type bronze or stainless-steel impellers.
   f. Column Pipe: ASTM A 53/A 53M, Schedule 40, galvanized-steel pipe with threaded ends and cast-iron or steel fittings, in sections 10 feet (3 m) or less.
   g. Suction Strainer: Cast or fabricated, bronze or stainless steel, and sized to restrict passage of 0.5-inch (12.7-mm) spheres.
3. Right-Angle Gear Drive:
   a. Description: FM-Approved, speed-reduction gear drive for pump speed control. Provide ratio for outlet speed of approximately 1760 rpm.
4. Engine-to-Gear Drive Shaft: FM-Approved, telescoping, steel drive shaft with universal joint and grease fitting at each end. Include metal shaft guard.
5. Driver:
   a. Standard: UL 1247.
   b. Type: Diesel engine.
   c. Emergency Manual Operator: Factory wired for starting and operating standby engine in case of malfunction in main controller or wiring.
   d. Engine Cooling System: Factory-installed radiator.
      1) Coolant: Type recommended by driver manufacturer.

      OR

      Engine Cooling System: Factory-installed water piping, valves, strainer, pressure regulator, heat exchanger, coolant pump, bypass piping, and fittings.
      1) Piping: ASTM B 88, Type L (ASTM B 88M, Type B), copper water tube; ASME B16.22, wrought-copper, solder-joint pressure fittings; AWS A5.8/A5.8M, BCuP Series brazing filler metal; and brazed joints.
   e. Engine-Jacket Water Heater: Factory-installed electric elements.
   f. Dual Batteries: Lead-acid-storage type with 100 percent standby reserve capacity.
   g. Fuel System: According to NFPA 20.
      1) Fuel Storage Tank: Size indicated but not less than required by NFPA 20. Include floor legs, direct-reading level gage, and secondary containment tank with capacity at least equal to fuel storage tank.

h. Exhaust System: ASTM A 53/A 53M, Type E or S, Schedule 40, black steel pipe; ASME B16.9, weld-type pipe fittings; ASME B16.5, steel flanges; and ASME B16.21, nonmetallic gaskets. Fabricate double-wall, ventilated thimble from steel pipe.
   1) Exhaust Connector: Flexible type.
   2) Exhaust Silencer: Industrial **OR** Residential, **as directed**, type.

C. Fire-Pump Accessories And Specialties
1. Automatic Air-Release Valves: Comply with NFPA 20 for installation in fire-pump discharge piping.
2. Relief Valves:
   a. Description: UL 1478, bronze or cast iron, spring loaded; for installation in fire-suppression water-supply piping.
3. Outlet Fitting: Concentric tapered reducer at pump-head discharge outlet.
4. Discharge Cone: Closed **OR** Open, **as directed**, type.
5. Hose Valve Manifold Assembly:
   a. Standard: Comply with requirements in NFPA 20.
   b. Header Pipe: ASTM A 53/A 53M, Schedule 40, galvanized steel with ends threaded according to ASME B1.20.1.
   c. Header Pipe Fittings: ASME B16.4, galvanized cast-iron threaded fittings.
   d. Automatic Drain Valve: UL 1726.
   e. Manifold:
      1) Test Connections: Comply with UL 405 except provide outlets without clappers instead of inlets.
      2) Body: Flush type, brass or ductile iron, with number of outlets required by NFPA 20.
      3) Nipples: ASTM A 53/A 53M, Schedule 40, galvanized-steel pipe with ends threaded according to ASME B1.20.1.
      4) Adapters and Caps with Chain: Brass or bronze, with outlet threaded according to NFPA 1963 and matching local fire-department threads.
      5) Escutcheon Plate: Brass or bronze; rectangular.
      6) Hose Valves: UL 668, bronze, with outlet threaded according to NFPA 1963 and matching local fire-department threads.
      7) Exposed Parts Finish: Polished **OR** Rough, **as directed**, brass, **as directed**, chrome plated, **as directed**.
      8) Escutcheon Plate Marking: Equivalent to "FIRE PUMP TEST."

      OR

      Manifold:
      1) Test Connections: Comply with UL 405 except provide outlets without clappers instead of inlets.
      2) Body: Exposed type, brass, with number of outlets required by NFPA 20.
      3) Escutcheon Plate: Brass or bronze; round.
      4) Hose Valves: UL 668, bronze, with outlet threaded according to NFPA 1963 and matching local fire-department threads. Include caps and chains.
      5) Exposed Parts Finish: Polished **OR** Rough, **as directed**, brass, **as directed**, chrome plated, **as directed**.
      6) Escutcheon Plate Marking: Equivalent to "FIRE PUMP TEST."

D. Flowmeter Systems
1. Description: UL-listed or FM-Approved, fire-pump flowmeter system with capability to indicate flow to not less than 175 percent of fire-pump rated capacity.
2. Pressure Rating: 175 psig (1200 kPa) minimum **OR** 250 psig (1725 kPa), **as directed**.
3. Sensor: Annubar probe, orifice plate, or venturi unless otherwise indicated. Sensor size shall match pipe, tubing, flowmeter, and fittings.
4. Permanently Mounted Flowmeter: Compatible with flow sensor; with dial not less than 4-1/2 inches (115 mm) in diameter. Include bracket or device for wall mounting.
   a. Tubing Package: NPS 1/8 or NPS 1/4 (DN 6 or DN 10) soft copper **OR** plastic, **as directed**, tubing with copper or brass fittings and valves.

OR

Portable Flowmeter: Compatible with flow sensor; with dial not less than 4-1/2 inches (115 mm) in diameter and with two 12-foot- (3.7-m-) long hoses in carrying case.

E. Grout
1. Standard: ASTM C 1107, Grade B, post-hardening and volume-adjusting, dry, hydraulic-cement grout.
2. Characteristics: Nonshrink and recommended for interior and exterior applications.
3. Design Mix: 5000-psi (34-MPa), 28-day compressive strength.
4. Packaging: Premixed and factory packaged.

F. Source Quality Control
1. Testing: Test and inspect fire pumps according to UL 448 requirements for "Operation Test" and "Manufacturing and Production Tests."
   a. Verification of Performance: Rate fire pumps according to UL 448.
2. Fire pumps will be considered defective if they do not pass tests and inspections.
3. Prepare test and inspection reports.

1.3 EXECUTION

A. Installation
1. Fire-Pump Installation Standard: Comply with NFPA 20 for installation of fire pumps, relief valves, and related components.
2. Equipment Mounting: Install fire pumps on concrete bases. Comply with requirements for concrete bases specified in Division 03 Section "Cast-in-place Concrete".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   d. Install anchor bolts to elevations required for proper attachment to supported equipment.
3. Install fire-pump discharge piping equal to or larger than size required by NFPA 20.
4. Support piping and pumps separately so weight of piping does not rest on pumps.
5. Install valves that are same size as connecting piping. Comply with requirements for fire-protection valves specified in Division 21 Section(s) "Fire-suppression Standpipes" OR "Wet-pipe Sprinkler Systems", **as directed**.
6. Install pressure gage on pump head discharge flange pressure-gage tapping. Comply with requirements for pressure gages specified in Division 21 Section(s) "Fire-suppression Standpipes" OR "Wet-pipe Sprinkler Systems", **as directed**.
7. Install piping hangers and supports, anchors, valves, gages, and equipment supports according to NFPA 20.
8. Install fuel system according to NFPA 20.
9. Install water supply and drain piping for diesel-engine heat exchangers. Extend drain piping from heat exchangers to point of disposal.
10. Install exhaust system piping for diesel engines. Extend to point of termination outside structure. Install pipe and fittings with welded joints; install components having flanged connections with gasketed joints.
11. Install condensate drain piping for diesel-engine exhaust system. Extend drain piping from low points of exhaust system to condensate traps and to point of disposal.
12. Install flowmeters and sensors. Install flowmeter-system components and make connections according to NFPA 20 and manufacturer's written instructions.
13. Electrical Wiring: Install electrical devices furnished by equipment manufacturers but not factory mounted. Furnish copies of manufacturers' wiring diagram submittals to electrical Installer.

14. Wiring Method: Conceal conductors and cables in accessible ceilings, walls, and floors where possible.

B. Alignment
1. Align fire-pump-driver, right-angle gear-drive, and fire-pump shafts after complete unit has been leveled on concrete base, grout has set, and anchor bolts have been tightened.
2. After alignment is correct, tighten anchor bolts evenly. Fill baseplate completely with grout, with metal blocks and shims or wedges in place. Tighten anchor bolts after grout has hardened. Check alignment and make required corrections.
3. Align piping connections.
4. Align pump and driver shafts for angular and parallel alignment according to HI 2.4 and to tolerances specified by manufacturer.

C. Connections
1. Comply with requirements for piping and valves specified in Division 21 Section(s) "Fire-suppression Standpipes" OR "Wet-pipe Sprinkler Systems", **as directed**. Drawings indicate general arrangement of piping, fittings, and specialties.
2. Install piping adjacent to pumps and equipment to allow service and maintenance.
3. Connect relief-valve discharge to drainage piping or point of discharge.
4. Connect flowmeter-system meters, sensors, and valves to tubing.
5. Connect fire pumps to their controllers.

D. Identification
1. Identify system components. Comply with requirements for fire-pump marking according to NFPA 20.

E. Field Quality Control
1. Test each fire pump with its right-angle gear drive and controller as a unit. Comply with requirements for electric-motor-driver fire-pump controllers specified in Division 21 Section(s) "Electric-drive, Centrifugal Fire Pumps" OR "Diesel-drive, Centrifugal Fire Pumps" OR "Electric-drive, Vertical-turbine Fire Pumps" OR "Diesel-drive, Vertical-turbine Fire Pumps".
2. Perform tests and inspections.
   a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
3. Tests and Inspections:
   a. After installing components, assemblies, and equipment including controller, test for compliance with requirements.
   b. Test according to NFPA 20 for acceptance and performance testing.
   c. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
   d. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   e. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
4. Components, assemblies, and equipment will be considered defective if they do not pass tests and inspections.
5. Prepare test and inspection reports.
6. Furnish fire hoses in number, size, and length required to reach storm drain or other acceptable location to dispose of fire-pump test water. Hoses are for tests only and do not convey to the Owner.

F. Startup Service
1. Perform startup service.
   a. Complete installation and startup checks according to manufacturer's written instructions.

G. Demonstration
   1. Train the Owner's maintenance personnel to adjust, operate, and maintain fire pumps, right-angle gear drives, and fire-pump controllers.

END OF SECTION 23 21 23 23a

Task	Specification	Specification Description
23 21 23 23	22 05 23 00	Piped Utilities Basic Materials And Methods
23 21 23 23	22 11 23 39	Water Supply Wells
23 21 29 00	22 05 23 00	Piped Utilities Basic Materials And Methods
23 21 29 00	22 11 23 39a	Hydronic Pumps
23 22 13 00	22 11 16 00d	Steam And Condensate Piping
23 22 16 00	22 05 23 00	Piped Utilities Basic Materials And Methods
23 22 16 00	21 05 19 00	Water Distribution
23 22 16 00	23 05 29 00	Steam Distribution
23 22 16 00	21 05 19 00a	Meters and Gages for Plumbing Piping
23 22 16 00	21 05 19 00b	Meters and Gages for HVAC Piping
23 22 16 00	22 11 16 00d	Steam And Condensate Piping
23 22 16 00	22 11 16 00e	Refrigerant Piping
23 22 16 00	22 11 16 00f	General-Service Compressed-Air Piping

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SECTION 23 22 23 13 - STEAM CONDENSATE PUMPS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for steam condensate pumps. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the products manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes electric-driven and pressure-powered steam condensate pumps.

C. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings: Include details of installation.
   a. Include wiring diagrams.
3. Operation and maintenance data.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. ASME Compliance: Fabricate and label steam condensate pumps to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

E. Delivery, Storage, and Handling
1. Manufacturer's Preparation for Shipping: Clean flanges and exposed machined metal surfaces and treat with anticorrosion compound after assembly and testing. Protect flanges, pipe openings, and nozzles with wooden flange covers or with screwed-in plugs.
2. Store steam condensate pumps in dry location.
3. Retain protective covers for flanges and protective coatings during storage.
4. Protect bearings and couplings against damage from sand, grit, and other foreign matter.
5. Comply with pump manufacturer's written rigging instructions.

1.2 PRODUCTS

A. Electric-Driven Steam Condensate Pumps
1. Description: Factory-fabricated, packaged, electric-driven pumps; with receiver, pump(s), controls, and accessories suitable for operation with steam condensate.
2. Configuration: Simplex **OR** Duplex, **as directed**, floor-mounting pump with receiver and float switch(es); rated to pump 200 deg F (93 deg C) steam condensate.
   a. Receiver: Floor-mounting, close-grained cast iron **OR** welded steel, **as directed**; with externally adjustable float switch(es), and flange(s) for pump mounting.
   b. Pump(s): Centrifugal, close coupled, vertical design, permanently aligned, and bronze fitted; with replaceable bronze case ring and mechanical seal; mounted on receiver flange.
   c. Factory Wiring: Between pump(s) and float switch(es), for single external electrical connection. Fused control power transformer if voltage exceeds 230 V.
   d. Electrical **OR** Mechanical, **as directed**, pump alternator to operate pumps in lead-lag sequence and allow both pumps to operate if the normal start level for a single pump is exceeded.
3. Configuration: Duplex floor-mounting pump with receiver and float switches; rated to pump 210 deg F (99 deg C) steam condensate.

a. Receiver: Floor-mounting, close-grained cast iron **OR** welded steel, **as directed**; with externally adjustable float switches and flanges for pump mounting.
b. Pumps: Regenerative turbine, close coupled, permanently aligned, and bronze fitted; with mechanical seals and an independent pump control circuit for each pump; mounted on base or receiver flange; rated to operate with a minimum of 2 feet (6 kPa) of NPSH.
c. Factory Wiring: Between pumps and float switches, for single external electrical connection. Fused control power transformer if voltage exceeds 230 V.
d. Electrical **OR** Mechanical, **as directed**, pump alternator to operate pumps in lead-lag sequence and allow both pumps to operate if the normal start level for a single pump is exceeded.

4. Configuration: Duplex floor-mounting pumps with receiver and float switches; rated to pump minimum 200 deg F (93 deg C) **OR** 210 deg F (99 deg C), **as directed**, steam condensate.
   a. Receiver: Floor-mounting, close-grained cast iron **OR** welded steel, **as directed**; externally adjustable float switches; with water-level gage, steam condensate thermometer, discharge-pressure gage for each pump, bronze gate valves between receiver and pumps, flanges for pump mounting, and lifting eyebolts.
   b. Inlet Strainer: Cast iron with self-cleaning bronze screen, dirt pocket, and cleanout plug on receiver inlet.
   c. Pumps: Centrifugal, close coupled, vertical design, permanently aligned, and bronze fitted; with replaceable bronze case rings, stainless-steel shafts, and mechanical seals; mounted on receiver flanges; rated to operate with a minimum of 2 feet (6 kPa) of NPSH.
   d. Control Panel: NEMA 250, Type 1 **OR** 2 **OR** 12, **as directed**, enclosure with hinged door and grounding lug, mounted on pump; factory wired for single external electrical connection; and with the following components within cabinet:
      1) Motor controller for each pump.
      2) Electrical pump alternator to operate pumps in lead-lag sequence and allow both pumps to operate on receiver high level.
      3) Manual lead-lag control to override electrical pump alternator to manually select the lead pump.
      4) Momentary contact "TEST" push button on cover for each pump.
      5) Numbered terminal strip.
      6) Disconnect switch.
      7) Fused transformer for control circuit.
5. Configuration: Duplex floor-mounting pump with elevated receiver, float switches, and connecting piping; rated to pump 212 deg F (100 deg C) steam condensate.
   a. Receiver: Close-grained cast iron **OR** Welded steel, **as directed**, mounted on fabricated-steel supports; externally adjustable float switches; with water-level gage, steam condensate thermometer, pump discharge pressure gages, bronze isolation valves between receiver and pumps, and lifting eyebolts.
   b. Inlet Strainer: Cast iron with self-cleaning bronze screen, dirt pocket, and cleanout plug on receiver inlet.
   c. Pumps: Centrifugal, close coupled, permanently aligned, and bronze fitted; with replaceable bronze case rings, stainless-steel shafts, and mechanical seals; mounted on base below receiver; rated to operate with a minimum of 2 feet (6 kPa) of NPSH.
   d. Pipe: ASTM A 53/A 53M, Type S, Grade B or ASTM A 106; Schedule 80; seamless steel.
   e. Fittings NPS 2 (DN 50) and Smaller: ASME B16.1, Class 125 cast iron, threaded.
   f. Fittings NPS 2-1/2 (DN 65) and Larger: ASTM A 234/A 234M, steel, for welded connections.
   g. Control Panel: NEMA 250, Type 1 **OR** 2 **OR** 12, **as directed**, enclosure with hinged door and grounding lug; mounted on pump; factory wired for single external electrical connection; and with the following components within cabinet:
      1) Motor controller for each pump.
      2) Electrical pump alternator to operate pumps in lead-lag sequence and allow both pumps to operate on receiver high level.

3) Manual lead-lag control to override electrical alternator to manually select the lead pump.
4) Momentary contact "TEST" push button on cover for each pump.
5) Numbered terminal strip.
6) Disconnect switch.
7) Fused transformer for control circuit.

6. Configuration: Underground duplex pump with basin and float switches; rated to pump 200 deg F (93 deg C) steam condensate.
   a. Basin: Cast iron, with hub-type inlets.
   b. Basin Cover: Cast iron or steel with gasketed openings for access, pumps, pump shafts, control rods, discharge piping, and vent connections.
      1) Anchor Flange: Cast iron, attached to basin, in location and of size required to anchor basin to concrete slab.
   c. Pumps: Wet-pit mounted, vertical, flexible coupled, and suspended.
      1) Casing: Cast iron with open inlet.
      2) Shaft and Bearings: Stainless-steel shaft with oil-lubricated, bronze, intermediate sleeve bearings; 48-inch (1200-mm) maximum intervals where basin depth is more than 48 inches (1200 mm); and grease-lubricated, ball-type, thrust bearings.
      3) Shaft Couplings: Flexible, capable of absorbing vibration.
      4) Seals: Mechanical; with carbon rotating ring, bearing on a ceramic seat held by a stainless-steel spring, and enclosed by a flexible bellows and gasket.
      5) Motors: Vertically mounted on cast-iron pedestal.
      6) Pump Discharge Piping: Manufacturer's standard steel or bronze pipe, unless otherwise indicated.
   d. Control Panel: NEMA 250, Type 1 **OR** 2 **OR** 12, **as directed**, enclosure with hinged door and grounding lug; mounted on pump; factory wired for single external electrical connection; and with the following components within cabinet:
      1) Motor controller for each pump.
      2) Electrical pump alternator to operate pumps in lead-lag sequence and allow both pumps to operate on receiver high level.
      3) Manual lead-lag control to override electrical alternator to manually select the lead pump.
      4) Momentary contact "TEST" push button on cover for each pump.
      5) Numbered terminal strip.
      6) Disconnect switch.
      7) Fused transformer for control circuit.

B. Pressure-Powered Steam Condensate Pumps
   1. Description: Factory-fabricated, pressure-powered pumps with mechanical controls, valves, piping connections, and accessories suitable for pumping steam condensate using steam **OR** compressed air, **as directed**.
   2. Configuration: Simplex **OR** Duplex, **as directed**, pump with float-operated valve control.
      a. Pump Body: Cast iron **OR** Welded steel, **as directed**.
      b. Piping Connections: Threaded; for steam condensate, operating medium, vent, and indicated accessories.
      c. Level Gage: Glass site gage with shutoff cocks.
      d. Valves: Manufacturer's standard check valves on inlet and outlet.
      e. Internal Parts: Stainless-steel float, springs, and actuating mechanism.
      f. Valve Seals: Replaceable from exterior.
      g. Receiver: Cast iron **OR** Welded steel, **as directed**, factory mounted on steel supports; with water-level site glass and threaded piping connections.
      h. Pipe: ASTM A 53/A 53M, Type S, Grade B or ASTM A 106; Schedule 80; seamless steel.
      i. Fittings: ASME B16.1, Class 125 cast iron, threaded.

C. Motors

1. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".

1.3 EXECUTION

A. Installation
1. Install pumps according to HI 1.1-1.5, "Centrifugal Pumps for Nomenclature, Definitions, Application and Operation."
2. Install pumps to provide access for periodic maintenance including removing motors, impellers, couplings, and accessories.
3. Support pumps and piping separately so piping is not supported by pumps.
4. Install pumps on concrete bases. Anchor pumps to bases using inserts or anchor bolts.
5. Install thermometers and pressure gages.

B. Connections
1. Install piping adjacent to machine to allow service and maintenance.
2. Install steam supply for pressure-powered pumps as required by Division 23 Section "Steam And Condensate Heating Piping".
3. Install compressed-air supply for pressure-powered pumps as required by Division 22 Section "General-service Compressed-air Piping".
4. Install gate and check valves on inlet and outlet of pressure-powered pumps.
5. Install check valve, gate valve, and globe valve at pump discharge connections for each electric-driven pump.
6. Pipe drain to nearest floor drain for overflow and drain piping connections.
7. Install full-size vent piping to outdoors, terminating in 180-degree elbow at point above highest steam system connection or as indicated.
8. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
9. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

END OF SECTION 23 22 23 13

Task	Specification	Specification Description
23 23 13 00	22 05 23 00	Piped Utilities Basic Materials And Methods
23 23 13 00	22 11 16 00e	Refrigerant Piping
23 23 16 00	07 63 00 00	Common Work Results for Fire Suppression
23 23 16 00	07 63 00 00a	Common Work Results for Plumbing
23 23 16 00	07 63 00 00b	Common Work Results for HVAC
23 23 16 00	22 11 16 00a	Sanitary Waste And Vent Piping
23 23 16 00	22 11 16 00b	Storm Drainage Piping
23 23 16 00	22 11 16 00c	Hydronic Piping
23 23 16 00	22 11 16 00e	Refrigerant Piping
23 23 16 00	23 01 60 00	Condensing Units
23 23 23 00	23 01 60 00	Condensing Units

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SECTION 23 25 13 00 - HVAC WATER TREATMENT

A. Description Of Work
   1. This specification covers the furnishing and installation of materials for HVAC water treatment. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the products manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work

B. Summary
   1. This Section includes the following HVAC water-treatment systems:
      a. Bypass chemical-feed equipment and controls.
      b. Biocide chemical-feed equipment and controls.
      c. Ozone-generator biocide equipment and controls.
      d. UV-irradiation unit, biocide equipment, and controls.
      e. Chemical treatment test equipment.
      f. HVAC water-treatment chemicals.
      g. Makeup water softeners.
      h. RO equipment for HVAC makeup water.
      i. Water filtration units for HVAC makeup water.

C. Definitions
   1. EEPROM: Electrically erasable, programmable read-only memory.
   2. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.
   3. RO: Reverse osmosis.
   4. TDS: Total dissolved solids.
   5. UV: Ultraviolet.

D. Performance Requirements
   1. Water quality for HVAC systems shall minimize corrosion, scale buildup, and biological growth for optimum efficiency of HVAC equipment without creating a hazard to operating personnel or the environment.
   2. Base HVAC water treatment on quality of water available at Project site, HVAC system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.
   3. Closed hydronic systems, including hot-water heating, chilled water, dual-temperature water, and glycol cooling, shall have the following water qualities:
      a. pH: Maintain a value within 9.0 to 10.5.
      b. "P" Alkalinity: Maintain a value within 100 to 500 ppm.
      c. Boron: Maintain a value within 100 to 200 ppm.
      d. Chemical Oxygen Demand: Maintain a maximum value of 100 ppm.
      e. Soluble Copper: Maintain a maximum value of 0.20 ppm.
      f. TDS: Maintain a maximum value of 10 ppm.
      g. Ammonia: Maintain a maximum value of 20 ppm.
      h. Free Caustic Alkalinity: Maintain a maximum value of 20 ppm.
      i. Microbiological Limits:
         1) Total Aerobic Plate Count: Maintain a maximum value of 1000 organisms/ml.
         2) Total Anaerobic Plate Count: Maintain a maximum value of 100 organisms/ml.
         3) Nitrate Reducers: Maintain a maximum value of 100 organisms/ml.
         4) Sulfate Reducers: Maintain a maximum value of 0 organisms/ml.
         5) Iron Bacteria: Maintain a maximum value of 0 organisms/ml.
   4. Steam Boiler and Steam Condensate:
      a. Steam Condensate:
         1) pH: Maintain a value within 7.8 to 8.4.
         2) Total Alkalinity: Maintain a value within 5 to 50 ppm.

3) Chemical Oxygen Demand: Maintain a maximum value of 15 ppm.
4) Soluble Copper: Maintain a maximum value of 0.20 ppm.
5) TDS: Maintain a maximum value of 10 ppm.
6) Ammonia: Maintain a maximum value of 20 ppm.
7) Total Hardness: Maintain a maximum value of 2 ppm.

b. Steam boiler operating at 15 psig (104 kPa) and less shall have the following water qualities:
1) "OH" Alkalinity: Maintain a value within 200 to 400 ppm.
2) TDS: Maintain a value within 600 to 3000 ppm.

c. Steam boiler operating at more than 15 psig (104 kPa) shall have the following water qualities:
1) "OH" Alkalinity: 200 to 400 ppm.
2) TDS: Maintain a value within 600 to 1200 ppm to maximum 30 times RO water TDS.

5. Open hydronic systems, including condenser **OR** fluid-cooler spray, **as directed**, water, shall have the following water qualities:
a. pH: Maintain a value within 8.0 to 9.1.
b. "P" Alkalinity: Maintain a maximum value of 100 ppm.
c. Chemical Oxygen Demand: Maintain a maximum value of 100ppm.
d. Soluble Copper: Maintain a maximum value of 0.20 ppm.
e. TDS: Maintain a maximum value of 10 ppm.
f. Ammonia: Maintain a maximum value of 20 ppm.
g. Free "OH" Alkalinity: Maintain a maximum value of 0 ppm.
h. Microbiological Limits:
1) Total Aerobic Plate Count: Maintain a maximum value of 10,000 organisms/ml.
2) Total Anaerobic Plate Count: Maintain a maximum value of 1000 organisms/ml.
3) Nitrate Reducers: Maintain a maximum value of 100 organisms/ml.
4) Sulfate Reducers: Maintain a maximum value of 0 organisms/ml.
5) Iron Bacteria: Maintain a maximum value of 0 organisms/ml.
i. Polymer Testable: Maintain a minimum value within 10 to 40.

6. Passivation for Galvanized Steel: For the first 60 days of operation.
a. pH: Maintain a value within 7 to 8.
b. Calcium Carbonate Hardness: Maintain a value within 100 to 300 ppm.
c. Calcium Carbonate Alkalinity: Maintain a value within 100 to 300 ppm.

E. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings: Pretreatment and chemical treatment equipment showing tanks, maintenance space required, and piping connections to HVAC systems. Include plans, elevations, sections, details, and attachments to other work.
a. Wiring Diagrams: Power and control wiring.
3. Field quality-control test reports.
4. Manufacturer Seismic Qualification Certification
5. Other Informational Submittals:
a. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in the "Performance Requirements" Article above.
b. Water Analysis: Illustrate water quality available at Project site.
c. Passivation Confirmation Report: Verify passivation of galvanized-steel surfaces, and confirm this observation in a letter to the Owner.

F. Quality Assurance
1. HVAC Water-Treatment Service Provider Qualifications: An experienced HVAC water-treatment service provider capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.

2. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

1.2 PRODUCTS

A. Manual Chemical-Feed Equipment
1. Bypass Feeders: Steel, with corrosion-resistant exterior coating, minimum 3-1/2-inch (89-mm) fill opening in the top, and NPS 3/4 (DN 20) bottom inlet and top side outlet. Quarter turn or threaded fill cap with gasket seal and diaphragm to lock the top on the feeder when exposed to system pressure in the vessel.
a. Capacity: 2 gal. (7.6 L) **OR** 5 gal. (19 L), **as directed**.
b. Minimum Working Pressure: 125 psig (860 kPa) **OR** 175 psig (1210 kPa), **as directed**.

B. Automatic Chemical-Feed Equipment
1. Water Meter:
a. AWWA C700, oscillating-piston, magnetic-drive, totalization meter.
b. Body: Bronze.
c. Maximum Pressure Loss at Design Flow: 3 psig (20 kPa).
d. Registration: Gallons (Liters) or cubic feet (cubic meters).
e. Controls: Flow-control switch with normally open contacts; rated for maximum 10 A, 250-V ac; and that will close at adjustable increments of total flow.
2. Water Meter:
a. AWWA C701, turbine-type, totalization meter.
b. Body: Bronze.
c. Minimum Working-Pressure Rating: 100 psig (690 kPa).
d. Maximum Pressure Loss at Design Flow: 3 psig (20 kPa).
e. Registration: Gallons (Liters) or cubic feet (cubic meters).
f. End Connections: Threaded.
g. Control: Low-voltage signal capable of transmitting 1000 feet (305 m).
3. Water Meter:

4. AWWA C701, turbine-type, totalization meter.
a. Body: Bronze **OR** Epoxy-coated cast iron, **as directed**.
b. Minimum Working-Pressure Rating: 150 psig (1035 kPa).
c. Maximum Pressure Loss at Design Flow: 3 psig (20 kPa).
d. Registration: Gallons (Liters) or cubic feet (cubic meters).
e. End Connections: Flanged.
f. Controls: Flow-control switch with normally open contacts; rated for maximum 10 A, 250-V ac; and that will close at adjustable increments of total flow.
5. Inhibitor Injection Timers:
a. Microprocessor-based controller with LCD display in NEMA 250, Type 12 enclosure with gasketed and lockable door. Interface for start/stop and status indication at central workstation as described in Division 23 Section "Instrumentation And Control For Hvac".
b. Programmable timers with infinite adjustment over full range, and mounted in cabinet with hand-off-auto switches and status lights.
c. Test switch.
d. Hand-off-auto switch for chemical pump.
e. Illuminated legend to indicate feed when pump is activated.
f. Programmable lockout timer with indicator light. Lockout timer to deactivate the pump and activate alarm circuits.
g. LCD makeup totalizer to measure amount of makeup and bleed-off water from two water meter inputs.
6. pH Controller:

a. Microprocessor-based controller, 1 percent accuracy in a range from zero to 14 units. Incorporate solid-state integrated circuits and digital LCD display in NEMA 250, Type 12 enclosure with gasketed and lockable door. Interface for start/stop and status indication at central workstation as described in Division 23 Section "Instrumentation And Control For Hvac".
b. Digital display and touch pad for input.
c. Sensor probe adaptable to sample stream manifold.
d. High, low, and normal pH indication.
e. High or low pH alarm light, trip points field adjustable; with silence switch.
f. Hand-off-auto switch for acid pump.
g. Internal adjustable hysteresis or deadband.

7. TDS Controller:
   a. Microprocessor-based controller, 1 percent accuracy in a range from zero to 5000 micromhos. Incorporate solid-state integrated circuits and digital LCD display in NEMA 250, Type 12 enclosure with gasketed and lockable door. Interface for start/stop and status indication at central workstation as described in Division 23 Section "Instrumentation And Control For Hvac".
   b. Digital display and touch pad for input.
   c. Sensor probe adaptable to sample stream manifold.
   d. High, low, and normal conductance indication.
   e. High or low conductance alarm light, trip points field adjustable; with silence switch.
   f. Hand-off-auto switch for solenoid bleed-off valve.
   g. Bleed-off valve activated indication.
   h. Internal adjustable hysteresis or deadband.
   i. Bleed Valves:
      1) Cooling Systems: Forged-brass body, globe pattern, general-purpose solenoid with continuous-duty coil, or motorized valve.
      2) Steam Boilers: Motorized ball valve, steel body, and TFE seats and seals.
8. Biocide Feeder Timer:
   a. Microprocessor-based controller with digital LCD display in NEMA 250, Type 12 enclosure with gasketed and lockable door. Interface for start/stop and status indication at central workstation as described in Division 23 Section "Instrumentation And Control For Hvac".
   b. 24-hour timer with 14-day skip feature to permit activation any hour of day.
   c. Precision, solid-state, bleed-off lockout timer and clock-controlled biocide pump timer. Prebleed and bleed lockout timers.
   d. Solid-state alternator to enable use of two different formulations.
   e. 24-hour display of time of day.
   f. 14-day display of day of week.
   g. Battery backup so clock is not disturbed by power outages.
   h. Hand-off-auto switches for biocide pumps.
   i. Biocide A and Biocide B pump running indication.
9. Chemical Solution Tanks:
   a. Chemical-resistant reservoirs fabricated from high-density opaque polyethylene with minimum 110 percent containment vessel.
   b. Molded cover with recess for mounting pump.
   c. Capacity: 30 gal. (114 L) **OR** 50 gal. (189 L) **OR** 120 gal. (454 L), **as directed**.
10. Chemical Solution Injection Pumps:
   a. Self-priming, positive-displacement; rated for intended chemical with minimum 25 percent safety factor for design pressure and temperature.
   b. Adjustable flow rate.
   c. Metal and thermoplastic construction.
   d. Built-in relief valve.
   e. Fully enclosed, continuous-duty, single-phase motor. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".

11. Chemical Solution Tubing: Polyethylene tubing with compression fittings and joints except ASTM A 269, Type 304, stainless steel for steam boiler injection assemblies.
12. Injection Assembly:
    a. Quill: Minimum NPS 1/2 (DN 15) with insertion length sufficient to discharge into at least 25 percent of pipe diameter.
    b. Ball Valve: Three **OR** Two, **as directed**,-piece, stainless steel; selected to fit quill.
    c. Packing Gland: Mechanical seal on quill of sufficient length to allow quill removal during system operation.
    d. Assembly Pressure/Temperature Rating: Minimum 600 psig (4137 kPa) at 200 deg F (93 deg C).

C. Ozone-Generator Biocide Equipment
1. Corona discharge generator with stainless-steel generating cells, and transformer housed in a NEMA 250, Type 4 enclosure. Assembly shall be suitable for continuous duty. Provide site glasses to verify proper operation of generator.
2. Water-cooled generators shall be provided with cooling water at maximum 70 deg F (21 deg C) and 35 psig (241 kPa).
3. Generator vessels exposed to system pressure shall be constructed according to ASME Boiler and Pressure Vessel Code and be equipped with pressure relief valve.
4. External air compressor or induced airflow through a cleanable prefilter supplies concentrated oxygen through a molecular sieve with minus 62 deg F (minus 52 deg C) dew point to avoid the formation of nitric acid.
5. Microprocessor-based control with software in EEPROM, surge protection, high-temperature cutout, and operational status lights. Interface for start/stop and status indication at central workstation as described in Division 23 Section "Instrumentation And Control For Hvac".
6. Ozone Contactors:
    a. Bubble diffusers.
    b. Induction injection nozzle.
    c. Injectors with static mixers.
7. Ozone Detector and Alarm Devices:
    a. Detector:
        1) Sensor: Metal dioxide semiconductor.
        2) Concentration Range: 0.01 to 0.14 ppm.
        3) Accuracy: Plus or minus 20 percent of range.
        4) Sensitivity: 0.01 ppm.
        5) Response Time: Maximum 10 seconds.
        6) Operating Temperature: 50 to 100 deg F (10 to 38 deg C).
        7) Relatively Humidity: 20 to 95 percent, noncondensing over the operating temperature range.
    b. Horns:
        1) Electric-vibrating-polarized type.
        2) 24-V dc; with provision for housing the operating mechanism behind a grille.
        3) Horns shall produce a sound-pressure level of 90 dBA, measured 10 feet (3 m) from the horn.
    c. Visible Alarm Devices:
        1) Xenon strobe lights listed in UL 1971, with clear or nominal white polycarbonate lens mounted on an aluminum faceplate.
        2) Rated Light Output: 75 **OR** 110, **as directed**, candela.
        3) Strobe Leads: Factory connected to screw terminals.
8. Self-Contained Breathing Apparatus: Open-circuit, pressure-demand, compressed air includes completely assembled, portable, self-contained devices designed for hazardous breathing environment application.
    a. Face Piece: EPDM or silicone rubber construction material, one-size-fits-all with double-sealing edge, stainless-steel speaking diaphragm and lens retainer, five adjustable straps to hold face piece to head (two straps on each side and one on top), exhalation valve in

mask, close-fitting nose piece to ensure no CO_2 buildup, and perspiration drain to avoid skin irritation and to prevent eyepiece, spectacle, and lens fogging.

b. Backplate: Orthopedically designed of chemical and impact-resistant, glass-fiber composite **OR** aluminum, **as directed**.

c. Harness and Carrier Assembly: Large triangular back pad, backplate, and adjustable waist and shoulder straps. Modular in design, detachable components, and easy to clean and maintain. Shoulder straps padded with flame-resistant material, reinforced with stainless-steel cable, and attached with T-nuts, washers, and screws.

d. Air Cylinder: 30 **OR** 45 **OR** 60, **as directed**,-minute, low-pressure, air-supply-loaded fiberglass **OR** aluminum **OR** steel, **as directed**, cylinders fitted with quick-fill assembly for refilling and air transfer.

e. Wall-Mounting Cabinet: Leakproof, corrosion-resistant, clear, plastic case.

f. Tested and Certified: By the National Institute for Occupational Safety and Health and by the Mine Safety and Health Administration, according to 42 CFR 84, Subpart H.

D. Stainless-Steel Pipes And Fittings

1. Stainless-Steel Tubing: Comply with ASTM A 269, Type 316.
2. Stainless-Steel Fittings: Complying with ASTM A 815/A 815M, Type 316, Grade WP-S.
3. Two-Piece, Full-Port, Stainless-Steel Ball Valves: ASTM A 351, Type 316 stainless-steel body; ASTM A 276, Type 316 stainless-steel stem and vented ball, carbon-filled TFE seats, threaded body design with adjustable stem packing, threaded ends, and 250-psig (1725-kPa) SWP and 600-psig (4140-kPa) CWP ratings.
4. Three-Piece, Full-Port, Stainless-Steel Ball Valves: ASTM A 351, Type 316 stainless-steel body; ASTM A 276, Type 316 stainless-steel stem and vented ball, threaded body design with adjustable stem packing, threaded ends, and 150-psig (1035-kPa) SWP and 600-psig (4140-kPa) CWP rating.

E. UV Biocide Equipment

1. Target Irradiation: Minimum 30,000 microwatts x s/sq. cm.
2. Light Source Vessels:
   a. ASTM A 666, Type 304 stainless steel.
   b. Construct for minimum 150 psig (1035 kPa) at 150 deg F (65 deg C) according to ASME Boiler and Pressure Vessel Code, and equipped with pressure relief valve.
   c. Light Source Sleeve: Quartz, with EPDM O-ring seals.
   d. Light Source: Replaceable UV lamp producing minimum target irradiation of 254-nm wavelength light.
3. Controls: Interlock with pumps to operate when water is circulating.

F. Chemical Treatment Test Equipment

1. Test Kit: Manufacturer-recommended equipment and chemicals in a wall-mounting cabinet for testing pH, TDS, inhibitor, chloride, alkalinity, and hardness; sulfite and testable polymer tests for high-pressure boilers, and oxidizing biocide test for open cooling systems.
2. Sample Cooler:
   a. Tube: Sample.
      1) Size: NPS 1/4 (DN 8) tubing.
      2) Material: ASTM A 666, Type 316 stainless steel.
      3) Pressure Rating: Minimum 2000 psig (13 790 kPa).
      4) Temperature Rating: Minimum 850 deg F (454 deg C).
   b. Shell: Cooling water.
      1) Material: ASTM A 666, Type 304 stainless steel.
      2) Pressure Rating: Minimum 250 psig (1725 kPa).
      3) Temperature Rating: Minimum 450 deg F (232 deg C).
   c. Capacities and Characteristics:
      1) Tube: Sample.
         a) Flow Rate: 0.25 gpm (0.016 L/s).

b) Entering Temperature: 400 deg F (204 deg C).
c) Leaving Temperature: 88 deg F (31 deg C).
d) Pressure Loss: 6.5 psig (44.8 kPa).

2) Shell: Cooling water.
a) Flow Rate: 3 gpm (0.19 L/s).
b) Entering Temperature: 70 deg F (21 deg C).
c) Pressure Loss: 1.0 psig (6.89 kPa).

3. Corrosion Test-Coupon Assembly: Constructed of corrosive-resistant material, complete with piping, valves, and mild steel and copper coupons. Locate copper coupon downstream from mild steel coupon in the test-coupon assembly.
   a. Two-station rack for closed-loop systems.
   b. Four-station rack for open systems.

G. Chemicals
1. Chemicals shall be as recommended by water-treatment system manufacturer that are compatible with piping system components and connected equipment, and that can attain water quality specified in Part 1.1 "Performance Requirements" Article.
2. Water Softener Chemicals:
   a. Mineral: High-capacity, sulfonated-polystyrene ion-exchange resin that is stable over entire pH range with good resistance to bead fracture from attrition or shock. Resin exchange capacity minimum 30,000 grains/cu. ft. (69 kg/cu. m) of calcium carbonate of resin when regenerated with 15 lb (6.8 kg) of salt.
   b. Salt for Brine Tanks: High-purity sodium chloride, free of dirt and foreign material. Rock and granulated forms are not acceptable.

H. HVAC Makeup Water Softener
1. Description: Twin mineral tanks and one brine tank, factory mounted on skid.
2. Fabricate supports and attachments to tanks with reinforcement strong enough to resist tank movement during seismic event when tank supports are anchored to building structure as recommended in writing by manufacturer.
3. Mineral Tanks:
   a. Fabricate and label steel filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
   b. Fabricate and label FRP filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section X, if indicated.
   c. Pressure Rating: 100 psig (690 kPa) **OR** 125 psig (860 kPa) **OR** 150 psig (1035 kPa), **as directed**, minimum.
   d. Wetted Components: Suitable for water temperatures from 40 to at least 100 deg F (5 to at least 38 deg C).
   e. Freeboard: 50 percent, minimum, for backwash expansion above the normal resin bed level.
   f. Support Legs or Skirt: Constructed of structural steel, welded or bonded to tank before testing and labeling.
   g. Finish: Hot-dip galvanized on exterior and interior of tank after fabrication.
   h. Upper Distribution System: Single-point type, fabricated from galvanized-steel pipe and fittings.
   i. Lower Distribution System: Hub and radial-arm or header-lateral type; fabricated from PVC pipe and fittings with individual, fine-slotted, nonclogging PE strainers; arranged for even-flow distribution through resin bed.
4. Controls: Automatic; factory mounted on mineral tanks and factory wired.
   a. Adjustable duration of regeneration steps.
   b. Push-button start and complete manual operation override.
   c. Pointer on pilot-control valve shall indicate cycle of operation.
   d. Means of manual operation of pilot-control valve if power fails.
   e. Main Operating Valves: Industrial, automatic, multiport, diaphragm type with the following features:

1) Slow opening and closing, nonslam operation.
2) Diaphragm guiding on full perimeter from fully open to fully closed.
3) Isolated dissimilar metals within valve.
4) Self-adjusting, internal, automatic brine injector that draws brine and rinses at constant rate independent of pressure.
5) Float-operated brine valve to automatically measure the correct amount of brine to the softener and refill with fresh water.
6) Sampling cocks for soft water.

f. Flow Control: Automatic control of backwash and flush rates over variations in operating pressures that do not require field adjustments. Equip mineral tanks with automatic-reset-head water meter that electrically activates cycle controller to initiate regeneration at preset total in gallons (liters), and automatically resets after regeneration to preset total in gallons (liters) for next service run. Include alternator to regenerate one mineral tank with the other in service.

5. Brine Tank: Combination measuring and wet-salt storing system.
   a. Tank and Cover Material: Fiberglass a minimum of 3/16 inch (4.8 mm) thick; or molded PE a minimum of 3/8 inch (9.5 mm) thick.
   b. Brine Valve: Float operated and plastic fitted for automatic control of brine withdrawn and freshwater refill.
   c. Size: Large enough for at least four regenerations at full salting.
6. Factory-Installed Accessories:
   a. Piping, valves, tubing, and drains.
   b. Sampling cocks.
   c. Main-operating-valve position indicators.
   d. Water meters.
7. Water Test Kit: Include water test kit in wall-mounting enclosure for water softener.

I. RO Equipment For HVAC Makeup Water
1. Description: Factory fabricated and tested with RO membrane elements in housings, high-pressure pumps and motors, controls, valves, and prefilter; mounted on skid.
2. Fabricate supports and attachments to tanks with reinforcement strong enough to resist tank movement during seismic event when tank supports are anchored to building structure as recommended in writing by manufacturer.
3. Skid Assembly: Welded-steel frame coated with epoxy protective finish.
4. RO Membrane and Housing:
   a. Element: Thin-film composite with U-cup brine seal with minimum 98 percent salt rejection based on 2000-ppm water supplied at 225 psig (1551 kPa) and 77 deg F (25 deg C).
   b. Housing: ASTM A 666, Type 304 stainless steel with PVC end caps held in place with stainless-steel straps.
5. High-Pressure Pumps and Motors:
   a. Pump:
      1) Vertical, multistage centrifugal operating at 3500 rpm with ASTM A 666, Type 304 stainless-steel casing, shaft, impellers, and inlet and discharge casting.
      2) Bearings shall be tungsten carbide and ceramic.
      3) Cast-iron frame and flanged suction and discharge connections.
   b. Motor: NEMA-standard, C-faced TEFC motor supported on the pump-bearing frame. General requirements for motors are specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
6. Controls:
   a. Microprocessor-based controller with LCD display.
   b. Interlock for remote start/stop control.
   c. Membrane flush sequence when pumps shut down.
   d. Run time indicator.
   e. Low-pressure safety cutoff.
   f. Panel-mounted gages as follows:

1) Product and concentrate.
2) Inlet, cartridge filter outlet, RO feed, RO concentrate, and RO product pressures.
3) Product conductivity monitor.

7. Valves:
   a. Stainless-steel pump, concentrate, and recycle throttling valves rated for minimum 300 psig (2068 kPa).
   b. Automatic inlet shutoff valve, diaphragm type; solenoid actuated, normally closed, and constructed of glass-reinforced noryl thermoplastic.
   c. PVC valves with EPDM seats and seals for isolation at inlet, and check and sample valves at product and concentrate. Sample valves at cartridge filter outlet, concentrate, and product outlet.
8. Prefilter:
   a. Housing: Polypropylene with built-in relief or vent valve.
   b. Element: Spun-wound polypropylene.
9. Inlet Water Tempering Valve: Thermostatic water-tempering valve to maintain 77 deg F (25 deg C), **as directed**, inlet water temperature to RO unit.
10. Activated Carbon Filter:
    a. Media Tank: Fiberglass-reinforced polyester rated for minimum 150 psig (1035 kPa) with internal backwash distributor and filtered water collector.
    b. Media: 12 x 40-mesh, bituminous coal-based activated carbon.
    c. Backwash Valve: Piston-operated control valve with drain-line, flow-control orifice.
    d. Backwash Control: Seven-day time clock.
11. Atmospheric Storage Tank:
    a. Tank: Polyethylene single piece with closed top and flat bottom with manway in top, 0.2-micron filter vent, inlet, discharge, and drain piping connections, and bulkhead fittings for level controls.
    b. Control: Level switches start and stop RO unit. Low-level limit shall stop repressurization pumps, and signal an alarm.
12. Repressurization Pumps:
    a. Pumps: Two close-coupled, single-stage centrifugal pumps, with mechanical seals. Wetted components ASTM A 666, Type 316 stainless steel.
    b. Controls: NEMA-4X pump control panel constructed of fiberglass to control pumps, one operating, one standby, with automatic alternator and fail-over control.
    c. Motor: ODP motor supported on the pump-bearing frame. General requirements for motors are specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
13. Water Test Kit: Include water test kit in wall-mounting cabinet for RO unit.

J. Filtration Equipment
1. Multimedia Filters:
   a. Description: Factory-fabricated and -tested, simplex, multimedia filter system of filter tank, media, strainer, circulating pump, piping, and controls for removing particles from water.
      1) Filter Tank: Corrosion resistant with distribution system and media.
         a) Fabricate and label steel filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
         b) Fabricate and label FRP filter tanks to comply with ASME Boiler and Pressure Vessel Code: Section X, if indicated.
         c) Pipe Connections NPS 2 (DN 50) and Smaller: Threaded according to ASME B1.20.1.
         d) Steel Tank Pipe Connections NPS 2-1/2 (DN 65) and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606.
         e) FRP Tank Pipe Connections NPS 2-1/2 (DN 65) and Larger: Type A, integral; Designation E, 125-psig (0.862-MPa) or F, 150-psig (1.034-MPa) pressure category flanges of grade same as tank material according to ASTM D 5421.

2) Motorized Valves: Flanged or grooved-end, ductile-iron butterfly type with EPDM valve seat and stem seal; with ASTM B 148 aluminum bronze disc.
3) Strainer: Basket type mounted on pump suction.
4) Piping: ASTM A 53/A 53M, Type S, F, or E; Grade B, Schedule 40 black steel, with flanged, grooved, or threaded joints and malleable, steel welding, or ductile-iron fittings.
5) Piping: ASTM B 88, Type L (ASTM B 88M, Type B) copper water tube, copper-alloy solder-joint fittings, and brazed, flanged, or grooved joints.
6) Safety Valves: Automatic pressure relief.
7) Circulating Pump: Overhung impeller, close coupled, single stage, end suction, centrifugal. Comply with UL 778 and with HI 1.1-1.2 and HI 1.3.
   a) Casing: Radially split, cast iron.
   b) Pressure Rating: 125 psig (860 kPa) **OR** 150 psig (1035 kPa), **as directed**, minimum.
   c) Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, closed, and keyed to shaft.
   d) Shaft and Shaft Sleeve: Steel shaft, with copper-alloy shaft sleeve.
   e) Seal: Mechanical.
   f) Motor: ODP motor supported on the pump-bearing frame. General requirements for motors are specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
8) Controls: Automatic control of circulating pump and tank backwash; factory wired for single electrical connection.
   a) Panel: NEMA 250, Type 4 enclosure with time clock and pressure gages.
   b) Pump: Automatic and manual switching; manual switch position bypasses safeties and controls.
   c) Backwash: Automatic; with time clock and differential pressure switch.
   d) Backwash Valve: Tank mounted with valves interlocked to single actuator.
9) Support: Skid mounting. Fabricate supports and base and attachment to tank with reinforcement strong enough to resist filter movement during a seismic event when filter base is anchored to building structure.

2. Self-Cleaning Strainers:
   a. Description: Factory-fabricated and -tested, ASTM A 126, Class B, cast-iron or steel, self-cleaning strainer system of tank, strainer, backwash arm or cleaning spiral, drive and motor, piping, and controls for removing particles from water.
      1) Fabricate and label ASTM A 126, Class B, cast-iron or steel strainer tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
      2) Pipe Connections:
         a) NPS 2 (DN 50) and Smaller: Threaded according to ASME B1.20.1.
         b) NPS 2-1/2 (DN 65) and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606.
   b. Motorized Valves: Flanged or grooved-end, ductile-iron angle type with EPDM valve seat and stem seal; with ASTM B 148 aluminum bronze disc.
   c. Strainer: ASTM A 666, Type 316 stainless steel.
   d. Piping: ASTM A 53/A 53M, Type S, F, or E; Grade B, Schedule 40 black steel, with flanged, grooved, or threaded joints and malleable, steel welding, or ductile-iron fittings.
   e. Safety Valves: Automatic pressure relief.
   f. Backwash Arm Drive:
      1) Drive Casing: Cast iron.
      2) Worm Gears: Immersed in oil.
      3) Motor: ODP motor supported on the strainer-bearing frame. General requirements for motors are specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   g. Controls: Automatic control of backwash; factory wired for single electrical connection.
      1) Panel: NEMA 250, Type 4 enclosure with time clock and pressure gages.

2) Backwash Arm Drive: Automatic and manual switching; manual switch position bypasses safeties and controls.
3) Backwash: Automatic; with time clock and differential pressure switch.
4) Backwash Valve: Electric actuator.

h. Support: Skid mounting. Fabricate supports and base and attachment to tank with reinforcement strong enough to resist strainer movement during a seismic event when strainer base is anchored to building structure.

3. Bag **OR** Cartridge, **as directed**,-Type Filters:
   a. Description: Floor-mounting housing with filter bags **OR** cartridges, **as directed**, for removing particles from water.
      1) Housing: Corrosion resistant; designed to separate inlet from outlet and to direct inlet through bag **OR** cartridge, **as directed**,-type water filter; with bag support and base, feet, or skirt.
         a) Pipe Connections NPS 2 (DN 50) and Smaller: Threaded according to ASME B1.20.1.
         b) Steel Housing Pipe Connections NPS 2-1/2 (DN 65) and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606.
         c) Plastic Housing Pipe Connections NPS 2-1/2 (DN 65) and Larger: 150-psig (1035-kPa) plastic flanges.
      2) Bag **OR** Cartridge, **as directed**: Replaceable; of shape to fit housing.
4. Centrifugal Separators:
   a. Description: Simplex separator housing with baffles and chambers for removing particles from water by centrifugal action and gravity.
   b. Housing: With manufacturer's proprietary system of baffles and chambers.
      1) Construction: Fabricate and label steel separator housing to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
      2) Inlet: Designed with tangential entry to produce centrifugal flow of feedwater.
      3) Vortex Chamber: Designed for downward vortex flow and gravity separation of particles.
      4) Collection Chamber: Designed to hold separated particles.
      5) Outlet: Near top of unit.
      6) Purge: At bottom of collection chamber.
      7) Pipe Connections NPS 2 (DN 50) and Smaller: Threaded according to ASME B1.20.1.
      8) Pipe Connections NPS 2-1/2 (DN 65) and Larger: Steel, Class 150 flanges according to ASME B16.5 or grooved according to AWWA C606. Provide stainless-steel flanges if tank is stainless steel.
   c. Motorized Purge Valve: Gate or plug pattern valve.
      1) Motorized Valves: Butterfly-type, flanged or grooved-end, ductile-iron body, with EPDM valve seat and stem seal; with ASTM B 148 aluminum bronze disc.
   d. Strainer: Stainless-steel basket type mounted on pump suction.
   e. Piping: ASTM A 53/A 53M, Type S, F, or E; Grade B, Schedule 40 black steel, with flanged, grooved, or threaded joints and malleable, steel welding, or ductile-iron fittings.
   f. Piping: ASTM B 88, Type L (ASTM B 88M, Type B) copper water tube, copper-alloy solder-joint fittings, and brazed, flanged, or grooved joints.
   g. Circulating Pump: Overhung impeller, close coupled, single stage, end suction, centrifugal. Comply with UL 778 and with HI 1.1-1.2 and HI 1.3.
      1) Casing: Radially split, cast iron.
      2) Pressure Rating: 125 psig (860 kPa) **OR** 150 psig (1035 kPa), **as directed**, minimum.
      3) Impeller: ASTM B 584, cast bronze; statically and dynamically balanced, closed, and keyed to shaft.
      4) Shaft and Shaft Sleeve: Steel shaft, with copper-alloy shaft sleeve.
      5) Seal: Mechanical.

6) Motor: ODP motor supported on the pump-bearing frame. General requirements for motors are specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".

h. Controls: Automatic control of circulating pump and separator purge; factory wired for single electrical connection.
   1) Panel: NEMA 250, Type 4 enclosure.
   2) Pump: Automatic and manual switching; manual switch position bypasses safeties and controls.
   3) Separator Purge: Automatic and manual.
   4) TDS Controller Interlock: Open separator purge valve with bleed-off control.

i. Support: Skid mounting. Fabricate supports and base and attachment to separator housing with reinforcement strong enough to resist separator movement during a seismic event when separator base is anchored to building structure.

1.3 EXECUTION

A. Water Analysis
   1. Perform an analysis of supply water to determine quality of water available at Project site.

B. Installation
   1. Install chemical application equipment on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor chemical tanks and floor-mounting accessories to substrate.
   2. Install seismic restraints for equipment and floor-mounting accessories and anchor to building structure. Refer to Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" for seismic restraints.
   3. Install water testing equipment on wall near water chemical application equipment.
   4. Install interconnecting control wiring for chemical treatment controls and sensors.
   5. Mount sensors and injectors in piping circuits.
   6. Bypass Feeders: Install in closed hydronic systems, including hot-water heating, chilled water, dual-temperature water, and glycol cooling, and equipped with the following:
      a. Install bypass feeder in a bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
      b. Install water meter in makeup water supply.
      c. Install test-coupon assembly in bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
      d. Install a gate or full-port ball isolation valves on inlet, outlet, and drain below feeder inlet.
      e. Install a swing check on inlet after the isolation valve.
   7. Install automatic chemical-feed equipment for steam boiler and steam condensate systems and include the following:
      a. Install makeup water softener.
      b. Install water meter in makeup water supply.
      c. Install inhibitor injection pumps and solution tanks with injection timer sensing contacts in water meter.
         1) Pumps shall operate for timed interval when contacts close at water meter in makeup water supply connection. Injection pump shall discharge into boiler feedwater tank or feedwater supply connection at boiler.
      d. Install test equipment and furnish test-kit to the Owner.
      e. Install RO unit for makeup water.
      f. Install TDS controller with sensor and bleed valves.
         1) Bleed valves shall cycle to maintain maximum TDS concentration.
      g. Install inhibitor injection timer with injection pumps and solution tanks.

1) Pumps shall operate for timed interval on contact closure at water meter in makeup water supply connection. Injection pump shall discharge into main steam supply header.

8. Install automatic chemical-feed equipment for condenser **OR** fluid-cooler spray, **as directed**, water and include the following:
   a. Install makeup water softener.
   b. Install water meter in makeup water supply.
   c. Install inhibitor injection pumps and solution tanks with injection timer sensing contacts in water meter.
      1) Pumps shall operate for timed interval on contact closure at water meter in makeup water supply connection. Injection pump shall discharge into boiler feedwater tank or feedwater supply connection at boiler.
   d. Install test equipment and provide test-kit to the Owner. Install test-coupon assembly in bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
   e. Install TDS controller with sensor and bleed valves.
      1) Bleed valves shall cycle to maintain maximum TDS concentration.
   f. Install pH sensor and controller with injection pumps and solution tanks.
      1) Injector pumps shall operate to maintain required pH.
   g. Install biocide feeder alternating timer with two sets of injection pumps and solution tanks.
      1) Injection pumps shall operate to feed biocide on an alternating basis.
   h. Install ozone generator with diffusers in condenser-water piping.
   i. Ozone generator shall operate continuously with condenser-water flow.
   j. Install UV-irradiation lamps in condenser-water piping.
      1) UV lights shall operate continuously with condenser-water flow.

C. Ozone-Generator Installation
1. Install ozone generator and equipment on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor mineral and brine tanks and floor-mounting accessories to substrate.
2. Install seismic restraints for equipment and floor-mounting accessories and anchor to building structure. Refer to Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" for seismic restraints.
3. Pipe ozone from ozone generator to condenser water with stainless-steel pipe and fittings with welded joints.
4. Install two **OR** three, **as directed**,-piece, stainless-steel ball valve in ozone supply to condenser water.
5. Pipe cooling water to ozone generator, and to air-gap drain fitting with stainless-steel pipe and fittings with welded joints where enclosed in ozone-generator room.
6. Install two **OR** three, **as directed**,-piece, stainless-steel ball valve in cooling water supply to ozone generator.
7. Mounting supports for ozone generator shall be ASTM A 666, Type 316 stainless steel.
8. Mount breathing apparatus outside ozone-generator room.
9. Mount and install ozone detector, warning lights, and audible alarm inside ozone-generator room. Mount another set of warning lights and audible alarm just outside the main entrance to ozone-generator room.

D. UV-Irradiation Unit Installation
1. Install UV-irradiation units on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor mineral and brine tanks and floor-mounting accessories to substrate.
2. Install seismic restraints for UV-irradiation units and floor-mounting accessories and anchor to building structure. Refer to Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" for seismic restraints.

E. Water Softener Installation

1. Install water softener equipment on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor mineral and brine tanks and floor-mounting accessories to substrate.
2. Install seismic restraints for tanks and floor-mounting accessories and anchor to building structure. Refer to Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" for seismic restraints.
3. Install brine lines and fittings furnished by equipment manufacturer but not factory installed.
4. Prepare mineral-tank distribution system and underbed for minerals and place specified mineral into mineral tanks.
5. Install water-testing sets on wall adjacent to water softeners.

F. RO Unit Installation
1. Install RO unit and storage tank on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor RO unit and storage tank with pumps to substrate.
2. Install seismic restraints for tanks and floor-mounting accessories and anchor to building structure. Refer to Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" for seismic restraints.
3. Install interconnecting piping and controls furnished by equipment manufacturer but not factory installed.
4. Install water testing sets on wall adjacent to RO unit.

G. Connections
1. Piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
2. Install piping adjacent to equipment to allow service and maintenance.
3. Make piping connections between HVAC water-treatment equipment and dissimilar-metal piping with dielectric fittings. Dielectric fittings are specified in Division 23 Section "Common Work Results For Hvac".
4. Install shutoff valves on HVAC water-treatment equipment inlet and outlet. Metal general-duty valves are specified in Division 23 Section "General-duty Valves For Hvac Piping".
5. Refer to Division 22 Section "Domestic Water Piping Specialties" for backflow preventers required in makeup water connections to potable-water systems.
6. Confirm applicable electrical requirements in Division 22 for connecting electrical equipment.
7. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
8. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

H. Field Quality Control
1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections. Report results in writing.
2. Perform tests and inspections and prepare test reports.
   a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
3. Tests and Inspections:
   a. Inspect field-assembled components and equipment installation, including piping and electrical connections.
   b. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational before introducing chemicals for water-treatment system.
   c. Place HVAC water-treatment system into operation and calibrate controls during the preliminary phase of HVAC systems' startup procedures.

d. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.
e. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
f. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
g. Cap and subject piping to static water pressure of 50 psig (345 kPa) above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow test pressure to stand for four hours. Leaks and loss in test pressure constitute defects.
h. Repair leaks and defects with new materials and retest piping until no leaks exist.

4. Remove and replace malfunctioning units and retest as specified above.
5. Sample boiler water at one-week intervals after boiler startup for a period of five weeks, and prepare test report advising the Owner of changes necessary to adhere to Part 1 "Performance Requirements" Article for each required characteristic. Sample boiler water at four **OR** six **OR** eight, **as directed**,-week intervals following the testing noted above to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section.
6. At four **OR** six **OR** eight, **as directed**,-week intervals following Final Completion, perform separate water analyses on hydronic systems to show that automatic chemical-feed systems are maintaining water quality within performance requirements specified in this Section. Submit written reports of water analysis advising the Owner of changes necessary to adhere to Part 1.1 "Performance Requirements" Article.
7. Comply with ASTM D 3370 and with the following standards:
   a. Silica: ASTM D 859.
   b. Steam System: ASTM D 1066.
   c. Acidity and Alkalinity: ASTM D 1067.
   d. Iron: ASTM D 1068.
   e. Water Hardness: ASTM D 1126.

I. Demonstration
1. Engage a factory-authorized service representative to train the Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.

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Task	Specification	Specification Description
23 25 13 00	22 05 23 00	Piped Utilities Basic Materials And Methods
23 25 13 00	22 12 23 26	Underground Storage Tanks
23 25 13 00	22 11 16 00c	Hydronic Piping

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SECTION 23 31 13 13 - METAL DUCTS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for metal ducts. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Single-wall rectangular ducts and fittings.
b. Double-wall rectangular ducts and fittings.
c. Single-wall round and flat-oval ducts and fittings.
d. Double-wall round and flat-oval ducts and fittings.
e. Sheet metal materials.
f. Duct liner.
g. Sealants and gaskets.
h. Hangers and supports.
i. Seismic-restraint devices.

C. Performance Requirements
1. Delegated Duct Design: Duct construction, including sheet metal thicknesses, seam and joint construction, reinforcements, and hangers and supports, shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and performance requirements and design criteria indicated in "Duct Schedule" Article.
2. Structural Performance: Duct hangers and supports and seismic restraints shall withstand the effects of gravity and seismic loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and ASCE/SEI 7 **OR** SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems", **as directed**.
a. Seismic Hazard Level A: Seismic force to weight ratio, 0.48.
OR
Seismic Hazard Level B: Seismic force to weight ratio, 0.30.
OR
Seismic Hazard Level C: Seismic force to weight ratio, 0.15.
3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Submittals
1. Product Data: For each type of the following products:
a. Liners and adhesives.
b. Sealants and gaskets.
c. Seismic-restraint devices.
2. LEED Submittals:
a. Product Data for Prerequisite EQ 1: Documentation indicating that duct systems comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
b. Product Data for Prerequisite EA 2: Documentation indicating that duct systems comply with ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."
c. Leakage Test Report for Prerequisite EA 2: Documentation of work performed for compliance with ASHRAE/IESNA 90.1, Section 6.4.4.2.2 - "Duct Leakage Tests."
d. Duct-Cleaning Test Report for Prerequisite EQ 1: Documentation of work performed for compliance with ASHRAE 62.1, Section 7.2.4 - "Ventilation System Start-Up."

e. Product Data for Credit EQ 4.1: For adhesives and sealants, including printed statement of VOC content.

3. Shop Drawings:
   a. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
   b. Factory- and shop-fabricated ducts and fittings.
   c. Duct layout indicating sizes, configuration, liner material, and static-pressure classes.
   d. Elevation of top of ducts.
   e. Dimensions of main duct runs from building grid lines.
   f. Fittings.
   g. Reinforcement and spacing.
   h. Seam and joint construction.
   i. Penetrations through fire-rated and other partitions.
   j. Equipment installation based on equipment being used on Project.
   k. Locations for duct accessories, including dampers, turning vanes, and access doors and panels.
   l. Hangers and supports, including methods for duct and building attachment, seismic restraints, and vibration isolation.
4. Delegated-Design Submittal:
   a. Sheet metal thicknesses.
   b. Joint and seam construction and sealing.
   c. Reinforcement details and spacing.
   d. Materials, fabrication, assembly, and spacing of hangers and supports.
   e. Design Calculations: Calculations, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation for selecting hangers and supports and seismic restraints.
5. Coordination Drawings: Plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
   a. Duct installation in congested spaces, indicating coordination with general construction, building components, and other building services. Indicate proposed changes to duct layout.
   b. Suspended ceiling components.
   c. Structural members to which duct will be attached.
   d. Size and location of initial access modules for acoustical tile.
   e. Penetrations of smoke barriers and fire-rated construction.
   f. Items penetrating finished ceiling including the following:
      1) Lighting fixtures.
      2) Air outlets and inlets.
      3) Speakers.
      4) Sprinklers.
      5) Access panels.
      6) Perimeter moldings.
6. Welding certificates.
7. Field quality-control reports.

E. Quality Assurance
1. Welding Qualifications: Qualify procedures and personnel according to the following:
   a. AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports.
   b. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports.
   c. AWS D9.1M/D9.1, "Sheet Metal Welding Code," for duct joint and seam welding.
2. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-Up."
3. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."

1.2 PRODUCTS

A. Single-Wall Rectangular Ducts And Fittings
1. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.
2. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 1-4, "Transverse (Girth) Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
3. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 1-5, "Longitudinal Seams - Rectangular Ducts," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
4. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 2, "Fittings and Other Construction," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

B. Double-Wall Rectangular Ducts And Fittings
1. Rectangular Ducts: Fabricate ducts with indicated dimensions for the inner duct.
2. Outer Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.
3. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 1-4, "Transverse (Girth) Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
4. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 1-5, "Longitudinal Seams - Rectangular Ducts," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
5. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."
   a. Maximum Thermal Conductivity: 0.27 Btu x in./h x sq. ft. x deg F (0.039 W/m x K) at 75 deg F (24 deg C) mean temperature.
   b. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.
   c. Coat insulation with antimicrobial coating.
   d. Cover insulation with polyester film complying with UL 181, Class 1.

   OR
6. Interstitial Insulation: Flexible elastomeric duct liner complying with ASTM C 534, Type II for sheet materials, and with NFPA 90A or NFPA 90B.
   a. Maximum Thermal Conductivity: 0.25 Btu x in./h x sq. ft. x deg F (0.034 W/m x K) at 75 deg F (24 deg C) mean temperature.
7. Inner Duct: Minimum 0.028-inch (0.7-mm) perforated galvanized sheet steel having 3/32-inch-(2.4-mm-) diameter perforations, with overall open area of 23 percent **OR** solid sheet steel, **as directed**.
8. Formed-on Transverse Joints (Flanges): Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 1-4, "Traverse (Girth) Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

9. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 1-5, "Longitudinal Seams - Rectangular Ducts," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

C. Single-Wall Round And Flat-Oval Ducts And Fittings
1. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated.
2. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension).
3. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Transverse Joints - Round Duct," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
   a. Transverse Joints in Ducts Larger Than 60 Inches (1524 mm) in Diameter: Flanged.
4. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Seams - Round Duct and Fittings," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
   a. Fabricate round ducts larger than 90 inches (2286 mm) in diameter with butt-welded longitudinal seams.
   b. Fabricate flat-oval ducts larger than 72 inches (1830 mm) in width (major dimension) with butt-welded longitudinal seams.
5. Tees and Laterals: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "90 Degree Tees and Laterals," and Figure 3-5, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

D. Double-Wall Round And Flat-Oval Ducts And Fittings
1. Flat-Oval Ducts: Indicated dimensions are the duct width (major dimension) and diameter of the round sides connecting the flat portions of the duct (minor dimension) of the inner duct.
2. Outer Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 3, "Round, Oval, and Flexible Duct," based on static-pressure class unless otherwise indicated.
   a. Transverse Joints: Select joint types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Transverse Joints - Round Duct," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
      1) Transverse Joints in Ducts Larger Than 60 Inches (1524 mm) in Diameter: Flanged.
   b. Longitudinal Seams: Select seam types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Seams - Round Duct and Fittings," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
      1) Fabricate round ducts larger than 90 inches (2286 mm) in diameter with butt-welded longitudinal seams.
      2) Fabricate flat-oval ducts larger than 72 inches (1830 mm) in width (major dimension) with butt-welded longitudinal seams.
   c. Tees and Laterals: Select types and fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "90 Degree Tees and Laterals," and Figure 3-5, "Conical Tees," for static-pressure class, applicable sealing requirements,

materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

3. Inner Duct: Minimum 0.028-inch (0.7-mm) perforated galvanized sheet steel having 3/32-inch-(2.4-mm-) diameter perforations, with overall open area of 23 percent **OR** solid sheet steel, **as directed**.
4. Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."
   a. Maximum Thermal Conductivity: 0.27 Btu x in./h x sq. ft. x deg F (0.039 W/m x K) at 75 deg F (24 deg C) mean temperature.
   b. Install spacers that position the inner duct at uniform distance from outer duct without compressing insulation.
   c. Coat insulation with antimicrobial coating.
   d. Cover insulation with polyester film complying with UL 181, Class 1.

   OR
5. Interstitial Insulation: Flexible elastomeric duct liner complying with ASTM C 534, Type II for sheet materials, and with NFPA 90A or NFPA 90B.
   a. Maximum Thermal Conductivity: 0.25 Btu x in./h x sq. ft. x deg F (0.034 W/m x K) at 75 deg F (24 deg C) mean temperature.

E. Sheet Metal Materials
1. General Material Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.
2. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
   a. Galvanized Coating Designation: G60 (Z180) **OR** G90 (Z275), **as directed**.
   b. Finishes for Surfaces Exposed to View: Mill phosphatized.
3. PVC-Coated, Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
   a. Galvanized Coating Designation: G60 (Z180) **OR** G90 (Z275), **as directed**.
   b. Minimum Thickness for Factory-Applied PVC Coating: 4 mils (0.10 mm) thick on sheet metal surface of ducts and fittings exposed to corrosive conditions, and minimum 1 mil (0.025 mm) thick on opposite surface, **as directed**.
   c. Coating Materials: Acceptable to authorities having jurisdiction for use on ducts listed and labeled by an NRTL for compliance with UL 181, Class 1.
4. Carbon-Steel Sheets: Comply with ASTM A 1008/A 1008M, with oiled, matte finish for exposed ducts.
5. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304 or 316, as indicated in the "Duct Schedule" Article; cold rolled, annealed, sheet. Exposed surface finish shall be No. 2B, No. 2D, No. 3, or No. 4 as indicated in the "Duct Schedule" Article.
6. Aluminum Sheets: Comply with ASTM B 209 (ASTM B 209M) Alloy 3003, H14 temper; with mill finish for concealed ducts, and standard, one-side bright finish for duct surfaces exposed to view.
7. Factory- or Shop-Applied Antimicrobial Coating:
   a. Apply to the surface of sheet metal that will form the interior surface of the duct. An untreated clear coating shall be applied to the exterior surface.
   b. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
   c. Coating containing the antimicrobial compound shall have a hardness of 2H, minimum, when tested according to ASTM D 3363.
   d. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
   e. Shop-Applied Coating Color: Black **OR** White, **as directed**.
   f. Antimicrobial coating on sheet metal is not required for duct containing liner treated with antimicrobial coating.
8. Reinforcement Shapes and Plates: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.

a. Where black- and galvanized-steel shapes and plates are used to reinforce aluminum ducts, isolate the different metals with butyl rubber, neoprene, or EPDM gasket materials.

9. Tie Rods: Galvanized steel, 1/4-inch (6-mm) minimum diameter for lengths 36 inches (900 mm) or less; 3/8-inch (10-mm) minimum diameter for lengths longer than 36 inches (900 mm).

F. Duct Liner

1. Fibrous-Glass Duct Liner: Comply with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."
   a. Maximum Thermal Conductivity:
      1) Type I, Flexible: 0.27 Btu x in./h x sq. ft. x deg F (0.039 W/m x K) at 75 deg F (24 deg C) mean temperature.
      2) Type II, Rigid: 0.23 Btu x in./h x sq. ft. x deg F (0.033 W/m x K) at 75 deg F (24 deg C) mean temperature.
   b. Antimicrobial Erosion-Resistant Coating: Apply to the surface of the liner that will form the interior surface of the duct to act as a moisture repellent and erosion-resistant coating. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
   c. Solvent-Based **OR** Water-Based, **as directed**, Liner Adhesive: Comply with NFPA 90A or NFPA 90B and with ASTM C 916.
      1) For indoor applications, use adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
2. Flexible Elastomeric Duct Liner: Preformed, cellular, closed-cell, sheet materials complying with ASTM C 534, Type II, Grade 1; and with NFPA 90A or NFPA 90B.
   a. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
   b. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.
      1) For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
3. Natural-Fiber Duct Liner: 85 percent cotton, 10 percent borate, and 5 percent polybinding fibers, treated with a microbial growth inhibitor and complying with NFPA 90A or NFPA 90B.
   a. Maximum Thermal Conductivity: 0.24 Btu x in./h x sq. ft. x deg F (0.034 W/m x K) at 75 deg F (24 deg C) mean temperature when tested according to ASTM C 518.
   b. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to ASTM E 84; certified by an NRTL.
   c. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.
      1) For indoor applications, use adhesive that has a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
4. Insulation Pins and Washers:
   a. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.106-inch- (2.6-mm-) **OR** 0.135-inch- (3.5-mm-), **as directed**, diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch (38-mm) galvanized carbon-steel washer.
   b. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- (0.41-mm-) thick galvanized steel **OR** aluminum **OR** stainless steel, **as directed**; with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches (38 mm) in diameter.
5. Shop Application of Duct Liner: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-19, "Flexible Duct Liner Installation."
   a. Adhere a single layer of indicated thickness of duct liner with at least 90 percent adhesive coverage at liner contact surface area. Attaining indicated thickness with multiple layers of duct liner is prohibited.
   b. Apply adhesive to transverse edges of liner facing upstream that do not receive metal nosing.

c. Butt transverse joints without gaps, and coat joint with adhesive.
d. Fold and compress liner in corners of rectangular ducts or cut and fit to ensure butted-edge overlapping.
e. Do not apply liner in rectangular ducts with longitudinal joints, except at corners of ducts, unless duct size and dimensions of standard liner make longitudinal joints necessary.
f. Apply adhesive coating on longitudinal seams in ducts with air velocity of 2500 fpm (12.7 m/s).
g. Secure liner with mechanical fasteners 4 inches (100 mm) from corners and at intervals not exceeding 12 inches (300 mm) transversely; at 3 inches (75 mm) from transverse joints and at intervals not exceeding 18 inches (450 mm) longitudinally.
h. Secure transversely oriented liner edges facing the airstream with metal nosings that have either channel or "Z" profiles or are integrally formed from duct wall. Fabricate edge facings at the following locations:
   1) Fan discharges.
   2) Intervals of lined duct preceding unlined duct.
   3) Upstream edges of transverse joints in ducts where air velocities are higher than 2500 fpm (12.7 m/s) or where indicated.
i. Secure insulation between perforated sheet metal inner duct of same thickness as specified for outer shell. Use mechanical fasteners that maintain inner duct at uniform distance from outer shell without compressing insulation.
   1) Sheet Metal Inner Duct Perforations: 3/32-inch (2.4-mm) diameter, with an overall open area of 23 percent.
j. Terminate inner ducts with buildouts attached to fire-damper sleeves, dampers, turning vane assemblies, or other devices. Fabricated buildouts (metal hat sections) or other buildout means are optional; when used, secure buildouts to duct walls with bolts, screws, rivets, or welds.

G. Sealant And Gaskets
1. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
2. Two-Part Tape Sealing System:
   a. Tape: Woven cotton fiber impregnated with mineral gypsum and modified acrylic/silicone activator to react exothermically with tape to form hard, durable, airtight seal.
   b. Tape Width: 3 inches (76 mm) **OR** 4 inches (102 mm) **OR** 6 inches (152 mm), **as directed**.
   c. Sealant: Modified styrene acrylic.
   d. Water resistant.
   e. Mold and mildew resistant.
   f. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive and negative.
   g. Service: Indoor and outdoor.
   h. Service Temperature: Minus 40 to plus 200 deg F (Minus 40 to plus 93 deg C).
   i. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum.
   j. For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
3. Water-Based Joint and Seam Sealant:
   a. Application Method: Brush on.
   b. Solids Content: Minimum 65 percent.
   c. Shore A Hardness: Minimum 20.
   d. Water resistant.
   e. Mold and mildew resistant.
   f. VOC: Maximum 75 g/L (less water).
   g. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive and negative.
   h. Service: Indoor or outdoor.

i. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

4. Solvent-Based Joint and Seam Sealant:
   a. Application Method: Brush on.
   b. Base: Synthetic rubber resin.
   c. Solvent: Toluene and heptane.
   d. Solids Content: Minimum 60 percent.
   e. Shore A Hardness: Minimum 60.
   f. Water resistant.
   g. Mold and mildew resistant.
   h. For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
   i. VOC: Maximum 395 g/L.
   j. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive or negative.
   k. Service: Indoor or outdoor.
   l. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.
5. Flanged Joint Sealant: Comply with ASTM C 920.
   a. General: Single-component, acid-curing, silicone, elastomeric.
   b. Type: S.
   c. Grade: NS.
   d. Class: 25.
   e. Use: O.
   f. For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
6. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.
7. Round Duct Joint O-Ring Seals:
   a. Seal shall provide maximum leakage class of 3 cfm/100 sq. ft. at 1-inch wg (0.14 L/s per sq. m at 250 Pa) and shall be rated for 10-inch wg (2500-Pa) static-pressure class, positive or negative.
   b. EPDM O-ring to seal in concave bead in coupling or fitting spigot.
   c. Double-lipped, EPDM O-ring seal, mechanically fastened to factory-fabricated couplings and fitting spigots.

H. Hangers And Supports
1. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.
2. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.
3. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 4-1 (Table 4-1M), "Rectangular Duct Hangers Minimum Size," and Table 4-2, "Minimum Hanger Sizes for Round Duct."
4. Steel Cables for Galvanized-Steel Ducts: Galvanized steel complying with ASTM A 603.
5. Steel Cables for Stainless-Steel Ducts: Stainless steel complying with ASTM A 492.
6. Steel Cable End Connections: Cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.
7. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.
8. Trapeze and Riser Supports:
   a. Supports for Galvanized-Steel Ducts: Galvanized-steel shapes and plates.
   b. Supports for Stainless-Steel Ducts: Stainless-steel shapes and plates.
   c. Supports for Aluminum Ducts: Aluminum or galvanized steel coated with zinc chromate.

I. Seismic-Restraint Devices
1. General Requirements for Restraint Components: Rated strengths, features, and applications shall be as defined in reports by an evaluation service member of the ICC Evaluation Service **OR**

the Office of Statewide Health Planning and Development for the State of California **OR** an agency acceptable to authorities having jurisdiction, **as directed**.

a. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least four times the maximum seismic forces to which they will be subjected.

2. Channel Support System: Shop- or field-fabricated support assembly made of slotted steel channels rated in tension, compression, and torsion forces and with accessories for attachment to braced component at one end and to building structure at the other end. Include matching components and corrosion-resistant coating.
3. Restraint Cables: ASTM A 603, galvanized-steel **OR** ASTM A 492, stainless-steel, **as directed**, cables with end connections made of cadmium-plated steel assemblies with brackets, swivel, and bolts designed for restraining cable service; and with an automatic-locking and clamping device or double-cable clips.
4. Hanger Rod Stiffener: Steel tube or steel slotted-support-system sleeve with internally bolted connections **OR** Reinforcing steel angle clamped, **as directed**, to hanger rod.
5. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

1.3 EXECUTION

A. Duct Installation

1. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and Coordination Drawings.
2. Install ducts according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.
3. Install round and flat-oval ducts in maximum practical lengths.
4. Install ducts with fewest possible joints.
5. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.
6. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.
7. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.
8. Install ducts with a clearance of 1 inch (25 mm), plus allowance for insulation thickness.
9. Route ducts to avoid passing through transformer vaults and electrical equipment rooms and enclosures.
10. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges of same metal thickness as the duct. Overlap openings on four sides by at least 1-1/2 inches (38 mm).
11. Where ducts pass through fire-rated interior partitions and exterior walls, install fire dampers. Comply with requirements in Division 23 Section "Air Duct Accessories" for fire and smoke dampers.
12. Protect duct interiors from moisture, construction debris and dust, and other foreign materials. Comply with SMACNA's "Duct Cleanliness for New Construction Guidelines", **as directed**.

B. Installation Of Exposed Ductwork

1. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.
2. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.

3. Grind welds to provide smooth surface free of burrs, sharp edges, and weld splatter. When welding stainless steel with a No. 3 or 4 finish, grind the welds flush, polish the exposed welds, and treat the welds to remove discoloration caused by welding.
4. Maintain consistency, symmetry, and uniformity in the arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.
5. Repair or replace damaged sections and finished work that does not comply with these requirements.

C. Additional Installation Requirements For Commercial Kitchen Hood Exhaust Duct
1. Install commercial kitchen hood exhaust ducts without dips and traps that may hold grease, and sloped a minimum of 2 percent to drain grease back to the hood.
2. Install fire-rated access panel assemblies at each change in direction and at maximum intervals of 20 feet (6 m) **OR** 12 feet (3.7 m), **as directed**, in horizontal ducts, and at every floor for vertical ducts, or as indicated on Drawings. Locate access panel on top or sides of duct a minimum of 1-1/2 inches (38 mm) from bottom of duct.
3. Do not penetrate fire-rated assemblies except as allowed by applicable building codes and authorities having jurisdiction.

D. Duct Sealing
1. Seal ducts for duct static-pressure, seal classes, and leakage classes specified in "Duct Schedule" Article according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
OR
Seal ducts to the following seal classes according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible":
   a. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
   b. Outdoor, Supply-Air Ducts: Seal Class A.
   c. Outdoor, Exhaust Ducts: Seal Class C.
   d. Outdoor, Return-Air Ducts: Seal Class C.
   e. Unconditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg (500 Pa) and Lower: Seal Class B.
   f. Unconditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg (500 Pa): Seal Class A.
   g. Unconditioned Space, Exhaust Ducts: Seal Class C.
   h. Unconditioned Space, Return-Air Ducts: Seal Class B.
   i. Conditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg (500 Pa) and Lower: Seal Class C.
   j. Conditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg (500 Pa): Seal Class B.
   k. Conditioned Space, Exhaust Ducts: Seal Class B.
   l. Conditioned Space, Return-Air Ducts: Seal Class C.

E. Hanger And Support Installation
1. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 4, "Hangers and Supports."
2. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.
   a. Where practical, install concrete inserts before placing concrete.
   b. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
   c. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 4 inches (100 mm) thick.
   d. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches (100 mm) thick.
   e. Do not use powder-actuated concrete fasteners for seismic restraints.

3. Hanger Spacing: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 4-1 (Table 4-1M), "Rectangular Duct Hangers Minimum Size," and Table 4-2, "Minimum Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within 24 inches (610 mm) of each elbow and within 48 inches (1200 mm) of each branch intersection.
4. Hangers Exposed to View: Threaded rod and angle or channel supports.
5. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, sheet metal screws, or blind rivets; support at each floor and at a maximum intervals of 16 feet (5 m).
6. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

F. Seismic-Restraint-Device Installation
1. Install ducts with hangers and braces designed to support the duct and to restrain against seismic forces required by applicable building codes. Comply with SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems" **OR** ASCE/SEI 7, **as directed**.
   a. Space lateral supports a maximum of 40 feet (12 m) o.c., and longitudinal supports a maximum of 80 feet (24 m) o.c.
   b. Brace a change of direction longer than 12 feet (3.7 m).
2. Select seismic-restraint devices with capacities adequate to carry present and future static and seismic loads.
3. Install cables so they do not bend across edges of adjacent equipment or building structure.
4. Install cable restraints on ducts that are suspended with vibration isolators.
5. Install seismic-restraint devices using methods approved by an evaluation service member of the ICC Evaluation Service **OR** the Office of Statewide Health Planning and Development for the State of California **OR** an agency acceptable to authorities having jurisdiction, **as directed**.
6. Attachment to Structure: If specific attachment is not indicated, anchor bracing and restraints to structure, to flanges of beams, to upper truss chords of bar joists, or to concrete members.
7. Drilling for and Setting Anchors:
   a. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcement or embedded items during drilling. Notify the the Owner if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
   b. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
   c. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
   d. Set anchors to manufacturer's recommended torque, using a torque wrench.
   e. Install zinc-coated steel anchors for interior applications and stainless-steel anchors for applications exposed to weather.

G. Connections
1. Make connections to equipment with flexible connectors complying with Division 23 Section "Air Duct Accessories".
2. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

H. Painting
1. Paint interior of metal ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, latex paint over a compatible galvanized-steel primer. Paint materials and application requirements are specified in Division 07.

I. Field Quality Control
1. Perform tests and inspections.

2. Leakage Tests:
   a. Comply with SMACNA's "HVAC Air Duct Leakage Test Manual." Submit a test report for each test.
   b. Test the following systems:
      1) Ducts with a Pressure Class Higher Than 3-Inch wg (750 Pa): Test representative duct sections, selected by the Owner from sections installed, **as directed**, totaling no less than 25 percent of total installed duct area for each designated pressure class.
      2) Supply Ducts with a Pressure Class of 2-Inch wg (500 Pa) **OR** 3-Inch wg (750 Pa) **OR** 4-Inch wg (1000 Pa), **as directed**, or Higher: Test representative duct sections, selected by the Owner from sections installed, **as directed**, totaling no less than 50 **OR** 100, **as directed**, percent of total installed duct area for each designated pressure class.
      3) Return Ducts with a Pressure Class of 2-Inch wg (500 Pa) **OR** 3-Inch wg (750 Pa) **OR** 4-Inch wg (1000 Pa), **as directed**, or Higher: Test representative duct sections, selected by the Owner from sections installed, **as directed**, totaling no less than 50 **OR** 100, **as directed**, percent of total installed duct area for each designated pressure class.
      4) Exhaust Ducts with a Pressure Class of 2-Inch wg (500 Pa) **OR** 3-Inch wg (750 Pa) **OR** 4-Inch wg (1000 Pa), **as directed**, or Higher: Test representative duct sections, selected by the Owner from sections installed, **as directed**, totaling no less than 50 **OR** 100, **as directed**, percent of total installed duct area for each designated pressure class.
      5) Outdoor Air Ducts with a Pressure Class of 2-Inch wg (500 Pa) **OR** 3-Inch wg (750 Pa) **OR** 4-Inch wg (1000 Pa), **as directed**, or Higher: Test representative duct sections, selected by the Owner from sections installed, **as directed**, totaling no less than 50 **OR** 100, **as directed**, percent of total installed duct area for each designated pressure class.
   c. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
   d. Test for leaks before applying external insulation.
   e. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If static-pressure classes are not indicated, test system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure.
   f. Give seven days' advance notice for testing.
3. Duct System Cleanliness Tests:
   a. Visually inspect duct system to ensure that no visible contaminants are present.
   b. Test sections of metal duct system, chosen randomly by the Owner, for cleanliness according to "Vacuum Test" in NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."
      1) Acceptable Cleanliness Level: Net weight of debris collected on the filter media shall not exceed 0.75 mg/100 sq. cm.
4. Duct system will be considered defective if it does not pass tests and inspections.
5. Prepare test and inspection reports.

J. Duct Cleaning
   1. Clean new **OR** existing **OR** new and existing, **as directed**, duct system(s) before testing, adjusting, and balancing.
   2. Use service openings for entry and inspection.
      a. Create new openings and install access panels appropriate for duct static-pressure class if required for cleaning access. Provide insulated panels for insulated or lined duct. Patch insulation and liner as recommended by duct liner manufacturer. Comply with Division 23 Section "Air Duct Accessories" for access panels and doors.
      b. Disconnect and reconnect flexible ducts as needed for cleaning and inspection.
      c. Remove and reinstall ceiling to gain access during the cleaning process.

3. Particulate Collection and Odor Control:
   a. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron-size (or larger) particles.
   b. When venting vacuuming system to outdoors, use filter to collect debris removed from HVAC system, and locate exhaust downwind and away from air intakes and other points of entry into building.
4. Clean the following components by removing surface contaminants and deposits:
   a. Air outlets and inlets (registers, grilles, and diffusers).
   b. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
   c. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
   d. Coils and related components.
   e. Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.
   f. Supply-air ducts, dampers, actuators, and turning vanes.
   g. Dedicated exhaust and ventilation components and makeup air systems.
5. Mechanical Cleaning Methodology:
   a. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
   b. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
   c. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.
   d. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet. Replace fibrous-glass duct liner that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.
   e. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
   f. Provide drainage and cleanup for wash-down procedures.
   g. Antimicrobial Agents and Coatings: Apply EPA-registered antimicrobial agents if fungus is present. Apply antimicrobial agents according to manufacturer's written instructions after removal of surface deposits and debris.

K. Start Up
1. Air Balance: Comply with requirements in Division 23 Section "Testing, Adjusting, And Balancing For Hvac".

L. Duct Schedule
1. Fabricate ducts with galvanized sheet steel except as otherwise indicated and as follows:
   a. Underground Ducts: Concrete-encased, galvanized sheet steel **OR** PVC-coated, galvanized sheet steel with thicker coating on duct exterior **OR** stainless steel, **as directed**.
2. Supply Ducts:
   a. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units:
      1) Pressure Class: Positive 1-inch wg (250 Pa) **OR** 2-inch wg (500 Pa), **as directed**.
      2) Minimum SMACNA Seal Class: A **OR** B **OR** C, **as directed**.
      3) SMACNA Leakage Class for Rectangular: 12 **OR** 24, **as directed**.
      4) SMACNA Leakage Class for Round and Flat Oval: 12 **OR** 24, **as directed**.
   b. Ducts Connected to Constant-Volume Air-Handling Units:
      1) Pressure Class: Positive 2-inch wg (500 Pa) **OR** 3-inch wg (750 Pa), **as directed**.
      2) Minimum SMACNA Seal Class: A **OR** B, **as directed**.
      3) SMACNA Leakage Class for Rectangular: 6 **OR** 12 **OR** 24, **as directed**.

4) SMACNA Leakage Class for Round and Flat Oval: 6 **OR** 12 **OR** 24, **as directed**.

c. Ducts Connected to Variable-Air-Volume Air-Handling Units:
1) Pressure Class: Positive 3-inch wg (750 Pa) **OR** 4-inch wg (1000 Pa), **as directed**.
2) Minimum SMACNA Seal Class: A **OR** B, **as directed**.
3) SMACNA Leakage Class for Rectangular: 3 **OR** 6, **as directed**.
4) SMACNA Leakage Class for Round and Flat Oval: 3 **OR** 6, **as directed**.

d. Ducts Connected to Equipment Not Listed Above:
1) Pressure Class: Positive 2-inch wg (500 Pa) **OR** 3-inch wg (750 Pa) **OR** 4-inch wg (1000 Pa), **as directed**.
2) Minimum SMACNA Seal Class: A **OR** B, **as directed**.
3) SMACNA Leakage Class for Rectangular: 3 **OR** 6 **OR** 12, **as directed**.
4) SMACNA Leakage Class for Round and Flat Oval: 3 **OR** 6 **OR** 12, **as directed**.

3. Return Ducts:

a. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units:
1) Pressure Class: Positive or negative 1-inch wg (250 Pa) **OR** 2-inch wg (500 Pa), **as directed**.
2) Minimum SMACNA Seal Class: A **OR** B **OR** C, **as directed**.
3) SMACNA Leakage Class for Rectangular: 12 **OR** 24, **as directed**.
4) SMACNA Leakage Class for Round and Flat Oval: 12 **OR** 24, **as directed**.

b. Ducts Connected to Air-Handling Units:
1) Pressure Class: Positive or negative 2-inch wg (500 Pa) **OR** 3-inch wg (750 Pa), **as directed**.
2) Minimum SMACNA Seal Class: A **OR** B, **as directed**.
3) SMACNA Leakage Class for Rectangular: 6 **OR** 12 **OR** 24, **as directed**.
4) SMACNA Leakage Class for Round and Flat Oval: 6 **OR** 12 **OR** 24, **as directed**.

c. Ducts Connected to Equipment Not Listed Above:
1) Pressure Class: Positive or negative 2-inch wg (500 Pa) **OR** 3-inch wg (750 Pa) **OR** 4-inch wg (1000 Pa), **as directed**.
2) Minimum SMACNA Seal Class: A **OR** B, **as directed**.
3) SMACNA Leakage Class for Rectangular: 3 **OR** 6 **OR** 12, **as directed**.
4) SMACNA Leakage Class for Round and Flat Oval: 3 **OR** 6 **OR** 12, **as directed**.

4. Exhaust Ducts:

a. Ducts Connected to Fans Exhausting (ASHRAE 62.1, Class 1 and 2) Air:
1) Pressure Class: Negative 1-inch wg (250 Pa) **OR** 2-inch wg (500 Pa) **OR** 3-inch wg (750 Pa), **as directed**.
2) Minimum SMACNA Seal Class: A **OR** B **OR** C, **as directed**, if negative pressure, and A if positive pressure.
3) SMACNA Leakage Class for Rectangular: 12 **OR** 24, **as directed**.
4) SMACNA Leakage Class for Round and Flat Oval: 6 **OR** 12 **OR** 24, **as directed**.

b. Ducts Connected to Air-Handling Units:
1) Pressure Class: Positive or negative 2-inch wg (500 Pa) **OR** 3-inch wg (750 Pa) **as directed**.
2) Minimum SMACNA Seal Class: A **OR** B, **as directed**, if negative pressure, and A if positive pressure.
3) SMACNA Leakage Class for Rectangular: 6 **OR** 12 **OR** 24, **as directed**.
4) SMACNA Leakage Class for Round and Flat Oval: 3 **OR** 6 **OR** 12 **OR** 24, **as directed**.

c. Ducts Connected to Commercial Kitchen Hoods: Comply with NFPA 96.
1) Exposed to View: Type 304, stainless-steel sheet, No. 4 **OR** No. 3, **as directed**, finish.
2) Concealed: Type 304, stainless-steel sheet, No. 2D finish **OR** Carbon-steel sheet, **as directed**.
3) Welded seams and joints.
4) Pressure Class: Positive or negative 2-inch wg (500 Pa) **OR** 3-inch wg (750 Pa) **OR** 4-inch wg (1000 Pa), **as directed**.

5) Minimum SMACNA Seal Class: Welded seams, joints, and penetrations.
6) SMACNA Leakage Class: 3.

d. Ducts Connected to Dishwasher Hoods:
1) Type 304, stainless-steel sheet.
2) Exposed to View: No. 4 **OR** No. 3, **as directed**, finish.
3) Concealed: No. 2D finish.
4) Welded seams and flanged joints with watertight EPDM gaskets.
5) Pressure Class: Positive or negative 2-inch wg (500 Pa) **OR** 3-inch wg (750 Pa), **as directed**.
6) Minimum SMACNA Seal Class: Welded seams, joints, and penetrations.
7) SMACNA Leakage Class: 3.

e. Ducts Connected to Fans Exhausting Laboratory and Process (ASHRAE 62.1, Class 3 and 4) Air:
1) Type 316 **OR** Type 304, **as directed**, stainless-steel sheet.
a) Exposed to View: No. 4 **OR** No. 3, **as directed**, finish.
b) Concealed: No. 2B **OR** No. 2D, **asdrected**, finish.
OR
PVC-coated, galvanized sheet steel with thicker coating on duct interior.
2) Pressure Class: Positive or negative 3-inch wg (750 Pa) **OR** 4-inch wg (1000 Pa) **OR** 6-inch wg (1500 Pa), **as directed**.
3) Minimum SMACNA Seal Class: A **OR** Welded seams, joints, and penetrations, **as directed**.
4) SMACNA Leakage Class: 3.

f. Ducts Connected to Equipment Not Listed Above:
1) Pressure Class: Positive or negative 2-inch wg (500 Pa) **OR** 3-inch wg (750 Pa) **OR** 4-inch wg (1000 Pa), **a directed**.
2) Minimum SMACNA Seal Class: A **OR** B, **as directed**, if negative pressure, and A if positive pressure.
3) SMACNA Leakage Class for Rectangular: 6 **OR** 12 **OR** 24, **as directed**.
4) SMACNA Leakage Class for Round and Flat Oval: 3 **OR** 6 **OR** 12 **OR** 24, **as directed**.

5. Outdoor-Air (Not Filtered, Heated, or Cooled) Ducts:
a. Ducts Connected to Fan Coil Units, Furnaces, Heat Pumps, and Terminal Units:
1) Pressure Class: Positive or negative 1-inch wg (250 Pa) **OR** 2-inch wg (500 Pa), **as directed**.
2) Minimum SMACNA Seal Class: A **OR** B **OR** C, **as directed**.
3) SMACNA Leakage Class for Rectangular: 12 **OR** 24, **as directed**.
4) SMACNA Leakage Class for Round and Flat Oval: 6 **OR** 12 **OR** 24, **as directed**.

b. Ducts Connected to Air-Handling Units:
1) Pressure Class: Positive or negative 2-inch wg (500 Pa) **OR** 3-inch wg (750 Pa), **as directed**.
2) Minimum SMACNA Seal Class: A **OR** B, **as directed**.
3) SMACNA Leakage Class for Rectangular: 6 **OR** 12 **OR** 24, **as directed**.
4) SMACNA Leakage Class for Round and Flat Oval: 3 **OR** 6 **OR** 12 **OR** 24, **as directed**.

c. Ducts Connected to Equipment Not Listed Above:
1) Pressure Class: Positive or negative 2-inch wg (500 Pa) **OR** 3-inch wg (750 Pa) **OR** 4-inch wg (1000 Pa), **as directed**.
2) Minimum SMACNA Seal Class: A **OR** B, **as directed**.
3) SMACNA Leakage Class for Rectangular: 3 **OR** 6 **OR** 12, **as directed**.
4) SMACNA Leakage Class for Round and Flat Oval: 3 **OR** 6 **OR** 12, **as directed**.

6. Intermediate Reinforcement:
a. Galvanized-Steel Ducts: Galvanized steel **OR** Carbon steel coated with zinc-chromate primer **OR** Galvanized steel or carbon steel coated with zinc-chromate primer, **as directed**.
b. PVC-Coated Ducts:
1) Exposed to Airstream: Match duct material.

2) Not Exposed to Airstream: Galvanized **OR** Match duct material, **as directed**.

c. Stainless-Steel Ducts:

1) Exposed to Airstream: Match duct material.

2) Not Exposed to Airstream: Galvanized **OR** Match duct material, **as directed**.

d. Aluminum Ducts: Aluminum **OR** galvanized sheet steel coated with zinc chromate, **as directed**.

7. Liner:

a. Supply Air Ducts: Fibrous glass, Type I **OR** Flexible elastomeric **OR** Natural fiber, **as directed**, 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (51 mm), **as directed**, thick.

b. Return Air Ducts: Fibrous glass, Type I **OR** Flexible elastomeric **OR** Natural fiber, **as directed**, 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (51 mm), **as directed**, thick.

c. Exhaust Air Ducts: Fibrous glass, Type I **OR** Flexible elastomeric **OR** Natural fiber, **as directed**, 1 inch (25 mm) thick.

d. Supply Fan Plenums: Fibrous glass, Type II **OR** Flexible elastomeric **OR** Natural fiber, **as directed**, 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (51 mm), **as directed**, thick.

e. Return- and Exhaust-Fan Plenums: Fibrous glass, Type II **OR** Flexible elastomeric **OR** Natural fiber, **as directed**, 2 inches (51 mm) thick.

f. Transfer Ducts: Fibrous glass, Type I **OR** Flexible elastomeric **OR** Natural fiber, **as directed**, 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (51 mm), **as directed**, thick.

8. Double-Wall Duct Interstitial Insulation:

a. Supply Air Ducts: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (51 mm), **as directed**, thick.

b. Return Air Ducts: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (51 mm, **as directed**, thick.

c. Exhaust Air Ducts: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (51 mm), **as direcrted**, thick.

9. Elbow Configuration:

a. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Elbows."

1) Velocity 1000 fpm (5 m/s) or Lower:

a) Radius Type RE 1 with minimum 0.5 radius-to-diameter ratio.

b) Mitered Type RE 4 without vanes.

2) Velocity 1000 to 1500 fpm (5 to 7.6 m/s):

a) Radius Type RE 1 with minimum 1.0 radius-to-diameter ratio.

b) Radius Type RE 3 with minimum 0.5 radius-to-diameter ratio and two vanes.

c) Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-3, "Vanes and Vane Runners," and Figure 2-4, "Vane Support in Elbows."

3) Velocity 1500 fpm (7.6 m/s) or Higher:

a) Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.

b) Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.

c) Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-3, "Vanes and Vane Runners," and Figure 2-4, "Vane Support in Elbows."

OR

b. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Elbows."

1) Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.

2) Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.

3) Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-3, "Vanes and Vane Runners," and Figure 2-4, "Vane Support in Elbows."

c. Round Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-3, "Round Duct Elbows."

1) Minimum Radius-to-Diameter Ratio and Elbow Segments: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 3-1, "Mitered Elbows." Elbows with less than 90-degree change of direction have proportionately fewer segments.

a) Velocity 1000 fpm (5 m/s) or Lower: 0.5 radius-to-diameter ratio and three segments for 90-degree elbow.

b) Velocity 1000 to 1500 fpm (5 to 7.6 m/s): 1.0 radius-to-diameter ratio and four segments for 90-degree elbow.

c) Velocity 1500 fpm (7.6 m/s) or Higher: 1.5 radius-to-diameter ratio and five segments for 90-degree elbow.

d) Radius-to Diameter Ratio: 1.5.

2) Round Elbows, 12 Inches (305 mm) and Smaller in Diameter: Stamped or pleated.

3) Round Elbows, 14 Inches (356 mm) and Larger in Diameter: Standing seam **OR** Welded, **as directed**.

10. Branch Configuration:

a. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-6, "Branch Connections."

1) Rectangular Main to Rectangular Branch: 45-degree entry.

2) Rectangular Main to Round Branch: Spin in.

b. Round and Flat Oval: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "90 Degree Tees and Laterals," and Figure 3-5, "Conical Tees." Saddle taps are permitted in existing duct.

1) Velocity 1000 fpm (5 m/s) or Lower: 90-degree tap.

2) Velocity 1000 to 1500 fpm (5 to 7.6 m/s): Conical tap.

3) Velocity 1500 fpm (7.6 m/s) or Higher: 45-degree lateral.

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SECTION 23 31 13 13a - HVAC CASINGS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for HVAC casings. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Factory- and Shop-fabricated, field-assembled, single- and double-wall casings for HVAC equipment.

C. Performance Requirements
1. Static-Pressure Classes:
a. Upstream from Fan(s): 2-inch wg (500 Pa).
b. Downstream from Fan(s): 2-inch wg (500 Pa) **OR** 3-inch wg (750 Pa) **OR** 4-inch wg (1000 Pa) **OR** 6-inch wg (1500 Pa) **OR** 10-inch wg (2500 Pa), **as directed**.
2. Acoustical Performance:
a. NRC: 1.09 **OR** 0.94, **as directed**, according to ASTM C 423.
b. STC: 40 **OR** 34, **as directed**, according to ASTM E 90.
3. Structural Performance:
a. Casings shall be fabricated to withstand 133 percent of the indicated static pressure without structural failure. Wall and roof deflection at the indicated static pressure shall not exceed 1/8 inch per foot (0.97 mm per meter) of width.
1) Fabricate outdoor casings to withstand wind load of 15 lbf/sq. ft. (720 N/sq. m) and snow load of 30 lbf/sq. ft. (1440 N/sq. m).
4. Seismic Performance: HVAC casings shall withstand the effects of earthquake motions determined according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and ASCE/SEI 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

D. Submittals
1. Product Data: For each type of product indicated.
2. LEED Submittals:
a. Product Data for Prerequisite EQ 1: Documentation indicating that duct systems comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
b. Product Data for Prerequisite EA 2: Documentation indicating that duct systems comply with ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."
c. Leakage Test Report for Prerequisite EA 2: Documentation of work performed for compliance with ASHRAE/IESNA 90.1, Section 6.4.4.2.2 - "Duct Leakage Tests."
d. Duct-Cleaning Test Report for Prerequisite EQ 1: Documentation of work performed for compliance with ASHRAE 62.1, Section 7.2.4 - "Ventilation System Start-Up."
e. Product Data for Credit EQ 4.1: For adhesives and sealants, including printed statement of VOC content.
3. Shop Drawings: For HVAC casings. Include plans, elevations, sections, components, and attachments to other work.
4. Welding certificates.
5. Field quality-control reports.

E. Quality Assurance
1. Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports **OR** AWS D9.1M/D9.1, "Sheet Metal Welding Code," for casing joint and seam welding, **as directed**.
2. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-Up."
3. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."

1.2 PRODUCTS

A. General Casing Fabrication Requirements
1. General Material Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 6, "Equipment and Casings," for acceptable materials, material thicknesses, and casing construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.
   a. Fabricate casings with more than 3-inch wg (750-Pa) negative static pressure according to SMACNA's "Rectangular Industrial Duct Construction Standards."
   b. Casings with more than 2-inch wg (500-Pa) positive static pressure may be fabricated according to SMACNA's "Rectangular Industrial Duct Construction Standards."
2. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
   a. Exterior Surface Galvanized Coating Designation: G60 (Z180) **OR** G90 (Z275), **as directed**.
   b. Interior Surface Galvanized Coating Designation:
      1) Sections Not Exposed to Moisture: G60 (Z180) **OR** G90 (Z275), **as directed**.
      2) Sections Housing and Downstream from Cooling Coil and Humidifiers: G90 (Z275).
3. Stainless Steel: ASTM A 480/A 480M, Type 304 **OR** Type 316, **as directed**, and having a No. 2D, **as directed**, finish.
4. Factory- or Shop-Applied Antimicrobial Coating:
   a. Apply to the interior sheet metal surfaces of casing in contact with the airstream. Apply untreated clear coating to the exterior surface.
   b. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
   c. Coating containing the antimicrobial compound shall have a hardness of 2H minimum when tested according to ASTM D 3363.
   d. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 according to UL 723; certified by an NRTL.
   e. Applied Coating Color: Standard **OR** Black **OR** White, **as directed**.
5. Reinforcement Shapes and Plates: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.
6. Sealing Requirement: SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Seal Class A. Seal all seams, joints, connections, and abutments to building.
7. Penetrations: Seal all penetrations airtight. Cover with escutcheons and gaskets, or fill with suitable compound so there is no exposed insulation. Provide shaft seals where fan shafts penetrate casing.
8. Access Doors: Fabricate access doors according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 6-11, "Casing Access Doors - 2-inch wg (500 Pa)," and Figure 6.12, "Casing Access Doors - 3-10-inch wg (750-2500 Pa)"; and according to pressure class of the plenum or casing section in which access doors are to be installed.
   a. Size: 20 by 54 inches (500 by 1370 mm).
   b. Vision Panel: Double-glazed, wire-reinforced safety glass with an airspace between panes and sealed with interior and exterior rubber seals.
   c. Hinges: Piano or butt hinges and latches, number and size according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

d. Latches: Minimum of two wedge-lever-type latches, operable from inside and outside.
e. Neoprene gaskets around entire perimeters of door frames.
f. Doors shall open against air pressure.

9. Condensate Drain Pans: Formed sections of Type 304, stainless-steel sheet **OR** G90 (Z275) coated, galvanized sheet steel, **as directed**, complying with requirements in ASHRAE 62.1. Pans shall extend a minimum of 12 inches (300 mm) past coil.
   a. Double-wall construction shall have space between walls filled with foam insulation and sealed moisture tight.
   b. Intermediate drain pan or drain trough shall collect condensate from top coil for units with stacked coils or stacked eliminators.
   c. Insulation: Polystyrene or polyurethane.
   d. Slopes shall be in a minimum of two planes to collect condensate from cooling coils (including coil piping connections and return bends), eliminators, and humidifiers when units are operating at maximum catalogued face velocity across cooling coil.
   e. Each drain pan connection shall have a trap. Drain traps with depth and height differential between inlet and outlet equal or greater to the design static pressure plus 2-inch wg (500 Pa), **as directed**. Include slab height in trap calculation.

B. Shop-Fabricated Casings
1. Single- and Double-Wall Casings: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for sheet metal thickness based on indicated static-pressure class unless otherwise indicated.
2. Double-Wall Casing Inner Panel: Perforated, galvanized sheet steel having 3/32-inch- (2.4-mm-) diameter perforations, with overall open area of 23 percent. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for sheet metal thickness based on indicated static-pressure class unless otherwise indicated.
   OR
   Double-Wall Casing Inner Panel: Solid sheet steel. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for sheet metal thickness based on indicated static-pressure class unless otherwise indicated.
3. Interstitial Insulation: Polyurethane foam complying with NFPA 90A or NFPA 90B.
   OR
   Interstitial Insulation: Fibrous-glass liner complying with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."
   a. Maximum Thermal Conductivity: 0.27 Btu x in./h x sq. ft. x deg F (0.039 W/m x K) at 75 deg F (24 deg C) mean temperature.
   b. Coat insulation with antimicrobial coating.
   c. Cover insulation with polyester film complying with UL 181, Class 1.
   OR
   Interstitial Insulation: Flexible-elastomeric duct liner complying with ASTM C 534, Type II for sheet materials and with NFPA 90A or NFPA 90B.
   a. Maximum Thermal Conductivity: 0.25 Btu x in./h x sq. ft. x deg F (0.034 W/m x K) at 75 deg F (24 deg C) mean temperature.
4. Fabricate casings with standing seams and angle-iron reinforcements unless otherwise indicated.
5. Fabricate close-off sheets from casing to dampers, filter frames, and coils and between stacked coils. Use galvanized sheet steel of same thickness as casing and with a galvanized coating designation of G90 (Z275).
6. Bolt close-off sheets to frame flanges and housings. Support coils on stands fabricated from galvanized-steel angles or channels.
7. Reinforce casings with galvanized-steel angles.

C. Manufactured Casings
1. Description: Double-wall, insulated, pressurized equipment casing.
2. Double-Wall Panel Fabrication: Solid, galvanized sheet steel exterior wall and solid **OR** perforated, **as directed**, galvanized sheet steel interior wall; with space between wall filled with insulation.

a. Wall Thickness: 2 inches (50 mm) **OR** 4 inches (100 mm), **as directed**.
b. Fabricate with a minimum number of joints.
c. Weld exterior and interior walls to perimeter; to interior, longitudinal, galvanized-steel channels; and to box-end internal closures. Paint welds.
d. Sheet metal thickness shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for static-pressure class indicated for casing.
OR
Sheet Metal Thicknesses:
1) Exterior Wall Thickness: 0.040 inch (1.0 mm) minimum.
2) Interior Wall Thickness: 0.034 inch (0.85 mm) minimum.
e. Double-Wall Casing Inner Panel: Perforated, galvanized sheet steel having 3/32-inch-(2.4-mm-) diameter perforations, with overall open area of 23 percent.
OR
Double-Wall Casing Inner Panel: Solid sheet steel.
f. Fill each panel assembly with insulating material that is noncombustible, inert, mildew resistant and vermin proof and that complies with NFPA 90A.
g. Fabricate panels with continuous tongue-and-groove **OR** self-locking, **as directed**, joints effective inside and outside each panel.

3. Trim Items: Fabricate from a minimum of 0.052-inch (1.3-mm) galvanized sheet steel, furnished in standard lengths for field cutting.

D. Casing Liner
1. Fibrous-Glass Liner: Comply with ASTM C 1071, NFPA 90A, or NFPA 90B and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."
a. Maximum Thermal Conductivity:
1) Type I, Flexible: 0.27 Btu x in./h x sq. ft. x deg F (0.039 W/m x K) at 75 deg F (24 deg C) mean temperature.
2) Type II, Rigid: 0.23 Btu x in./h x sq. ft. x deg F (0.033 W/m x K) at 75 deg F (24 deg C) mean temperature.
b. Antimicrobial Erosion-Resistant Coating: Apply to surface of the liner that will form the interior surface of casing to act as a moisture repellent and an erosion-resistant coating. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
c. Solvent **OR** Water, **as directed**,-Based Liner Adhesive: Comply with NFPA 90A or NFPA 90B and with ASTM C 916.
1) For indoor applications, use adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

2. Flexible-Elastomeric Casing Liner: Preformed, cellular, closed-cell, sheet materials complying with ASTM C 534, Type II, Grade 1, and with NFPA 90A or NFPA 90B.
a. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
b. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.
1) For indoor applications, use adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

3. Natural-Fiber Casing Liner: 85 percent cotton, 10 percent borate, and 5 percent polybinding fibers, treated with a microbial growth inhibitor, and complying with NFPA 90A or NFPA 90B.
a. Maximum Thermal Conductivity: 0.24 Btu x in./h x sq. ft. x deg F (0.034 W/m x K) at 75 deg F (24 deg C) mean temperature when tested according to ASTM C 518.
b. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
c. Liner Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.
1) For indoor applications, use adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

4. Insulation Pins and Washers:
   a. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.106-inch- (2.6-mm-) **OR** 0.135-inch- (3.5-mm-), **as directed**, diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch (38-mm) galvanized carbon-steel washer.
   b. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- (0.41-mm-) thick, galvanized **OR** stainless, **as directed**, steel, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches (38 mm) in diameter.
5. Shop or Factory Application of Casing Liner: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-19, "Flexible Duct Liner Installation."
   a. Adhere a single layer of indicated thickness of casing liner with at least 90 percent adhesive coverage at liner contact surface area. Attaining indicated thickness with multiple layers of casing liner is prohibited.
   b. Apply adhesive to transverse edges of liner facing upstream that do not receive metal nosing.
   c. Butt transverse joints without gaps, and coat joint with adhesive.
   d. Fold and compress liner in corners of casings or cut and fit to ensure butted-edge overlapping.
   e. Apply adhesive coating on longitudinal seams in casings with air velocity of 2500 fpm (12.7 m/s).
   f. Secure liner with mechanical fasteners 4 inches (100 mm) from corners and at intervals not exceeding 12 inches (300 mm) transversely; at 3 inches (75 mm) from transverse joints and at intervals not exceeding 18 inches (450 mm) longitudinally.
   g. Secure transversely oriented liner edges facing the airstream with metal nosings that have either channel or "Z" profiles or are integrally formed from casing wall. Fabricate edge facings at the following locations:
      1) Fan discharges.
      2) Intervals of lined casing preceding unlined duct.
      3) Upstream edges of transverse joints in casings where air velocities are higher than 2500 fpm (12.7 m/s) or where indicated.
   h. Secure insulation between perforated sheet metal inner wall of same thickness as specified for outer wall. Use mechanical fasteners that maintain inner wall at uniform distance from outer wall without compressing insulation.

E. Sealant Materials
1. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested according to UL 723; certified by an NRTL.
2. Water-Based Joint and Seam Sealant:
   a. Application Method: Brush on.
   b. Solids Content: Minimum 65 percent.
   c. Shore A Hardness: Minimum 20.
   d. Water resistant.
   e. Mold and mildew resistant.
   f. VOC: Maximum 75 g/L (less water).
      OR
      For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
   g. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive or negative.
   h. Service: Indoor or outdoor.
   i. Substrate: Compatible with galvanized sheet steel or stainless steel.
3. Solvent-Based Joint and Seam Sealant:
   a. Application Method: Brush on.
   b. Base: Synthetic rubber resin.
   c. Solvent: Toluene and heptane.
   d. Solids Content: Minimum 60 percent.

e. Shore A Hardness: Minimum 60.
f. Water resistant.
g. Mold and mildew resistant.
h. VOC: Maximum 395 g/L.
OR
For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
i. Maximum Static-Pressure Class: 10-inch wg (2500 Pa), positive or negative.
j. Service: Indoor or outdoor.
k. Substrate: Compatible with galvanized sheet steel or stainless steel.

4. Flanged Joint Sealant: Comply with ASTM C 920.
   a. General: Single component, acid curing, silicone, elastomeric.
   b. Type: S.
   c. Grade: NS.
   d. Class: 25.
   e. Use: O.
   f. For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
5. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

1.3 EXECUTION

A. Installation
1. Install casings according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
2. Equipment Mounting: Install HVAC casings on concrete base. Comply with requirements for concrete base specified in Division 07 Section "Manufactured Roof Expansion Joints".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   b. For supported casings, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   d. Install anchor bolts to elevations required for proper attachment to supported equipment.
3. Install seismic restraints on casings. Comply with requirements for seismic-restraint devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment"
4. Apply sealant to joints, connections, and mountings.
5. Field-cut openings for pipe and conduit penetrations; insulate and seal according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
6. Support casings on floor or foundation system. Secure and seal to base.
7. Support components rigidly with ties, braces, brackets, seismic restraints, **as directed**, and anchors of types that will maintain housing shape and prevent buckling.
8. Align casings accurately at connections, with 1/8-inch (3-mm) misalignment tolerance and with smooth interior surfaces.

B. Field Quality Control
1. Tests and Inspections:
   a. Perform field tests and inspections according to SMACNA's "HVAC Air Duct Leakage Test Manual."
   b. Test the following systems:
      1) Systems required by ASHRAE/IESNA 90.1.
      2) Supply Air: 100 **OR** 50, **as directed**, percent of total installed duct area with a pressure class of 3-inch wg (750 Pa) **OR** 4-inch wg (1000 Pa), **as directed**, or higher.

c. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If pressure classes are not indicated, test entire system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure. Give seven days' advance notice for testing.

d. Determine leakage from entire system or section of system by relating leakage to surface area of test section. Comply with requirements for leakage classification of ducts connected to casings.

e. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.

2. HVAC casings will be considered defective if they do not pass tests and inspections.

3. Prepare test and inspection reports.

C. Cleaning

1. Comply with requirements for cleaning in Division 23 Section "Metal Ducts".

END OF SECTION 23 31 13 13a

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Task	Specification	Specification Description
23 31 13 16	23 31 13 13	Metal Ducts
23 31 13 16	23 31 13 13a	HVAC Casings
23 31 13 19	23 31 13 13	Metal Ducts
23 31 13 19	23 31 13 13a	HVAC Casings
23 31 13 23	23 31 13 13	Metal Ducts
23 31 13 23	23 31 13 13a	HVAC Casings

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SECTION 23 31 13 33 - DUCT ACCESSORIES

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for duct accessories. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Backdraft and pressure relief dampers.
b. Barometric relief dampers.
c. Manual volume dampers.
d. Control dampers.
e. Fire dampers.
f. Ceiling dampers.
g. Smoke dampers.
h. Combination fire and smoke dampers.
i. Corridor dampers.
j. Flange connectors.
k. Duct silencers.
l. Turning vanes.
m. Remote damper operators.
n. Duct-mounted access doors.
o. Flexible connectors.
p. Flexible ducts.
q. Duct security bars.
r. Duct accessory hardware.

C. Submittals
1. Product Data: For each type of product indicated.
a. For duct silencers, include pressure drop and dynamic insertion loss data. Include breakout noise calculations for high transmission loss casings.
2. LEED Submittal:
a. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
3. Shop Drawings: For duct accessories. Include plans, elevations, sections, details and attachments to other work.
a. Detail duct accessories fabrication and installation in ducts and other construction. Include dimensions, weights, loads, and required clearances; and method of field assembly into duct systems and other construction. Include the following:
1) Special fittings.
2) Manual volume damper installations.
3) Control damper installations.
4) Fire-damper, smoke-damper, combination fire- and smoke-damper, ceiling, and corridor damper installations, including sleeves; and duct-mounted access doors and remote damper operators.
5) Duct security bars.
6) Wiring Diagrams: For power, signal, and control wiring.
4. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which ceiling-mounted access panels and access doors required for access to duct accessories are shown and coordinated with each other, using input from Installers of the items involved.

5. Source quality-control reports.
6. Operation and Maintenance Data: For air duct accessories to include in operation and maintenance manuals.

D. Quality Assurance
1. Comply with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems," and with NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."
2. Comply with AMCA 500-D testing for damper rating.

1.2 PRODUCTS

A. Materials
1. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.
2. Galvanized Sheet Steel: Comply with ASTM A 653/A 653M.
   a. Galvanized Coating Designation: G60 (Z180) **OR** G90 (Z275),**as directed**.
   b. Exposed-Surface Finish: Mill phosphatized.
3. Stainless-Steel Sheets: Comply with ASTM A 480/A 480M, Type 304, and having a No. 2 finish for concealed ducts and <**Insert finish designation**> finish for exposed ducts.
4. Aluminum Sheets: Comply with ASTM B 209 (ASTM B 209M), Alloy 3003, Temper H14; with mill finish for concealed ducts and standard, 1-side bright finish for exposed ducts.
5. Extruded Aluminum: Comply with ASTM B 221 (ASTM B 221M), Alloy 6063, Temper T6.
6. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.
7. Tie Rods: Galvanized steel, 1/4-inch (6-mm) minimum diameter for lengths 36 inches (900 mm) or less; 3/8-inch (10-mm) minimum diameter for lengths longer than 36 inches (900 mm).

B. Backdraft And Pressure Relief Dampers
1. Description: Gravity balanced.
2. Maximum Air Velocity: 2000 fpm (10 m/s) **OR** 3000 fpm (15 m/s), **as directed**.
3. Maximum System Pressure: 1-inch wg (0.25 kPa) **OR** 2-inch wg (0.5 kPa), **as directed**.
4. Frame: 0.052-inch- (1.3-mm-) thick, galvanized sheet steel **OR** 0.063-inch- (1.6-mm-) thick extruded aluminum **OR** 0.052-inch- (1.3-mm-) thick stainless steel, **as directed**, with welded corners and mounting flange, **as directed**.
5. Blades: Multiple single-piece blades, center-pivoted, **as directed**, maximum 6-inch (150-mm) width, 0.025-inch- (0.6-mm-) thick, roll-formed aluminum **OR** 0.050-inch- (1.2-mm-) thick aluminum sheet **OR** noncombustible, tear-resistant, neoprene-coated fiberglass, **as directed**, with sealed edges.
6. Blade Action: Parallel.
7. Blade Seals: Felt **OR** Vinyl foam **OR** Extruded vinyl, mechanically locked **OR** Neoprene, mechanically locked, **as directed**.
8. Blade Axles:
   a. Material: Nonferrous metal **OR** Galvanized steel **OR** Plated steel **OR** Stainless steel **OR** Non-metallic **OR** Aluminum, **as directed**.
   b. Diameter: 0.20 inch (5 mm).
9. Tie Bars and Brackets: Aluminum **OR** Galvanized steel, **as directed**.
10. Return Spring: Adjustable tension.
11. Bearings: Steel ball **OR** Synthetic pivot bushings **OR** Steel ball or synthetic pivot bushings, **as directed**.
12. Accessories:
   a. Adjustment device to permit setting for varying differential static pressure.
   b. Counterweights and spring-assist kits for vertical airflow installations.

c. Electric actuators.
d. Chain pulls.
e. Screen Mounting: Front mounted in sleeve.
   1) Sleeve Thickness: 20-gage (1.0-mm) minimum.
   2) Sleeve Length: 6 inches (152 mm) minimum.
   OR
   Screen Mounting: Rear mounted.
f. Screen Material: Galvanized steel **OR** Aluminum, **as directed**.
g. Screen Type: Bird **OR** Insect, **as directed**.
h. 90-degree stops.

C. Barometric Relief Dampers
1. Suitable for horizontal or vertical mounting.
2. Maximum Air Velocity: 2000 fpm (10 m/s) **OR** 2500 fpm (13 m/s), **as directed**.
3. Maximum System Pressure: 2-inch wg (0.5 kPa).
4. Frame: 0.064-inch- (1.6-mm-) thick, galvanized sheet steel **OR** 0.063-inch- (1.6-mm-) thick extruded aluminum, **as directed**, with welded corners and mounting flange, **as directed**.
5. Blades:
   a. Multiple, 0.025-inch- (0.6-mm-) thick, roll-formed aluminum **OR** 0.050-inch- (1.2-mm-) thick aluminum sheet, **as directed**.
   b. Maximum Width: 6 inches (150 mm).
   c. Action: Parallel.
   d. Balance: Gravity.
   e. Eccentrically pivoted.
6. Blade Seals: Vinyl **OR** Neoprene, **as directed**.
7. Blade Axles: Galvanized steel **OR** Nonferrous metal, **as directed**.
8. Tie Bars and Brackets:
   a. Material: Aluminum **OR** Galvanized steel, **as directed**.
   b. Rattle free with 90-degree stop.
9. Return Spring: Adjustable tension.
10. Bearings: Synthetic **OR** Stainless steel **OR** Bronze, **as directed**.
11. Accessories:
   a. Flange on intake.
   b. Adjustment device to permit setting for varying differential static pressures.

D. Manual Volume Dampers
1. Standard, Steel, Manual Volume Dampers:
   a. Standard leakage rating, with linkage outside airstream, **as directed**.
   b. Suitable for horizontal or vertical applications.
   c. Frames:
      1) Hat-shaped, galvanized-steel **OR** stainless-steel, **as directed**, channels, 0.064-inch (1.62-mm) minimum thickness.
      2) Mitered and welded corners.
      3) Flanges for attaching to walls and flangeless frames for installing in ducts.
   d. Blades:
      1) Multiple or single blade.
      2) Parallel- or opposed-blade design.
      3) Stiffen damper blades for stability.
      4) Galvanized-steel **OR** Stainless-steel, **as directed**, 0.064 inch (1.62 mm) thick.
   e. Blade Axles: Galvanized steel **OR** Stainless steel **OR** Nonferrous metal, **as directed**.
   f. Bearings:
      1) Oil-impregnated bronze **OR** Molded synthetic **OR** Stainless-steel sleeve, **as directed**.
      2) Dampers in ducts with pressure classes of 3-inch wg (750 Pa) or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
   g. Tie Bars and Brackets: Galvanized steel.

2. Standard, Aluminum, Manual Volume Dampers:
   a. Standard leakage rating, with linkage outside airstream, **as directed**.
   b. Suitable for horizontal or vertical applications.
   c. Frames: Hat-shaped, 0.10-inch- (2.5-mm-) thick, aluminum sheet channels; frames with flanges for attaching to walls and flangeless frames for installing in ducts.
   d. Blades:
      1) Multiple or single blade.
      2) Parallel- or opposed-blade design.
      3) Stiffen damper blades for stability.
      4) Roll-Formed Aluminum Blades: 0.10-inch- (2.5-mm-) thick aluminum sheet.
         OR
         Extruded-Aluminum Blades: 0.050-inch- (1.2-mm-) thick extruded aluminum.
   e. Blade Axles: Galvanized steel **OR** Stainless steel **OR** Nonferrous metal, **as directed**.
   f. Bearings:
      1) Oil-impregnated bronze **OR** Molded synthetic **OR** Stainless-steel sleeve, **as directed**.
      2) Dampers in ducts with pressure classes of 3-inch wg (750 Pa) or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
   g. Tie Bars and Brackets: Aluminum.
3. Low-Leakage, Steel, Manual Volume Dampers:
   a. Low-leakage rating, with linkage outside airstream, **as directed**, and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.
   b. Suitable for horizontal or vertical applications.
   c. Frames:
      1) Hat **OR** U **OR** Angle, **as directed**, shaped.
      2) Galvanized-steel **OR** Stainless-steel, **as directed**, channels, 0.064 inch (1.62 mm) thick.
      3) Mitered and welded corners.
      4) Flanges for attaching to walls and flangeless frames for installing in ducts.
   d. Blades:
      1) Multiple or single blade.
      2) Parallel- or opposed-blade design.
      3) Stiffen damper blades for stability.
      4) Galvanized **OR** Stainless, **as directed**, roll-formed steel, 0.064 inch (1.62 mm) thick.
   e. Blade Axles: Galvanized steel **OR** Stainless steel **OR** Nonferrous metal, **as directed**.
   f. Bearings:
      1) Oil-impregnated bronze **OR** Molded synthetic **OR** Stainless-steel sleeve, **as directed**.
      2) Dampers in ducts with pressure classes of 3-inch wg (750 Pa) or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
   g. Blade Seals: Felt **OR** Vinyl **OR** Neoprene, **as directed**.
   h. Jamb Seals: Cambered stainless steel **OR** aluminum, **as directed**.
   i. Tie Bars and Brackets: Galvanized steel **OR** Aluminum, **as directed**.
   j. Accessories:
      1) Include locking device to hold single-blade dampers in a fixed position without vibration.
4. Low-Leakage, Aluminum, Manual Volume Dampers:
   a. Low-leakage rating, with linkage outside airstream, **as directed**, and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.
   b. Suitable for horizontal or vertical applications.
   c. Frames: Hat **OR** U **OR** Angle, **as directed**,-shaped, 0.10-inch- (2.5-mm-) thick, aluminum sheet channels; frames with flanges for attaching to walls and flangeless frames for installing in ducts.
   d. Blades:
      1) Multiple or single blade.

2) Parallel- or opposed-blade design.
3) Roll-Formed Aluminum Blades: 0.10-inch- (2.5-mm-) thick aluminum sheet.
OR
Extruded-Aluminum Blades: 0.050-inch- (1.2-mm-) thick extruded aluminum.

e. Blade Axles: Galvanized steel **OR** Stainless steel **OR** Nonferrous metal, **as directed**.

f. Bearings:
1) Oil-impregnated bronze **OR** Molded synthetic **OR** Stainless-steel sleeve, **as directed**.
2) Dampers in ducts with pressure classes of 3-inch wg (750 Pa) or less shall have axles full length of damper blades and bearings at both ends of operating shaft.

g. Blade Seals: Felt **OR** Vinyl **OR** Neoprene, **as directed**.

h. Jamb Seals: Cambered stainless steel **OR** aluminum, **as directed**.

i. Tie Bars and Brackets: Galvanized steel **OR** Aluminum, **as directed**.

j. Accessories:
1) Include locking device to hold single-blade dampers in a fixed position without vibration.

5. Jackshaft:
a. Size: 1-inch (25-mm) diameter.
b. Material: Galvanized-steel pipe rotating within pipe-bearing assembly mounted on supports at each mullion and at each end of multiple-damper assemblies.
c. Length and Number of Mountings: As required to connect linkage of each damper in multiple-damper assembly.

6. Damper Hardware:
a. Zinc-plated, die-cast core with dial and handle made of 3/32-inch- (2.4-mm-) thick zinc-plated steel, and a 3/4-inch (19-mm) hexagon locking nut.
b. Include center hole to suit damper operating-rod size.
c. Include elevated platform for insulated duct mounting.

E. Control Dampers
1. Low-leakage rating, with linkage outside airstream, **as directed**, and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.
2. Frames:
a. Hat **OR** U **OR** Angle, **as directed**, shaped.
b. Galvanized-steel **OR** Stainless-steel, **as directed**, channels, 0.064 inch (1.62 mm) thick.
c. Mitered and welded corners.
3. Blades:
a. Multiple blade with maximum blade width of 8 inches (200 mm).
b. Parallel **OR** Parallel- and opposed **OR** Opposed, **as directed**,-blade design.
c. Galvanized **OR** Stainless, **as directed**, steel.
d. 0.064 inch (1.62 mm) thick.
e. Blade Edging: Closed-cell neoprene edging.
OR
Blade Edging: Inflatable seal blade edging, or replaceable rubber seals.
4. Blade Axles: 1/2-inch- (13-mm-) diameter; galvanized steel **OR** stainless steel **OR** nonferrous metal, **as directed**; blade-linkage hardware of zinc-plated steel and brass; ends sealed against blade bearings.
a. Operating Temperature Range: From minus 40 to plus 200 deg F (minus 40 to plus 93 deg C).
5. Bearings:
a. Oil-impregnated bronze **OR** Molded synthetic **OR** Stainless-steel sleeve, **as directed**.
b. Dampers in ducts with pressure classes of 3-inch wg (750 Pa) or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
c. Thrust bearings at each end of every blade.

F. Fire Dampers

1. Type: Static **OR** Dynamic **OR** Static and dynamic, **as directed**; rated and labeled according to UL 555 by an NRTL.
2. Closing rating in ducts up to 4-inch wg (1-kPa) static pressure class and minimum 4000-fpm (20-m/s) velocity.
3. Fire Rating: 1-1/2 **OR** 3, **as directed**, hours.
4. Frame: Curtain type with blades inside airstream **OR** Curtain type with blades outside airstream **OR** Multiple-blade type **OR** Curtain type with blades outside airstream except when located behind grille where blades may be inside airstream, **as directed**; fabricated with roll-formed, 0.034-inch- (0.85-mm-) thick galvanized steel; with mitered and interlocking corners.
5. Mounting Sleeve: Factory- or field-installed, galvanized sheet steel.
   a. Minimum Thickness: 0.052 or 0.138 inch (1.3 or 3.5 mm) thick, as indicated, and of length to suit application.
   b. Exception: Omit sleeve where damper-frame width permits direct attachment of perimeter mounting angles on each side of wall or floor; thickness of damper frame must comply with sleeve requirements.
6. Mounting Orientation: Vertical or horizontal as indicated.
7. Blades: Roll-formed, interlocking, 0.034-inch- (0.85-mm-) thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch- (0.85-mm-) thick, galvanized-steel blade connectors.
8. Horizontal Dampers: Include blade lock and stainless-steel closure spring.
9. Heat-Responsive Device: Replaceable, 165 deg F (74 deg C) **OR** 212 deg F (100 deg C), **as directed**, rated, fusible links.
   OR
   Heat-Responsive Device: Electric **OR** Pneumatic, **as directed**, resettable link and switch package, factory installed, 165 deg F (74 deg C) **OR** 212 deg F (100 deg C), **as directed**, rated.

G. Ceiling Dampers
1. General Requirements:
   a. Labeled according to UL 555C by an NRTL.
   b. Comply with construction details for tested floor- and roof-ceiling assemblies as indicated in UL's "Fire Resistance Directory."
2. Frame: Galvanized sheet steel, round or rectangular, style to suit ceiling construction.
3. Blades: Galvanized sheet steel with refractory insulation.
4. Heat-Responsive Device: Replaceable, 165 deg F (74 deg C) **OR** 212 deg F (100 deg C), **as directed**, rated, fusible links.
5. Fire Rating: 2 **OR** 3, **as directed**, hours.

H. Smoke Dampers
1. General Requirements: Label according to UL 555S by an NRTL.
2. Smoke Detector: Integral, factory wired for single-point connection.
3. Frame: Curtain type with blades inside airstream **OR** Curtain type with blades outside airstream **OR** Multiple-blade type **OR** Curtain type with blades outside airstream except when located behind grille where blades may be inside airstream, **as directed**; fabricated with roll-formed, 0.034-inch- (0.85-mm-) thick galvanized steel; with mitered and interlocking corners.
4. Blades: Roll-formed, horizontal, interlocking, 0.034-inch- (0.85-mm-) thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch- (0.85-mm-) thick, galvanized-steel blade connectors.
5. Leakage: Class I **OR** Class II, **as directed**.
6. Rated pressure and velocity to exceed design airflow conditions.
7. Mounting Sleeve: Factory-installed, 0.052-inch- (1.3-mm-) thick, galvanized sheet steel; length to suit wall or floor application with factory-furnished silicone calking, **as directed**.
8. Damper Motors: Modulating **OR** Two-position, **as directed**, action.
9. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".

a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
b. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 23 Section(s) "Instrumentation And Control For Hvac" OR Division 22, **as directed**.
c. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
d. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf (17 N x m) and breakaway torque rating of 150 in. x lbf (17 N x m).
e. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 deg F (minus 40 deg C).
f. Nonspring-Return Motors: For dampers larger than 25 sq. ft. (2.3 sq. m), size motor for running torque rating of 150 in. x lbf (17 N x m) and breakaway torque rating of 300 in. x lbf (34 N x m).
g. Electrical Connection: 115 V, single phase, 60 Hz.

10. Accessories:
a. Auxiliary switches for signaling **OR** fan control **OR** position indication, **as directed**.
b. Momentary test switch **OR** Test and reset switches, **as directed**, damper **OR** remote, **as directed**, mounted.

I. Combination Fire And Smoke Dampers
1. Type: Static **OR** Dynamic **OR** Static and dynamic, **as directed**; rated and labeled according to UL 555 and UL 555S by an NRTL.
2. Closing rating in ducts up to 4-inch wg (1-kPa) static pressure class and minimum 4000-fpm (20-m/s) velocity.
3. Fire Rating: 1-1/2 **OR** 3, **as directed**, hours.
4. Frame: Curtain type with blades inside airstream **OR** Curtain type with blades outside airstream **OR** Multiple-blade type **OR** Curtain type with blades outside airstream except when located behind grille where blades may be inside airstream, **as directed**; fabricated with roll-formed, 0.034-inch- (0.85-mm-) thick galvanized steel; with mitered and interlocking corners.
5. Heat-Responsive Device: Replaceable, 165 deg F (74 deg C) **OR** 212 deg F (100 deg C), **as directed**, rated, fusible links.
OR
Heat-Responsive Device: Electric **OR** Pneumatic, **as directed**, resettable link and switch package, factory installed, rated.
6. Smoke Detector: Integral, factory wired for single-point connection.
7. Frame: Curtain type with blades inside airstream **OR** Curtain type with blades outside airstream **OR** Multiple-blade type **OR** Curtain type with blades outside airstream except when located behind grille where blades may be inside airstream, **as directed**; fabricated with roll-formed, 0.034-inch- (0.85-mm-) thick galvanized steel; with mitered and interlocking corners.
8. Blades: Roll-formed, horizontal, interlocking, 0.034-inch- (0.85-mm-) thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch- (0.85-mm-) thick, galvanized-steel blade connectors.
9. Leakage: Class I **OR** Class II, **as directed**.
10. Rated pressure and velocity to exceed design airflow conditions.
11. Mounting Sleeve: Factory-installed, 0.052-inch- (1.3-mm-) thick, galvanized sheet steel; length to suit wall or floor application with factory-furnished silicone calking, **as directed**.
12. Master control panel for use in dynamic smoke-management systems.
13. Damper Motors: Modulating **OR** Two-position, **as directed**, action.
14. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".

a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
b. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 23 Section(s) "Instrumentation And Control For Hvac" OR Division 22, **as directed**.
c. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
d. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf (17 N x m) and breakaway torque rating of 150 in. x lbf (17 N x m).
e. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 deg F (minus 40 deg C).
f. Nonspring-Return Motors: For dampers larger than 25 sq. ft. (2.3 sq. m), size motor for running torque rating of 150 in. x lbf (17 N x m) and breakaway torque rating of 300 in. x lbf (34 N x m).
g. Electrical Connection: 115 V, single phase, 60 Hz.

15. Accessories:
a. Auxiliary switches for signaling **OR** fan control **OR** position indication, **as directed**.
b. Momentary test switch **OR** Test and reset switches, **as directed**, damper **OR** remote, **as directed**, mounted.

J. Corridor Dampers
1. General Requirements: Label combination fire and smoke dampers according to UL 555 for 1-1/2-hour rating by an NRTL.
2. Heat-Responsive Device: Replaceable, 165 deg F (74 deg C) **OR** 212 deg F (100 deg C), **as directed**, rated, fusible links.
OR
Heat-Responsive Device: Electric **OR** Pneumatic, **as directed**, resettable link and switch package, factory installed, rated.
3. Frame: Curtain type with blades inside airstream **OR** Curtain type with blades outside airstream **OR** Multiple-blade type **OR** Curtain type with blades outside airstream except when located behind grille where blades may be inside airstream, **as directed**; fabricated with roll-formed, 0.034-inch- (0.85-mm-) thick galvanized steel; with mitered and interlocking corners.
4. Blades: Roll-formed, horizontal, interlocking, 0.034-inch- (0.85-mm-) thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch- (0.85-mm-) thick, galvanized-steel blade connectors.
5. Mounting Sleeve: Factory-installed, 0.052-inch- (1.3-mm-) thick, galvanized sheet steel; length to suit wall or floor application.
6. Damper Motors: Modulating **OR** Two-position, **as directed**, action.
7. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
b. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 23 Section(s) "Instrumentation And Control For Hvac" OR Division 22, **as directed**.
c. Permanent-Split-Capacitor or Shaded-Pole Motors: With oil-immersed and sealed gear trains.
d. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf (17 N x m) and breakaway torque rating of 150 in. x lbf (17 N x m).

e. Outdoor Motors and Motors in Outdoor-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 deg F (minus 40 deg C).
f. Nonspring-Return Motors: For dampers larger than 25 sq. ft. (2.3 sq. m), size motor for running torque rating of 150 in. x lbf (17 N x m) and breakaway torque rating of 300 in. x lbf (34 N x m).
g. Electrical Connection: 115 V, single phase, 60 Hz.

K. Flange Connectors
1. Description: Add-on **OR** Roll-formed, **as directed**, factory-fabricated, slide-on transverse flange connectors, gaskets, and components.
2. Material: Galvanized steel.
3. Gage and Shape: Match connecting ductwork.

L. Duct Silencers
1. General Requirements:
a. Factory fabricated.
b. Fire-Performance Characteristics: Adhesives, sealants, packing materials, and accessory materials shall have flame-spread index not exceeding 25 and smoke-developed index not exceeding 50 when tested according to ASTM E 84.
c. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
2. Shape:
a. Rectangular straight with splitters or baffles.
b. Round straight with center bodies or pods.
c. Rectangular elbow with splitters or baffles.
d. Round elbow with center bodies or pods.
e. Rectangular transitional with splitters or baffles.
3. Rectangular Silencer Outer Casing: ASTM A 653/A 653M, G90 (Z275) **OR** G60 (Z180), **as directed**, galvanized sheet steel, 0.034 inch (0.85 mm) **OR** 0.040 inch (1.02 mm), **as directed**, thick.
4. Round Silencer Outer Casing: ASTM A 653/A 653M, G90 (Z275) **OR** G60 (Z180), **as directed**, galvanized sheet steel.
a. Sheet Metal Thickness for Units up to 24 Inches (600 mm) in Diameter: 0.034 inch (0.85 mm) thick.
b. Sheet Metal Thickness for Units 26 through 40 Inches (660 through 1000 mm) in Diameter: 0.040 inch (1.02 mm) thick.
c. Sheet Metal Thickness for Units 42 through 52 Inches (1060 through 1300 mm) in Diameter: 0.052 inch (1.3 mm) thick.
d. Sheet Metal Thickness for Units 54 through 60 Inches (1370 through 1500 mm) in Diameter: 0.064 inch (1.62 mm) thick.
5. Inner Casing and Baffles: ASTM A 653/A 653M, G90 (Z275) **OR** G60 (Z180), **as directed**, galvanized sheet metal, 0.034 inch (0.85 mm) thick, and with 1/8-inch- (3-mm-) diameter perforations.
6. Special Construction:
a. Suitable for outdoor use.
b. High transmission loss to achieve STC 45, **as directed**.
7. Connection Sizes: Match connecting ductwork unless otherwise indicated.
8. Principal Sound-Absorbing Mechanism:
a. Controlled impedance membranes and broadly tuned resonators without absorptive media.
b. Dissipative **OR** Film-lined, **as directed**, type with fill material.
1) Fill Material: Inert and vermin-proof fibrous material, packed under not less than 5 percent compression **OR** Inert and vermin-proof fibrous material, packed under not less than 15 percent compression **OR** Moisture-proof nonfibrous material, **as directed**.
2) Erosion Barrier: Polymer bag enclosing fill, and heat sealed before assembly.

c. Lining: None **OR** Mylar **OR** Tedlar **OR** Fiberglas cloth, **as directed**.

9. Fabricate silencers to form rigid units that will not pulsate, vibrate, rattle, or otherwise react to system pressure variations. Do not use mechanical fasteners for unit assemblies.
   a. Lock form and seal or continuously weld joints **OR** Flange connections, **as directed**.
   b. Suspended Units: Factory-installed suspension hooks or lugs attached to frame in quantities and spaced to prevent deflection or distortion.
   c. Reinforcement: Cross or trapeze angles for rigid suspension.
10. Accessories:
   a. Integral 1-1/2 **OR** 3, **as directed**,-hour fire damper with access door. Access door to be high transmission loss to match silencer, **as directed**.
   b. Factory-installed end caps to prevent contamination during shipping.
   c. Removable splitters.
   d. Airflow measuring devices.
   e. Source Quality Control: Test according to ASTM E 477.
   f. Testing to be witnessed by the Owner.
   g. Record acoustic ratings, including dynamic insertion loss and generated-noise power levels with an airflow of at least 2000-fpm (10-m/s) face velocity.
   h. Leak Test: Test units for airtightness at 200 percent of associated fan static pressure or 6-inch wg (1500-Pa) static pressure, whichever is greater.

M. Turning Vanes
1. Manufactured Turning Vanes for Metal Ducts: Curved blades of galvanized sheet steel; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.
   a. Acoustic Turning Vanes: Fabricate airfoil-shaped aluminum extrusions with perforated faces and fibrous-glass fill.
2. Manufactured Turning Vanes for Nonmetal Ducts: Fabricate curved blades of resin-bonded fiberglass with acrylic polymer coating; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.
3. General Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 2-3, "Vanes and Vane Runners," and 2-4, "Vane Support in Elbows."
4. Vane Construction: Single **OR** Double, **as directed**, wall.
   OR
   Vane Construction: Single wall for ducts up to 48 inches (1200 mm) wide and double wall for larger dimensions.

N. Remote Damper Operators
1. Description: Cable system designed for remote manual damper adjustment.
2. Tubing: Brass.
3. Cable: Stainless steel.
4. Wall-Box Mounting: Recessed, 3/4 inches (19 mm) deep **OR** Recessed, 2 inches (50 mm) deep **OR** Surface, **as directed**.
5. Wall-Box Cover-Plate Material: Steel **OR** Stainless steel, **as directed**.

O. Duct-Mounted Access Doors
1. Duct-Mounted Access Doors: Fabricate access panels according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 2-10, "Duct Access Doors and Panels," and 2-11, "Access Panels - Round Duct."
   a. Door:
      1) Double wall, rectangular.
      2) Galvanized sheet metal with insulation fill and thickness as indicated for duct pressure class.
      3) Vision panel.
      4) Hinges and Latches: 1-by-1-inch (25-by-25-mm) butt or piano hinge and cam latches.
      5) Fabricate doors airtight and suitable for duct pressure class.

b. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets.
c. Number of Hinges and Locks:
1) Access Doors Less Than 12 Inches (300 mm) Square: No hinges and two sash locks.
2) Access Doors up to 18 Inches (460 mm) Square: Two hinges and two sash locks.
3) Access Doors up to 24 by 48 Inches (600 by 1200 mm): Three hinges and two compression latches with outside and inside handles, **as directed**.
4) Access Doors Larger Than 24 by 48 Inches (600 by 1200 mm): Four hinges and two compression latches with outside and inside handles.

2. Pressure Relief Access Door:
a. Door and Frame Material: Galvanized sheet steel.
b. Door: Single wall **OR** Double wall with insulation fill, **as directed**, with metal thickness applicable for duct pressure class.
c. Operation: Open outward for positive-pressure ducts and inward for negative-pressure ducts.
d. Factory set at 10-inch wg (2500 Pa).
e. Doors close when pressures are within set-point range.
f. Hinge: Continuous piano.
g. Latches: Cam.
h. Seal: Neoprene or foam rubber.
i. Insulation Fill: 1-inch- (25-mm-) thick, fibrous-glass or polystyrene-foam board.

P. Duct Access Panel Assemblies
1. Labeled according to UL 1978 by an NRTL.
2. Panel and Frame: Minimum thickness 0.0528-inch (1.3-mm) carbon **OR** 0.0428-inch (1.1-mm) stainless, **as directed**, steel.
3. Fasteners: Carbon **OR** Stainless, **as directed**, steel. Panel fasteners shall not penetrate duct wall.
4. Gasket: Comply with NFPA 96; grease-tight, high-temperature ceramic fiber, rated for minimum 2000 deg F (1093 deg C).
5. Minimum Pressure Rating: 10-inch wg (2500 Pa), positive or negative.

Q. Flexible Connectors
1. Materials: Flame-retardant or noncombustible fabrics.
2. Coatings and Adhesives: Comply with UL 181, Class 1.
3. Metal-Edged Connectors: Factory fabricated with a fabric strip 3-1/2 inches (89 mm) **OR** 5-3/4 inches (146 mm), **as directed**, wide attached to 2 strips of 2-3/4-inch- (70-mm-) wide, 0.028-inch- (0.7-mm-) thick, galvanized sheet steel or 0.032-inch- (0.8-mm-) thick aluminum sheets. Provide metal compatible with connected ducts.
4. Indoor System, Flexible Connector Fabric: Glass fabric double coated with neoprene.
a. Minimum Weight: 26 oz./sq. yd. (880 g/sq. m).
b. Tensile Strength: 480 lbf/inch (84 N/mm) in the warp and 360 lbf/inch (63 N/mm) in the filling.
c. Service Temperature: Minus 40 to plus 200 deg F (Minus 40 to plus 93 deg C).
5. Outdoor System, Flexible Connector Fabric: Glass fabric double coated with weatherproof, synthetic rubber resistant to UV rays and ozone.
a. Minimum Weight: 24 oz./sq. yd. (810 g/sq. m).
b. Minimum Tensile Strength: 500 lbf/inch (88 N/mm) in the warp and 440 lbf/inch (77 N/mm) in the filling.
c. Service Temperature: Minus 50 to plus 250 deg F (Minus 45 to plus 121 deg C).
6. High-Temperature System, Flexible Connectors: Glass fabric coated with silicone rubber.
a. Minimum Weight: 16 oz./sq. yd. (542 g/sq. m).
b. Tensile Strength: 285 lbf/inch (50 N/mm) in the warp and 185 lbf/inch (32 N/mm) in the filling.
c. Service Temperature: Minus 67 to plus 500 deg F (Minus 55 to plus 260 deg C).

7. High-Corrosive-Environment System, Flexible Connectors: Glass fabric with chemical-resistant coating.
   a. Minimum Weight: 14 oz./sq. yd. (474 g/sq. m).
   b. Tensile Strength: 450 lbf/inch (79 N/mm) in the warp and 340 lbf/inch (60 N/mm) in the filling.
   c. Service Temperature: Minus 67 to plus 500 deg F (Minus 55 to plus 260 deg C).
8. Thrust Limits: Combination coil spring and elastomeric insert with spring and insert in compression, and with a load stop. Include rod and angle-iron brackets for attaching to fan discharge and duct.
   a. Frame: Steel, fabricated for connection to threaded rods and to allow for a maximum of 30 degrees of angular rod misalignment without binding or reducing isolation efficiency.
   b. Outdoor Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
   c. Minimum Additional Travel: 50 percent of the required deflection at rated load.
   d. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
   e. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.
   f. Elastomeric Element: Molded, oil-resistant rubber or neoprene.
   g. Coil Spring: Factory set and field adjustable for a maximum of 1/4-inch (6-mm) movement at start and stop.

R. Flexible Ducts
1. Noninsulated, Flexible Duct: UL 181, Class 1, 2-ply vinyl film supported by helically wound, spring-steel wire.
   a. Pressure Rating: 10-inch wg (2500 Pa) positive and 1.0-inch wg (250 Pa) negative.
   b. Maximum Air Velocity: 4000 fpm (20 m/s).
   c. Temperature Range: Minus 10 to plus 160 deg F (Minus 23 to plus 71 deg C).
2. Noninsulated, Flexible Duct: UL 181, Class 1, black polymer film supported by helically wound, spring-steel wire.
   a. Pressure Rating: 4-inch wg (1000 Pa) positive and 0.5-inch wg (125 Pa) negative.
   b. Maximum Air Velocity: 4000 fpm (20 m/s).
   c. Temperature Range: Minus 20 to plus 175 deg F (Minus 29 to plus 79 deg C).
3. Noninsulated, Flexible Duct: UL 181, Class 1, multiple layers of aluminum laminate supported by helically wound, spring-steel wire.
   a. Pressure Rating: 10-inch wg (2500 Pa) positive and 1.0-inch wg (250 Pa) negative.
   b. Maximum Air Velocity: 4000 fpm (20 m/s).
   c. Temperature Range: Minus 20 to plus 210 deg F (Minus 29 to plus 99 deg C).
4. Noninsulated, Flexible Duct: UL 181, Class 1, aluminum laminate and polyester film with latex adhesive supported by helically wound, spring-steel wire.
   a. Pressure Rating: 10-inch wg (2500 Pa) positive and 1.0-inch wg (250 Pa) negative.
   b. Maximum Air Velocity: 4000 fpm (20 m/s).
   c. Temperature Range: Minus 20 to plus 210 deg F (Minus 29 to plus 99 deg C).
5. Noninsulated, Flexible Duct: UL 181, Class 0, interlocking spiral of aluminum foil.
   a. Pressure Rating: 8-inch wg (2280 Pa) positive or negative.
   b. Maximum Air Velocity: 5000 fpm (25 m/s).
   c. Temperature Range: Minus 100 to plus 435 deg F (Minus 73 to plus 224 deg C).
6. Insulated, Flexible Duct: UL 181, Class 1, 2-ply vinyl film supported by helically wound, spring-steel wire; fibrous-glass insulation; polyethylene **OR** aluminized, **as directed**, vapor-barrier film.
   a. Pressure Rating: 10-inch wg (2500 Pa) positive and 1.0-inch wg (250 Pa) negative.
   b. Maximum Air Velocity: 4000 fpm (20 m/s).
   c. Temperature Range: Minus 10 to plus 160 deg F (Minus 23 to plus 71 deg C).
   d. Insulation R-value: Comply with ASHRAE/IESNA 90.1.
7. Insulated, Flexible Duct: UL 181, Class 1, black polymer film supported by helically wound, spring-steel wire; fibrous-glass insulation; polyethylene **OR** aluminized, **as directed**, vapor-barrier film.

a. Pressure Rating: 4-inch wg (1000 Pa) positive and 0.5-inch wg (125 Pa) negative.
b. Maximum Air Velocity: 4000 fpm (20 m/s).
c. Temperature Range: Minus 20 to plus 175 deg F (Minus 29 to plus 79 deg C).
d. Insulation R-Value: Comply with ASHRAE/IESNA 90.1.

8. Insulated, Flexible Duct: UL 181, Class 1, multiple layers of aluminum laminate supported by helically wound, spring-steel wire; fibrous-glass insulation; polyethylene **OR** aluminized, **as directed**, vapor-barrier film.
   a. Pressure Rating: 10-inch wg (2500 Pa) positive and 1.0-inch wg (250 Pa) negative.
   b. Maximum Air Velocity: 4000 fpm (20 m/s).
   c. Temperature Range: Minus 20 to plus 210 deg F (Minus 29 to plus 99 deg C).
   d. Insulation R-value: Comply with ASHRAE/IESNA 90.1.
9. Insulated, Flexible Duct: UL 181, Class 1, aluminum laminate and polyester film with latex adhesive supported by helically wound, spring-steel wire; fibrous-glass insulation; polyethylene **OR** aluminized, **as directed**, vapor-barrier film.
   a. Pressure Rating: 10-inch wg (2500 Pa) positive and 1.0-inch wg (250 Pa) negative.
   b. Maximum Air Velocity: 4000 fpm (20 m/s).
   c. Temperature Range: Minus 20 to plus 210 deg F (Minus 29 to plus 99 deg C).
   d. Insulation R-value: Comply with ASHRAE/IESNA 90.1.
10. Insulated, Flexible Duct: UL 181, Class 0, interlocking spiral of aluminum foil; fibrous-glass insulation; polyethylene **OR** aluminized, **as directed**, vapor-barrier film.
    a. Pressure Rating: 8-inch wg (2280 Pa) positive or negative.
    b. Maximum Air Velocity: 5000 fpm (25 m/s).
    c. Temperature Range: Minus 20 to plus 250 deg F (Minus 29 to plus 121 deg C).
    d. Insulation R-value: Comply with ASHRAE/IESNA 90.1.
11. Flexible Duct Connectors:
    a. Clamps: Stainless-steel band with cadmium-plated hex screw to tighten band with a worm-gear action **OR** Nylon strap, **as directed**, in sizes 3 through 18 inches (75 through 460 mm), to suit duct size.
    b. Non-Clamp Connectors: Adhesive **OR** Liquid adhesive plus tape **OR** Adhesive plus sheet metal screws, **as directed**.

S. Duct Security Bars
1. Description: Field-fabricated **OR** Factory-fabricated and field-installed **OR** Field- or factory-fabricated and field-installed, **as directed**, duct security bars.
2. Configuration:
   a. Frame: 10 gage by 2 inches (3.57 mm by 50 mm).
   b. Sleeve: 3/16-inch (4.8-mm), continuously welded **OR** bent, **as directed**, steel frames with 1-by-1-by-3/16-inch (25-by-25-by-4.8-mm) angle frame factory welded to 1 end **OR** furnished loose for field welding on other end, **as directed**. To be poured in place or set with concrete block or welded or bolted to wall, one side only. Duct connections on both sides.
   c. Horizontal Bars: 1/2 inch (13 mm) **OR** 2 by 1/4 inch (50 by 6 mm), **as directed**.
   d. Vertical Bars: 1/2 inch (13 mm) **OR** 3/4 inch (19 mm) **OR** 1 inch (25 mm), **as directed**.
   e. Bar Spacing: 6 inches (150 mm).
   f. Mounting: Metal deck or roofing **OR** Bolted or welded **OR** Bolted or welded with masonry anchors **OR** Ductwork or other framing **OR** Poured in place or set with concrete block **OR** Welded or bolted to one wall (one side only) **OR** Bar extends 6 inches (150 mm) into wall, **as directed**.

T. Duct Accessory Hardware
1. Instrument Test Holes: Cast iron or cast aluminum to suit duct material, including screw cap and gasket. Size to allow insertion of pitot tube and other testing instruments and of length to suit duct-insulation thickness.
2. Adhesives: High strength, quick setting, neoprene based, waterproof, and resistant to gasoline and grease.

1.3 EXECUTION

A. Installation
1. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts and in NAIMA AH116, "Fibrous Glass Duct Construction Standards," for fibrous-glass ducts.
2. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel and fibrous-glass ducts, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.
3. Install backdraft **OR** control, **as directed**, dampers at inlet of exhaust fans or exhaust ducts as close as possible to exhaust fan unless otherwise indicated.
4. Install volume dampers at points on supply, return, and exhaust systems where branches extend from larger ducts. Where dampers are installed in ducts having duct liner, install dampers with hat channels of same depth as liner, and terminate liner with nosing at hat channel.
   a. Install steel volume dampers in steel ducts.
   b. Install aluminum volume dampers in aluminum ducts.
5. Set dampers to fully open position before testing, adjusting, and balancing.
6. Install test holes at fan inlets and outlets and elsewhere as indicated.
7. Install fire and smoke, **as directed**, dampers according to UL listing.
8. Install duct security bars. Construct duct security bars from 0.164-inch (4.18-mm) steel sleeve, continuously welded at all joints and 1/2-inch- (13-mm-) diameter steel bars, 6 inches (150 mm) o.c. in each direction in center of sleeve. Weld each bar to steel sleeve and each crossing bar. Weld 2-1/2-by-2-1/2-by-1/4-inch (63-by-63-by-6-mm) steel angle to 4 sides and both ends of sleeve. Connect duct security bars to ducts with flexible connections. Provide 12-by-12-inch (300-by-300-mm) hinged access panel with cam lock in duct in each side of sleeve.
9. Connect ducts to duct silencers with flexible duct connectors **OR** rigidly, **as directed**.
10. Install duct access doors on sides of ducts to allow for inspecting, adjusting, and maintaining accessories and equipment at the following locations:
    a. On both sides of duct coils.
    b. Upstream **OR** Upstream and downstream, **as directed**, from duct filters.
    c. At outdoor-air intakes and mixed-air plenums.
    d. At drain pans and seals.
    e. Downstream from manual volume dampers, control dampers, backdraft dampers, and equipment.
    f. Adjacent to and close enough to fire or smoke dampers, to reset or reinstall fusible links. Access doors for access to fire or smoke dampers having fusible links shall be pressure relief access doors and shall be outward operation for access doors installed upstream from dampers and inward operation for access doors installed downstream from dampers.
    g. At each change in direction and at maximum 50-foot (15-m) spacing.
    h. Upstream **OR** Upstream and downstream, **as directed**, from turning vanes.
    i. Upstream or downstream from duct silencers.
    j. Control devices requiring inspection.
    k. Elsewhere as indicated.
11. Install access doors with swing against duct static pressure.
12. Access Door Sizes:
    a. One-Hand or Inspection Access: 8 by 5 inches (200 by 125 mm).
    b. Two-Hand Access: 12 by 6 inches (300 by 150 mm).
    c. Head and Hand Access: 18 by 10 inches (460 by 250 mm).
    d. Head and Shoulders Access: 21 by 14 inches (530 by 355 mm).
    e. Body Access: 25 by 14 inches (635 by 355 mm).
    f. Body plus Ladder Access: 25 by 17 inches (635 by 430 mm).
13. Label access doors according to Division 21 Section "Fire-suppression Systems Insulation" to indicate the purpose of access door.
14. Install flexible connectors to connect ducts to equipment.

15. For fans developing static pressures of 5-inch wg (1250 Pa) and more, cover flexible connectors with loaded vinyl sheet held in place with metal straps.
16. Connect terminal units to supply ducts directly or, **as directed**, with maximum 12-inch (300-mm) lengths of flexible duct. Do not use flexible ducts to change directions.
17. Connect diffusers or light troffer boots to ducts directly or, **as directed**, with maximum 60-inch (1500-mm) lengths of flexible duct clamped or strapped in place.
18. Connect flexible ducts to metal ducts with adhesive **OR** liquid adhesive plus tape **OR** draw bands **OR** adhesive plus sheet metal screws, **as directed**.
19. Install duct test holes where required for testing and balancing purposes.
20. Install thrust limits at centerline of thrust, symmetrical on both sides of equipment. Attach thrust limits at centerline of thrust and adjust to a maximum of 1/4-inch (6-mm) movement during start and stop of fans.

B. Field Quality Control
1. Tests and Inspections:
   a. Operate dampers to verify full range of movement.
   b. Inspect locations of access doors and verify that purpose of access door can be performed.
   c. Operate fire, smoke, and combination fire and smoke dampers to verify full range of movement and verify that proper heat-response device is installed.
   d. Inspect turning vanes for proper and secure installation.
   e. Operate remote damper operators to verify full range of movement of operator and damper.

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SECTION 23 31 16 13 - NONMETAL DUCTS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for nonmetal ducts. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Fibrous-glass ducts and fittings.
b. Phenolic-foam ducts and fittings.
c. Thermoset FRP ducts and fittings.
d. PVC ducts and fittings.

C. Performance Requirements
1. Delegated Duct Design: Duct construction, including duct closure, reinforcements, and hangers and supports, shall comply with SMACNA's "Fibrous Glass Duct Construction Standards" and performance requirements and design criteria indicated.
a. Static-Pressure Classes:
1) Supply Ducts (except in Mechanical Rooms): 1-inch wg (250 Pa).
2) Supply Ducts (Upstream from Air Terminal Units): 2-inch wg (500 Pa).
3) Supply Ducts (Downstream from Air Terminal Units): 1-inch wg (250 Pa).
4) Supply Ducts (in Mechanical Equipment Rooms): 2-inch wg (500 Pa).
5) Return Ducts (Negative Pressure): 1-inch wg (250 Pa).
6) Exhaust Ducts (Negative Pressure): 1-inch wg (250 Pa).
2. Structural Performance: Duct hangers and supports and seismic restraints, **as directed**, shall withstand the effects of gravity and seismic, **as directed**, loads and stresses within limits and under conditions to comply with ASCE/SEI 7 **OR** SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems", **as directed**.
a. Seismic Hazard Level A: Seismic force to weight ratio, 0.48.
OR
Seismic Hazard Level B: Seismic force to weight ratio, 0.30.
OR
Seismic Hazard Level C: Seismic force to weight ratio, 0.15.
3. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

D. Submittals
1. Product Data: For each type of product indicated.
2. LEED Submittals:
a. Product Data for Prerequisite EQ 1: Documentation indicating that duct systems comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
b. Product Data for Prerequisite EA 2: Documentation indicating that duct systems comply with ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."
c. Leakage Test Report for Prerequisite EA 2: Documentation of work performed for compliance with ASHRAE/IESNA 90.1, Section 6.4.4.2.2 - "Duct Leakage Tests."
d. Duct-Cleaning Test Report for Prerequisite EQ 1: Documentation of work performed for compliance with ASHRAE 62.1, Section 7.2.4 - "Ventilation System Start-Up."
e. Product Data for Credit EQ 4.1: For adhesives and sealants, including printed statement of VOC content.
3. Shop Drawings:

a. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
b. Duct layout indicating sizes and pressure classes.
c. Elevation of top of ducts.
d. Dimensions of main duct runs from building grid lines.
e. Fittings.
f. Reinforcement and spacing.
g. Seam and joint construction.
h. Penetrations through fire-rated and other partitions.
i. Equipment installation based on equipment being used on Project.
j. Hangers and supports, including methods for duct and building attachment, seismic restraints, **as directed**, and vibration isolation.

4. Delegated-Design Submittal:
   a. Duct materials and thicknesses.
   b. Joint and seam construction and sealing.
   c. Reinforcement details and spacing.
   d. Design Calculations: Calculations, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation, **as directed**, for selecting hangers and supports and seismic restraints, **as directed**.
5. Coordination Drawings: Plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
   a. Duct installation in congested spaces, indicating coordination with general construction, building components, and other building services. Indicate proposed changes to duct layout.
   b. Suspended ceiling components.
   c. Structural members to which duct will be attached.
   d. Size and location of initial access modules for acoustical tile.
   e. Penetrations of smoke barriers and fire-rated construction.
   f. Items penetrating finished ceiling including the following:
      1) Lighting fixtures.
      2) Air outlets and inlets.
      3) Speakers.
      4) Sprinklers.
      5) Access panels.
      6) Perimeter moldings.
6. Welding certificates.
7. Field quality-control reports.

E. Quality Assurance
1. Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel," for hangers and supports **OR** AWS D1.2/D1.2M, "Structural Welding Code - Aluminum," for aluminum supports, **as directed**.
2. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-Up."
3. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."
4. NFPA Compliance:
   a. NFPA 90A, "Installation of Air Conditioning and Ventilating Systems."
   b. NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

1.2 PRODUCTS

A. Fibrous-Glass Ducts And Fittings

1. Fibrous-Glass Duct Materials: Resin-bonded fiberglass, faced on the outside surface with fire-resistive FSK vapor retarder and with a smooth fiberglass mat finish on the air-side surface.
   a. Duct Board: Factory molded into rectangular boards.
   b. Round Duct: Factory molded into straight round duct and smooth fittings.
   c. Temperature Limits: 40 to 250 deg F (5 to 121 deg C) inside ducts; 150 deg F (66 deg C) ambient temperature surrounding ducts.
   d. Maximum Thermal Conductivity: 0.24 Btu x in./h x sq. ft. x deg F (0.035 W/m x K) at 75 deg F (24 deg C) mean temperature.
   e. Moisture Absorption: Not exceeding 5 percent by weight at 120 deg F (49 deg C) and 95 percent relative humidity for 96 hours when tested according to ASTM C 1104/C 1104M.
   f. Permeability: 0.02 perms (1.15 ng/Pa x s x sq. m) maximum when tested according to ASTM E 96/E 96M, Procedure A.
   g. Antimicrobial Agent: Compound shall be tested for efficacy by an NRTL, and registered by the EPA for use in HVAC systems.
   h. Noise-Reduction Coefficient: 0.65 minimum when tested according to ASTM C 423, Mounting A.
   i. Required Markings: EI rating, UL label, and other markings required by UL 181 on each full sheet of duct board.
2. Closure Materials:
   a. Pressure-Sensitive Tape: Comply with UL 181A; imprinted by the manufacturer with the coding "181A-P," the manufacturer's name, and a date code.
      1) Tape: Aluminum foil-scrim tape imprinted with listing information.
      2) Minimum Tape Width: 2-1/2 inches (64 mm); 3 inches (76 mm) for duct board thicker than 1 inch (25 mm).
      3) Staples: 1/2-inch (13-mm) outward clinching, 2 inches (51 mm) o.c. in tabs, one tab per joint.
      4) Water resistant.
      5) Mold and mildew resistant.
   b. Heat-Activated Tape: Comply with UL 181A; imprinted by the manufacturer with the coding "181A-H," the manufacturer's name, and a date code.
      1) Tape: Aluminum foil-scrim tape imprinted with listing information.
      2) Minimum Tape Width: 3 inches (76 mm).
      3) Heat-Sensitive Imprint: Printed indicator on tape to show proper heating during application has been achieved.
      4) Water resistant.
      5) Mold and mildew resistant.
   c. Two-Part Tape Sealing System: Comply with UL 181A; imprinted by the manufacturer with the coding "181A-M," the manufacturer's name, and a date code.
      1) Tape: Woven glass fiber impregnated with mineral gypsum.
      2) Minimum Tape Width: 3 inches (76 mm).
      3) Sealant: Modified styrene acrylic.
      4) Water resistant.
      5) Mold and mildew resistant.
      6) For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
3. Fabrication:
   a. Select joints, seams, transitions, elbows, and branch connections and fabricate according to SMACNA's "Fibrous Glass Duct Construction Standards," Chapter 2, "Specifications and Closure," and Chapter 4, "Fittings and Connections" **OR** NAIMA AH116, "Fibrous Glass Duct Construction Standards," Section II, "Fabrication of Straight Duct Modules," Section III, "Fabrication of Fittings from Modules or Flat Board," and Section IV, "Closure", **as directed**.
   b. Fabricate 90-degree mitered elbows to include turning vanes.
   c. Reinforcements: Comply with requirements in SMACNA's "Fibrous Glass Duct Construction Standards," Chapter 5, "Reinforcement" **OR** NAIMA AH116, "Fibrous Glass

Duct Construction Standards," Section V, "Reinforcement", **as directed**, for channel- and tie-rod reinforcement materials, spacing, and fabrication.

d. Preformed Round Duct: Comply with NAIMA AH116, "Fibrous Glass Duct Construction Standards," Section VII, "Preformed Round Duct."

B. Phenolic-Foam Ducts And Fittings

1. Duct Panel: CFC-free phenolic-foam bonded on both sides with factory-applied 0.001-inch-(0.025-mm-) thick, aluminum foil reinforced with fiberglass scrim.
   a. Maximum Temperature: 158 deg F (70 deg C) inside ducts or ambient temperature surrounding ducts.
   b. Maximum Thermal Conductivity: 0.13 Btu x in./h x sq. ft. x deg F (0.019 W/m x K) at 75 deg F (24 deg C) mean temperature.
   c. Permeability: 0.0002 perms (0.0115 ng/Pa x s x sq. m) maximum when tested according to ASTM E 96/E 96M, Procedure A.
   d. Antimicrobial Agent: Compound shall be tested for efficacy by an NRTL, and registered by the EPA for use in HVAC systems.
   e. Noise-Reduction Coefficient: 0.65 minimum when tested according to ASTM C 423, Mounting A.
   f. Required Markings: UL label and other markings required by UL 181 on each full sheet of duct panel; UL ratings for closure materials.
2. Closure Materials:
   a. V-Groove Adhesive: Silicone.
      1) For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
   b. Pressure-Sensitive Tape: Comply with UL 181A; imprinted by the manufacturer with the coding "181A-P," the manufacturer's name, and a date code.
      1) Tape: Aluminum foil tape imprinted with listing information.
      2) Minimum Tape Width: 3 inches (76 mm).
      3) Water resistant.
      4) Mold and mildew resistant.
   c. Polymeric Sealing System:
      1) Structural Membrane: Woven glass fiber.
      2) Minimum Tape Width: 3 inches (76 mm).
      3) Sealant: Water based.
      4) Color: White.
      5) Water resistant.
      6) Mold and mildew resistant.
      7) For indoor applications, use sealant that has a VOC content of 250 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
3. Fabrication:
   a. Fabricate joints, seams, transitions, reinforcement, elbows, branch connections, access doors and panels, and damage repairs according to Knauf Insulation's "Knauf KoolDuct System Design Guide," Section 4, "Duct Construction," and Section 5, "Ductwork System General."
   b. Fabricate 90-degree mitered elbows to include turning vanes.

C. Thermoset FRP Ducts And Fittings

1. Duct and Fittings:
   a. Thermoset FRP Resin: Manufacture duct with resin that complies with UL 181, Class 1, maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested by an NRTL according to ASTM E 84.
   b. Inner Liner: FSK liner rated by an NRTL to comply with UL 181, Class 1.
   c. Round Duct: ASTM D 2996, Type I, Grade 2, Class E, filament-wound duct, minimum 0.125-inch (3.2-mm) wall thickness, with tapered bell and spigot ends for adhesive joints, or plain ends with couplings.

d. Round Fittings: Compression or spray-up/contact, molded of same material, pressure class, and joining method as duct.
e. Rectangular Fittings: Minimum 0.125-inch- (3.2-mm-) thick flat sheet with fiberglass roving and resin-reinforced joints and seams.
f. Double-Wall Insulated Duct: Inner and outer duct complying with requirements for "Round Duct" description above. Polyurethane foam or isocyanurate insulation with maximum thermal conductivity of 0.14 Btu x in./h x sq. ft. x deg F (0.020 W/m x K) at 75 deg F (24 deg C) mean temperature.

2. Joining Materials: Roving and polyester resin.
   a. Use fiberglass adhesive that has a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
3. Fabrication:
   a. Fabricate joints, seams, transitions, reinforcement, elbows, branch connections, and access doors and panels according to SMACNA's "Thermoset FRP Duct Construction Manual," Chapter 7, "Requirements."
   b. Fabricate 90-degree rectangular mitered elbows to include turning vanes, 90-degree round elbows with a minimum of three segments for 12 inches (300 mm) and smaller and a minimum of five segments for 14 inches (350 mm) and larger.
4. Drains: Formed drain pockets with a minimum of NPS 1 (DN 25) threaded pipe connections.

D. PVC Ducts And Fittings
1. Duct and Fittings:
   a. Round Duct: Comply with cell Classification 12454-B in ASTM D 1784, with external loading properties of ASTM D 2412.
   b. Round Fittings: Socket end molded of same material, pressure class, and joining method as duct.
   c. Rectangular Fittings: Minimum 0.125-inch- (3.2-mm-) thick flat sheet with heat-formed corners and continuous welded butt joints.
2. Joining Materials: PVC solvent cement complying with ASTM D 2564.
   a. Use PVC solvent cement that has a VOC content of 510 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
   b. Use adhesive primer that has a VOC content of 550 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
3. Fabrication:
   a. Fabricate joints, seams, transitions, reinforcement, elbows, branch connections, and access doors and panels according to SMACNA's "Thermoplastic Duct (PVC) Construction Manual," Chapter 3, "Standards of Construction for PVC Duct Systems."
   b. Fabricate 90-degree rectangular mitered elbows to include turning vanes, 90-degree round elbows with a minimum of three segments for 12 inches (300 mm) and smaller and a minimum of five segments for 14 inches (350 mm) and larger.
4. Drains: PVC drain pockets with a minimum of NPS 1 (DN 25) threaded PVC pipe connections.

E. Hangers And Supports
1. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.
2. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.
3. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 4-1 (Table 4-1M), "Rectangular Duct Hangers Minimum Size," and Table 4-2, "Minimum Hanger Sizes for Round Duct."
4. Steel Cables: ASTM A 603, galvanized **OR** ASTM A 492, stainless, **as directed**, steel with end connections made of cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.
5. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.
6. Trapeze and Riser Supports: Steel shapes complying with ASTM A 36/A 36M.

F. Seismic-Restraint Devices
1. General Requirements for Restraint Components: Rated strengths, features, and applications shall be as defined in reports by an evaluation service member of the ICC Evaluation Service **OR** the Office of Statewide Health Planning and Development for the State of California **OR** an agency acceptable to authorities having jurisdiction, **as directed**.
   a. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least four times the maximum seismic forces to which they will be subjected.
2. Channel Support System: Shop- or field-fabricated support assembly made of slotted steel channels with accessories for attachment to braced component at one end and to building structure at the other end. Include matching components and corrosion-resistant coating.
3. Restraint Cables: ASTM A 603, galvanized **OR** ASTM A 492, stainless, **as directed**,-steel cables with end connections made of cadmium-plated steel assemblies with brackets, swivel, and bolts designed for restraining cable service; and with an automatic-locking and clamping device or double-cable clips.
4. Hanger Rod Stiffener: Steel tube or steel slotted-support-system sleeve with internally bolted connections **OR** Reinforcing steel angle clamped, **as directed**, to hanger rod.
5. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

1.3 EXECUTION

A. Duct Installation
1. Install ducts with fewest possible joints.
2. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.
3. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.
4. Install ducts with a clearance of 1 inch (25 mm), plus allowance for insulation thickness.
5. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges. Overlap openings on four sides by at least 1-1/2 inches (38 mm).
6. Where ducts pass through fire-rated interior partitions and exterior walls, install fire dampers. Comply with requirements in Division 23 Section "Air Duct Accessories" for fire and smoke dampers.
7. Protect duct interiors from the moisture, construction debris and dust, and other foreign materials. Comply with SMACNA's "Duct Cleanliness for New Construction Guidelines", **as directed**.
8. Install fibrous-glass ducts and fittings to comply with NAIMA AH116, "Fibrous Glass Duct Construction Standards **OR** SMACNA's "Fibrous Glass Duct Construction Standards", **as directed**.
9. Install foam ducts and fittings to comply with Knauf Insulation's "Knauf KoolDuct System Design Guide."
10. Install thermoset FRP ducts and fittings to comply with SMACNA's "Thermoset FRP Duct Construction Manual."
11. Install PVC ducts and fittings to comply with SMACNA's "Thermoplastic Duct (PVC) Construction Manual."

B. Hanger And Support Installation
1. Install hangers and supports for fibrous-glass ducts and fittings to comply with SMACNA's "Fibrous Glass Duct Construction Standards," Chapter 6, "Hangers and Supports" **OR** NAIMA AH116, "Fibrous Glass Duct Construction Standards," Section VI, "Hangers and Supports", **as directed**.
2. Install hangers and supports for phenolic-foam ducts and fittings to comply with Knauf Insulation's "Knauf KoolDuct System Design Guide," Section 5, "Ductwork System General."

3. Install hangers and supports for thermoset FRP ducts and fittings to comply with SMACNA's "Thermoset FRP Duct Construction Manual," Chapter 7, "Requirements."
4. Install hangers and supports for PVC ducts and fittings to comply with SMACNA's "Thermoplastic Duct (PVC) Construction Manual," Chapter 3, "Standards of Construction for PVC Duct Systems."
5. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.
   a. Install concrete inserts before placing concrete.
   b. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
   c. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 4 inches (100 mm) thick.
   d. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches (100 mm) thick.
   e. Do not use powder-actuated concrete fasteners for seismic restraints.
6. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

C. Seismic-Restraint-Device Installation
1. Install ducts with hangers and braces designed to support the duct and to restrain against seismic forces required by applicable building codes. Comply with SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems" **OR** ASCE/SEI 7, **as directed**.
   a. Space lateral supports a maximum of 40 feet (12 m) o.c., and longitudinal supports a maximum of 80 feet (24 m) o.c.
   b. Brace a change of direction longer than 12 feet (3.7 m).
2. Select sizes of components so strength will be adequate to carry present and future static and seismic loads within restraint device capacity.
3. Install cables so they do not bend across edges of adjacent equipment or building structure.
4. Install cable restraints where ducts are suspended with vibration isolators.
5. Install seismic-restraint devices using methods approved by an evaluation service member of the ICC Evaluation Service **OR** the Office of Statewide Health Planning and Development for the State of California **OR** an agency acceptable to authorities having jurisdiction, **as directeed**.
6. Attachment to Structure: If specific attachment is not indicated, anchor bracing and restraints to structure to flanges of beams, to upper truss chords of bar joists, or to concrete members.
7. Drilling for and Setting Anchors:
   a. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcement or embedded items during drilling. Notify the the Owner if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
   b. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
   c. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
   d. Set anchors to manufacturer's recommended torque, using a torque wrench.
   e. Install zinc-coated steel anchors for interior applications and stainless-steel anchors for applications exposed to weather.

D. Painting
1. Paint interior of thermoset FRP and PVC ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, latex paint over a compatible galvanized-steel primer. Paint materials and application requirements are specified in Division 07.

E. Field Quality Control
1. Perform tests and inspections.
2. Leakage Tests:

a. Comply with SMACNA's "HVAC Air Duct Leakage Test Manual." Submit a test report for each test.
b. Test the following systems:
   1) Ducts with a Pressure Class Higher Than 3-Inch wg (750 Pa): Test representative duct sections, selected by the Owner from sections installed, **as directed**, totaling no less than 25 percent of total installed duct area for each designated pressure class.
   2) Supply Ducts with a Pressure Class of 2-Inch wg (500 Pa) **OR** 3-Inch wg (750 Pa) **OR** 4-Inch wg (1000 Pa), **as directed**, or Higher: Test representative duct sections, selected by the Owner from sections installed, **as directed**, totaling no less than 50 **OR** 100, **as directed**, percent of total installed duct area for each designated pressure class.
   3) Return Ducts with a Pressure Class of 2-Inch wg (500 Pa) **OR** 3-Inch wg (750 Pa) **OR** 4-Inch wg (1000 Pa), **as directed**, or Higher: Test representative duct sections, selected by the Owner from sections installed, **as directed**, totaling no less than 50 **OR** 100, **as directed**, percent of total installed duct area for each designated pressure class.
   4) Exhaust Ducts with a Pressure Class of 2-Inch wg (500 Pa) **OR** 3-Inch wg (750 Pa) **OR** 4-Inch wg (1000 Pa), **as directed**, or Higher: Test representative duct sections, selected by the Owner from sections installed, **as directed**, totaling no less than 50 **OR** 100, **as directed**, percent of total installed duct area for each designated pressure class.
   5) Outdoor Air Ducts with a Pressure Class of 2-Inch wg (500 Pa) **OR** 3-Inch wg (750 Pa) **OR** 4-Inch wg (1000 Pa), **as directed**, or Higher: Test representative duct sections, selected by the Owner from sections installed, **as directed**, totaling no less than 50 **OR** 100, **as directed**, percent of total installed duct area for each designated pressure class.
c. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
d. Test for leaks before applying external insulation.
e. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If static-pressure classes are not indicated, test entire system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure. Give seven days' advance notice for testing.

3. Duct System Cleanliness Tests:
   a. Visually inspect duct system to ensure that no visible contaminants are present.
   b. Test sections of nonmetal duct system, chosen randomly by the Owner, for cleanliness according to "Vacuum Test" in NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."
      1) Acceptable Cleanliness Level: Net weight of debris collected on the filter media shall not exceed 0.75 mg/100 sq. cm.
4. Duct system will be considered defective if it does not pass tests and inspections.
5. Prepare test and inspection reports.

F. Duct Cleaning
1. Clean new **OR** existing **OR** new and existing, **as directed**, duct system(s) before testing, adjusting, and balancing.
2. Use service openings for entry and inspection.
   a. Create new openings and install access panels appropriate for duct static-pressure class if required for cleaning access. Provide insulated panels for insulated or lined duct. Patch duct as recommended by duct manufacturer. Comply with Division 23 Section "Air Duct Accessories" for access panels and doors.
   b. Disconnect and reconnect flexible ducts as needed for cleaning and inspection.
   c. Remove and reinstall ceiling to gain access during the cleaning process.
3. Particulate Collection and Odor Control:

a. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron-size (or larger) particles.
b. When venting vacuuming system to outdoors, use filter to collect debris removed from HVAC system, and locate exhaust downwind and away from air intakes and other points of entry into building.

4. Clean the following components by removing surface contaminants and deposits:
   a. Air outlets and inlets (registers, grilles, and diffusers).
   b. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
   c. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
   d. Coils and related components.
   e. Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.
   f. Supply-air ducts, dampers, actuators, and turning vanes.
   g. Dedicated exhaust and ventilation components and makeup air systems.
5. Mechanical Cleaning Methodology:
   a. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
   b. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of ducts or duct accessories.
   c. Clean fibrous-glass duct with HEPA vacuuming equipment; do not permit duct to get wet. Replace fibrous-glass duct that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.
   d. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
   e. Provide drainage and cleanup for wash-down procedures.
   f. Antimicrobial Agents and Coatings: Apply EPA-registered antimicrobial agents if fungus is present. Apply antimicrobial agents according to manufacturer's written instructions after removal of surface deposits and debris.

G. Start Up
1. Air Balance: Comply with requirements in Division 23 Section "Testing, Adjusting, And Balancing For Hvac".

H. Duct Schedule
1. Indoor Ducts and Fittings:
   a. Fibrous-Glass Rectangular Ducts and Fittings:
      1) Minimum Flexural Rigidity: EI-475 **OR** 800 **OR** 1400, **as directed**.
      2) Minimum Board Thickness: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (51 mm), **as directed**.
   b. Fibrous-Glass Round Ducts and Fittings:
      1) Minimum Thickness: 1 inch (25 mm).
   c. Phenolic-Foam Rectangular Ducts and Fittings:
      1) Minimum Panel Thickness: 7/8 inch (22 mm) **OR** 1-3/32 inches (28 mm), **as directed**.
      2) Aluminum Cladding: Minimum 0.025 inch (0.635 mm) thick.
2. Outdoor Ducts and Fittings:
   a. Phenolic-Foam Rectangular Ducts and Fittings:
      1) Minimum Panel Thickness: 7/8 inch (22 mm) **OR** 1-3/32 inches (28 mm), **as directed**.
      2) Aluminum Cladding: Minimum 0.032 inch (0.813 mm) thick.

3) Polymeric Sealing System: Coat ducts, including gang-nail couplings, grip flanges, and couplings.

b. Thermoset FRP Round Ducts and Fittings:

1) Double-Wall Insulated Ducts: Minimum 5/8-inch (15.9-mm) **OR** 7/8-inch (22.2-mm), **as directed**, insulation thickness.

c. PVC Round Ducts and Fittings:

3. Underground Ducts:

a. Thermoset FRP Round Ducts and Fittings:

1) Insulation Thickness: 1 inch (25 mm).

2) Drain: Minimum NPS 1 (DN 25) PVC pipe with P-trap to air-gap drain.

b. PVC Round Ducts and Fittings:

1) Drain: Minimum NPS 1 (DN 25) PVC pipe with P-trap to air-gap drain.

END OF SECTION 23 31 16 13

Task	Specification	Specification Description
23 31 16 13	23 31 13 13	Metal Ducts
23 31 16 16	23 31 13 13	Metal Ducts
23 31 16 16	23 31 16 13	Nonmetal Ducts

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SECTION 23 33 13 13 - DRAFT CONTROL DEVICES

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for draft control devices. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following:
a. Draft inducer fans.
b. Venturi-draft inducer fans.
c. Mechanical-draft vent fans.
d. Vent exhaust fans.
e. Barometric dampers.
f. Vent dampers.
g. Combustion-air fans.

C. Submittals
1. Product Data: For each type of product indicated.
2. Wiring Diagrams: Power, signal, and control wiring.
3. Operation and Maintenance Data.
4. Warranty: Warranty specified in this Section.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

E. Warranty
1. Manufacturer's standard form in which manufacturer agrees to repair or replace components of draft inducer fans, venturi-draft inducer fans, mechanical-draft vent fans, vent exhaust fans, barometric dampers, vent dampers, and/or combustion-air fans that fail in materials or workmanship within two **OR** 10, **as directed**, years from date of Final Completion.
a. Failures include failure of the fan due to corrosion.

1.2 PRODUCTS

A. Draft Inducer Fans
1. Fan Construction: Galvanized **OR** Aluminized, **as directed**,-steel housing and radial-blade centrifugal fan.
a. Fan Motor: Permanent split-capacitor type.
2. Controls:
a. Draft proving switch.
b. Control kit to cycle fan with gas flow to a single burner.

B. Venturi-Draft Inducer Fans
1. Fan Construction: Enameled-steel venturi tube for vents 20 inches (508 mm) in diameter and smaller, and ASTM A 666, Type 304, stainless-steel venturi tube for vents 22 to 48 inches (559 to 1219 mm) in diameter. Galvanized **OR** Enameled, **as directed**,-steel fan housing with radial-blade centrifugal wheel.

a. Fan Motor: Permanent split-capacitor type.

2. Controls:
   a. Draft proving switch.
   b. Control kit to cycle fan with gas flow to a single burner.

C. Mechanical-Draft Vent Fans
1. Fan Construction: Forward-curved centrifugal fan and scroll fabricated of aluminized **OR** galvanized, **as directed**, steel; direct-drive, ball-bearing motor lubricated with synthetic oil; internal cooling fan; stainless-steel shaft; and integral pressure-sensing switch.
   a. Fan Motor: Permanent split-capacitor type.
2. Controls:
   a. Draft proving switch.
   b. Control kit to cycle fan with gas flow to single **OR** multiple, **as directed**, burner(s).
3. Accessories:
   a. Aluminized **OR** Stainless, **as directed**,-steel, wall-vent hood.

D. Vent Exhaust Fans
1. General: Centrifugal fan with variable **OR** constant, **as directed**,-speed control mounted at end of sidewall **OR** vertical, **as directed**, vent.
2. Test Standard: UL 378, for fans exposed to flue gases up to 640 deg F (337 deg C).
3. Fan Construction: Cast-aluminum **OR** Galvanized-steel **OR** Stainless-steel, **as directed**, housing painted manufacturer's standard color of baked enamel, **as directed**. Galvanized **OR** Stainless, **as directed**,-steel vent. Cast-aluminum **OR** Stainless-steel, **as directed**, wheel. Backward-inclined centrifugal or axial fan wheel statically and dynamically balanced. Provide access to clean the discharge area. Concentric makeup air inlet duct surrounding the vent to allow zero clearance to combustibles, **as directed**.
4. Motor: Fully enclosed, variable-speed duty, **as directed**, permanent split capacitor, out of the airstream, with prelubricated and sealed ball bearings.
5. Constant-Speed Controls: Boiler interlock relay starts fan when burner control cycles on. Pressure switch permits burner operation via interlock with boiler. Fan proving switch is adjustable between minus 0.07- and minus 0.15-inch wg (minus 17 and minus 37 Pa).
6. Variable-Speed Controls: Boiler interlock relay starts fan when burner control cycles on. Pressure controller, control transformer, and miscellaneous controls for automatic modulation of fan speed to maintain preset negative pressure between 0- and minus 1.0-inch wg (0 and minus 249 Pa). Include controller with indicator lights, pressure differential transmitter, chimney pressure sensor probe, and fan proving switch adjustable between minus 0.07- and minus 0.15-inch wg (minus 17 and minus 37 Pa). Include tubing.

E. Barometric Dampers
1. Damper Construction: High-temperature-enamel-painted steel damper and housing with galvanized-steel breeching connection. Adjustable counterweight with lock. Include knife-edge bearings that do not require lubrication.

F. Vent Dampers
1. Damper Construction: Stainless-steel damper blade, shaft, and vent pipe with metal, prelubricated bearings.
   a. Electric motor sized to power damper open and closed in approximately 15 seconds in each direction. Power is off when damper is at rest.
   b. Comply with ANSI Z21.66.
2. Controls:
   a. Control transformer.
   b. Keyed wiring harness.
   c. Damper end-switch to prove damper is open.
   d. Interlock with boiler to permit burner operation when damper is open.
   e. Hold-open switch for troubleshooting boiler controls.

G. Combustion-Air Fans
1. Fan Construction: Galvanized **OR** Aluminized, **as directed**,-steel housing; steel forward-curved fan and scroll; direct-drive, totally enclosed, fan-cooled motor with ball bearings; stainless-steel shaft; and integral pressure-sensing switch.
   a. Internal bypass to temper supply-air temperature to room.
2. Controls:
   a. Fan proving switch to permit burner operation when combustion-air fan is operating.
   b. Multiple appliance control starts fan with operation of any one of three **OR** four, **as directed**, appliances.
   c. Modulating combustion-air fan speed to control pressure differential in room with respect to outdoors.
   d. Manual-reset, high-limit switch stops operation with 160 deg F (71 deg C) room temperature.
   e. Optional Controls:
      1) Alarm circuit.
      2) Excessive negative pressure limit.
      3) Interface relay for vent exhaust fan, draft inducer fan, or mechanical-draft vent fan.
      4) Galvanized-steel **OR** Aluminum, **as directed**, intake hood.

H. Motors
1. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".

1.3 EXECUTION

A. Installation
1. Install listed components in a manner complying with the listing.
2. Secure barometric dampers to breechings with hardware compatible with connected materials.
3. Locate barometric and motorized vent dampers as close to draft hood collar as possible.
4. Secure barometric and motorized vent dampers to appliances, breechings, or chimneys with hardware compatible with connected materials.
5. Install draft inducer fans in single-wall vent section that is designed to couple with other vent materials.
6. Secure draft inducer fans to appliances, breechings, or stacks with hardware compatible with connected materials.
7. Install draft inducer fans with clearances for service and maintenance.
8. Install PVC, **as directed**, intake duct that is sized according to manufacturer's written instructions.

B. Connections
1. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
2. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

C. Startup Service
1. Engage a factory-authorized service representative to perform startup service.
   a. Complete installation and startup checks according to manufacturer's written instructions.
2. Remove and replace malfunctioning components and recheck.

D. Adjusting
1. Set field-adjustable switches and controls as indicated.

E. Demonstration
1. Engage a factory-authorized service representative to train **OR** Train, **as directed**, Owner's maintenance personnel to adjust, operate, and maintain draft control devices.

END OF SECTION 23 33 13 13

Task	Specification	Specification Description
23 33 13 13	23 31 13 33	Duct Accessories
23 33 13 16	23 31 13 33	Duct Accessories
23 33 13 29	23 33 13 13	Draft Control Devices
23 33 13 29	23 31 13 33	Duct Accessories
23 33 13 33	23 31 13 33	Duct Accessories
23 33 13 43	23 31 13 33	Duct Accessories
23 33 23 00	23 31 13 33	Duct Accessories
23 33 33 00	23 31 13 33	Duct Accessories
23 33 43 00	23 31 13 33	Duct Accessories
23 33 46 00	23 31 13 13	Metal Ducts
23 33 46 00	23 31 13 33	Duct Accessories
23 33 53 00	01 22 16 00	No Specification Required
23 33 53 00	23 31 13 13	Metal Ducts
23 33 53 00	23 31 13 13a	HVAC Casings
23 33 56 00	23 31 13 13	Metal Ducts
23 33 56 00	23 31 13 33	Duct Accessories
23 33 59 00	23 31 13 33	Duct Accessories

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SECTION 23 34 13 00 - AXIAL FANS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for axial fans. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following:
a. Tubeaxial fans.
b. Vaneaxial fans.
c. Mixed-flow fans.

C. Performance Requirements
1. Project Altitude: Base fan performance ratings on actual Project site elevations above sea level.
2. Operating Limits: Classify according to AMCA 99.

D. Submittals
1. Product Data: Include rated capacities, furnished specialties, and accessories for each type of product indicated and include the following:
a. Certified fan performance curves with system operating conditions indicated.
b. Certified fan sound-power ratings.
c. Motor ratings and electrical characteristics, plus motor and electrical accessories.
d. Material thickness and finishes, including color charts.
e. Dampers, including housings, linkages, and operators.
f. Fan speed controllers.
2. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
a. Wiring Diagrams: Power, signal, and control wiring.
b. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
c. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.
3. Coordination Drawings: Show fan room layout and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate and certify field measurements.
4. Field quality-control test reports.
5. Operation and Maintenance Data: For axial fans to include in emergency, operation, and maintenance manuals.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. AMCA Compliance: Products shall comply with performance requirements and shall be licensed to use the AMCA-Certified Ratings Seal.
3. NEMA Compliance: Motors and electrical accessories shall comply with NEMA standards.

F. Delivery, Storage, And Handling

1. Deliver fans as factory-assembled units, to the extent allowable by shipping limitations, with protective crating and covering.
2. Disassemble and reassemble units, as required for moving to final locations, according to manufacturer's written instructions.
3. Lift and support units with manufacturer's designated lifting or supporting points.

G. Coordination
1. Coordinate size and location of structural-steel support members.
2. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 31..
3. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Division 07 Section "Roof Accessories".

1.2 PRODUCTS

A. Tubeaxial Fans
1. Description: Fan wheel and housing, factory-mounted motor with belt drive or direct drive, an inlet cone section, and accessories.
2. Housings: Steel **OR** Galvanized steel **OR** Aluminum **OR** Fiberglass-reinforced plastic **OR** Stainless steel, **as directed,** with flanged inlet and outlet connections.
3. Wheel Assemblies: Cast or extruded aluminum with airfoil-shaped blades mounted on cast-iron wheel plate keyed to shaft with solid-steel key **OR** Fiberglass-reinforced plastic cured under pressure with airfoil-shaped blades keyed to stainless steel shaft **OR** Cast aluminum, machined and fitted to shaft, **as directed**.
4. Drives: Factory mounted, with final alignment and belt adjustment made after installation.
   a. Service Factor Based on Fan Motor Size: 1.2 **OR** 1.3 **OR** 1.4 **OR** 1.5, **as directed**.
   b. Fan Shaft: Turned, ground, and polished steel designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
   c. Fan Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
   d. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
   e. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
   f. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.
   g. Motor Mount: Adjustable base.
   h. Shaft Bearings: Radial, self-aligning ball or roller bearings.
      1) Ball-Bearing Rating Life: ABMA 9, L10 of 100,000 hours.
         OR
         Roller-Bearing Rating Life: ABMA 11, L10 of 100,000 hours.
      2) Extend lubrication lines to outside of casing and terminate with grease fittings.
5. Accessories:
   a. Companion Flanges: Rolled flanges of same material as housing.
   b. Inspection Door: Bolted door allowing limited access to internal parts of fan, of same material as housing.
   c. Propeller Access Section Door: Short duct section bolted to fan inlet **OR** outlet **OR** inlet and outlet, **as directed,** allowing access to internal parts of fan for inspection and cleaning, of same material as housing.
   d. Swingout Construction: Assembly allowing entire fan section to swing out from duct for cleaning and servicing, of same material as housing.
   e. Mounting Clips: Horizontal ceiling **OR** Vertical mounting, **as directed,** clips welded to fan housing, of same material as housing.
   f. Horizontal Support: Pair of supports bolted to fan housing, of same material as housing.
   g. Vertical Support: Short duct section with welded brackets bolted to fan housing, of same material as housing.

h. Inlet and Outlet Screens: Wire-mesh screen on fans not connected to ductwork, of same material as housing.
i. Backdraft Dampers: Butterfly style, for bolting to the discharge of fan or outlet cone, of same material as housing.
j. Shaft Seal: Elastomeric seal and Teflon wear plate, suitable for up to 300 deg F (149 deg C).
k. Motor Cover: Cover with side vents to dissipate motor heat, of same material as housing.
l. Inlet Vanes: Adjustable; with peripheral control linkage operated from outside of airstream, bronze sleeve bearings on each end of vane support, and provision for manual or automatic operation of same material as housing.
m. Inlet Bell: Curved inlet for when fan is not attached to duct, of same material as housing **OR** aluminum, **as directed**.
n. Inlet Cones: Round-to-round transition of same material as housing.
o. Outlet Cones: Round-to-round transition of same material as housing.
p. Stack Cap: Vertical discharge assembly with backdraft dampers, of same material as housing.

6. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   a. Enclosure Type: Totally enclosed, fan cooled **OR** Totally enclosed, nonventilated, **as directed**.
   b. Direct-Driven Units: Encase motor in housing outside of airstream, factory wired to disconnect switch located on outside of fan housing, **as directed**.
7. Factory Finishes:
   a. Sheet Metal Parts: Prime coat before final assembly.
   b. Exterior Surfaces: Baked-enamel finish coat after assembly.
   c. Coatings: Thermoplastic vinyl **OR** Epoxy **OR** Zinc **OR** Synthetic resin **OR** Phenolic **OR** Color-match enamel **OR** Polytetrafluoroethylene **OR** Vinyl ester **OR** Hot-dip galvanized **OR** Powder-baked enamel, **as directed**.
      1) Apply to finished housings.
      2) Apply to fan wheels.

B. Vaneaxial Fans
1. Description: Fan wheel and housing, straightening vane section**,** factory-mounted motor with belt drive or direct drive, an inlet cone section, and accessories.
   a. Variable-Pitch Fans: Internally mounted pneumatic **OR** electric **OR** electronic, **as directed,** actuator, externally mounted positive positioner, and mechanical-blade-pitch indicator.
2. Housings: Steel **OR** Galvanized steel **OR** Aluminum **OR** Fiberglass-reinforced plastic **OR** Stainless steel, **as directed**.
   a. Inlet and Outlet Connections: Flanges.
   b. Guide Vane Section: Integral guide vanes downstream from fan wheel designed to straighten airflow.
3. Wheel Assemblies: Cast aluminum with airfoil-shaped blades mounted on cast-iron wheel plate keyed to shaft with solid-steel key **OR** Fiberglass-reinforced plastic cured under pressure with airfoil-shaped blades keyed to stainless steel shaft **OR** Cast-aluminum hub assembly, machined and fitted with threaded bearing wells to receive blade-bearing assemblies with replaceable, cast-aluminum blades; factory mounted and balanced, **as directed**.
4. Drives: Factory mounted, with final alignment and belt adjustment made after installation.
   a. Service Factor Based on Fan Motor Size: 1.2 **OR** 1.3 **OR** 1.4 **OR** 1.5, **as directed**.
   b. Fan Shaft: Turned, ground, and polished steel designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
   c. Fan Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
   d. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
   e. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.

f. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.
g. Motor Mount: Adjustable base.
h. Shaft Bearings: Radial, self-aligning ball or roller bearings.
1) Ball-Bearing Rating Life: ABMA 9, L10 of 100,000 hours.
OR
Roller-Bearing Rating Life: ABMA 11, L10 of 100,000 hours.
2) Extend lubrication lines to outside of casing and terminate with grease fittings.

5. Accessories:
a. Companion Flanges: Rolled flanges of same material as housing.
b. Inspection Door: Bolted door allowing limited access to internal parts of fan, of same material as housing.
c. Propeller Access Section Door: Short duct section bolted to fan inlet **OR** outlet **OR** inlet and outlet, **as directed,** allowing access to internal parts of fan for inspection and cleaning, of same material as housing.
d. Swingout Construction: Assembly allowing entire fan section to swing out from duct for cleaning and servicing, of same material as housing.
e. Mounting Clips: Horizontal ceiling **OR** Vertical mounting, **as directed**, clips welded to fan housing, of same material as housing.
f. Horizontal Support: Pair of supports bolted to fan housing, of same material as housing.
g. Vertical Support: Short duct section with welded brackets bolted to fan housing, of same material as housing.
h. Inlet and Outlet Screens: Wire-mesh screen on fans not connected to ductwork of same material as housing.
i. Backdraft Dampers: Butterfly style, for mounting with flexible connection to the discharge of fan or direct mounted to the discharge diffuser section of same material as housing.
j. Stall Alarm Probe: Sensing probe capable of detecting fan operation in stall and signaling control devices. Control devices and sequence of operation are specified in Division 23 Section(s) "Instrumentation And Control For Hvac" AND "Sequence Of Operations For Hvac Controls".
k. Flow Measurement Port: Pressure measurement taps installed in the inlet of fan to detect and signal airflow readings to temperature-control systems. Control devices and sequence of operation are specified in Division 23 Section(s) "Instrumentation And Control For Hvac" AND "Sequence Of Operations For Hvac Controls".
l. Shaft Seal: Elastomeric seal and Teflon wear plate, suitable for up to300 deg F (148 deg C).
m. Motor Cover: Cover with side vents to dissipate motor heat, of same material as housing.
n. Inlet Vanes: Adjustable; with peripheral control linkage operated from outside of airstream, bronze sleeve bearings on each end of vane support, and provision for manual or automatic operation of same material as housing.
o. Inlet Bell: Curved inlet for when fan is not attached to duct, of same material as housing.
p. Inlet Cones: Round-to-round transition of same material as housing.
q. Outlet Cones: Round-to-round transition of same material as housing.
r. Stack Cap: Vertical discharge assembly with backdraft dampers, of same material as housing.

6. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
a. Enclosure Type: Totally enclosed, fan cooled **OR** Totally enclosed, nonventilated, **as directed**.
b. Direct-Driven Units: Encase motor in housing outside of airstream, factory wired to disconnect switch located on outside of fan housing, **as directed**.

7. Factory Finishes:
a. Sheet Metal Parts: Prime coat before final assembly.
b. Exterior Surfaces: Baked-enamel finish coat after assembly.

c. Coatings: Thermoplastic vinyl **OR** Epoxy **OR** Zinc **OR** Synthetic resin **OR** Phenolic **OR** Color-match enamel **OR** Polytetrafluoroethylene **OR** Vinyl ester **OR** Hot-dip galvanized **OR** Powder-baked enamel, **as directed**.
   1) Apply to finished housings.
   2) Apply to fan wheels.

C. Mixed-Flow Fans
1. Description: Fan wheel and housing, straightening vane section, **as directed**, factory-mounted motor with belt drive, and accessories.
2. Housings: Steel **OR** Galvanized steel **OR** Aluminum, **as directed**.
   a. Inlet and Outlet Connections: Outer mounting frame and companion flanges.
   b. Guide Vane Section: Integral guide vanes downstream from fan wheel designed to straighten airflow.
   c. Mixed-Flow Outlet Connection: One **OR** Two, **as directed,** flanged discharge(s) perpendicular to fan inlet.
3. Wheel Assemblies: Cast aluminum with airfoil-shaped blades mounted on cast-iron wheel plate keyed to shaft with solid-steel key.
4. Drives: Factory mounted, with final alignment and belt adjustment made after installation.
   a. Service Factor Based on Fan Motor Size: 1.2 **OR** 1.3 **OR** 1.4 **OR** 1.5, **as directed**.
   b. Fan Shaft: Turned, ground, and polished steel designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
   c. Fan Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
   d. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
   e. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
   f. Motor Mount: Adjustable base.
   g. Shaft Bearings: Radial, self-aligning ball or roller bearings.
      1) Ball-Bearing Rating Life: ABMA 9, L10 of 100,000 hours.
         OR
         Roller-Bearing Rating Life: ABMA 11, L10 of 100,000 hours.
      2) Extend lubrication lines to outside of casing and terminate with grease fittings.
5. Accessories:
   a. Mounting Clips: Horizontal ceiling **OR** Vertical mounting, **as directed,** clips welded to fan housing, of same material as housing.
   b. Inlet and Outlet Screens: Wire-mesh screen on fans not connected to ductwork of same material as housing.
   c. Backdraft Dampers: Butterfly style, for mounting with flexible connection to the discharge of fan or direct mounted to the discharge diffuser section of same material as housing.
   d. Motor Cover: Cover with side vents to dissipate motor heat, of same material as housing.
   e. Inlet Bell: Curved inlet for when fan is not attached to duct, of same material as housing.
   f. Inlet Cones: Round-to-round transition of same material as housing.
   g. Outlet Cones: Round-to-round transition of same material as housing.
   h. Stack Cap: Vertical discharge assembly with backdraft dampers, of same material as housing.
6. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   a. Enclosure Type: Totally enclosed, fan cooled **OR** Totally enclosed, nonventilated, **as directed**.
   b. Direct-Driven Units: Encase motor in housing outside of airstream, factory wired to disconnect switch located on outside of fan housing.
7. Factory Finishes:
   a. Sheet Metal Parts: Prime coat before final assembly.
   b. Exterior Surfaces: Baked-enamel finish coat after assembly.

c. Coatings: Thermoplastic vinyl **OR** Epoxy **OR** Zinc **OR** Synthetic resin **OR** Phenolic **OR** Color-match enamel **OR** Polytetrafluoroethylene **OR** Vinyl ester **OR** Hot-dip galvanized **OR** Powder-baked enamel, **as directed**.
   1) Apply to finished housings.
   2) Apply to fan wheels.

D. Source Quality Control
1. Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Factory test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Label fans with the AMCA-Certified Ratings Seal.
2. Fan Performance Ratings: Establish flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests and ratings according to AMCA 210, "Laboratory Methods of Testing Fans for Rating."

1.3 EXECUTION

A. Installation
1. Install axial fans level and plumb.
2. Support floor-mounting units using spring isolators **OR** restrained spring isolators, **as directed,** having a static deflection of 1 inch (25 mm). Vibration- and seismic-control devices are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   a. Secure vibration and seismic controls to concrete bases using anchor bolts cast in concrete base.
3. Install floor-mounting units on concrete bases. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-place Concrete".
4. Install floor-mounting units on concrete bases designed to withstand, without damage to equipment, the seismic force required by authorities having jurisdiction. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-place Concrete".
5. Support suspended units from structure using threaded steel rods and elastomeric hangers **OR** spring hangers **OR** spring hangers with vertical-limit stops, **as directed,** having a static deflection of 1 inch (25 mm). Vibration-control devices are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
6. Install units with clearances for service and maintenance.
7. Label fans according to requirements specified in Division 23 Section "Identification For Hvac Piping And Equipment".

B. Connections
1. Duct installation and connection requirements are specified in other Division 21. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Division 23 Section "Air Duct Accessories".
2. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
3. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

C. Field Quality Control
1. Perform the following field tests and inspections and prepare test reports:
   a. Verify that shipping, blocking, and bracing are removed.
   b. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
   c. Verify that cleaning and adjusting are complete.

d. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
e. Adjust belt tension.
f. Adjust damper linkages for proper damper operation.
g. Verify lubrication for bearings and other moving parts.
h. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.
i. Disable automatic temperature-control operators, energize motor and confirm proper motor rotation and unit operation, adjust fan to indicated rpm, and measure and record motor voltage and amperage.
j. Shut unit down and reconnect automatic temperature-control operators.
k. Remove and replace malfunctioning units and retest as specified above.

2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

D. Adjusting
1. Adjust damper linkages for proper damper operation.
2. Adjust belt tension.
3. Lubricate bearings.

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SECTION 23 34 16 00 - CENTRIFUGAL FANS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for centrifugal fans. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following:
a. Airfoil centrifugal fans.
b. Backward-inclined centrifugal fans.
c. Forward-curved centrifugal fans.
d. Plenum fans.
e. Plug fans.

C. Performance Requirements
1. Project Altitude: Base fan performance ratings on actual Project site elevations above sea level.
2. Operating Limits: Classify according to AMCA 99.

D. Submittals
1. Product Data: Include rated capacities, furnished specialties, and accessories for each type of product indicated.
2. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Field quality-control test reports.
4. Operation and maintenance data.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. AMCA Compliance: Products shall comply with performance requirements and shall be licensed to use the AMCA-Certified Ratings Seal.
3. NEMA Compliance: Motors and electrical accessories shall comply with NEMA 1.

F. Delivery, Storage, And Handling
1. Deliver fans as factory-assembled units, to the extent allowable by shipping limitations, with protective crating and covering.
2. Disassemble and reassemble units, as required for moving to the final location, according to manufacturer's written instructions.
3. Lift and support units with manufacturer's designated lifting or supporting points.

1.2 PRODUCTS

A. Airfoil Centrifugal Fans
1. Description: Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, **as directed,**, drive assembly, and support structure.

2. Housings: Formed panels to make curved-scroll housings with shaped cutoff, with doors or panels to allow access to internal parts and components.
   a. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
   b. Horizontally split, bolted-flange housing.
   c. Spun inlet cone with flange.
   d. Outlet flange.
3. Airfoil Wheels: Single-width-single-inlet and double-width-double-inlet construction with curved inlet flange; heavy backplate; hollow die-formed, airfoil-shaped blades continuously welded at tip flange and backplate; and cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws; and special coating, **as directed**.
4. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.
   a. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
   b. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
5. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings.
   a. Ball-Bearing Rating Life: ABMA 9, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
   b. Roller-Bearing Rating Life: ABMA 11, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
6. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing.
   a. Ball-Bearing Rating Life: ABMA 9, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
   b. Roller-Bearing Rating Life: ABMA 11, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
7. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing.
   a. Ball-Bearing Rating Life: ABMA 9, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
   b. Roller-Bearing Rating Life: ABMA 11, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
8. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.
   a. Service Factor Based on Fan Motor Size: 1.5 **OR** 1.4 **OR** 1.3 **OR** 1.2, **as directed**.
   b. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
   c. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
   d. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
   e. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
   f. Motor Mount: Adjustable for belt tensioning.
9. Accessories:
   a. Scroll Access Doors: Shaped to conform to scroll, with quick-opening latches and gaskets.
   b. Cleanout Door: Bolted **OR** Quick-opening, latch-type, **as directed,** gasketed door allowing access to fan scroll, of same material as housing.
   c. Scroll Drain Connection: NPS 1 (DN 25) steel pipe coupling welded to low point of fan scroll.
   d. Companion Flanges: Rolled flanges for duct connections of same material as housing.
   e. Variable Inlet Vanes: With blades supported at both ends with two permanently lubricated bearings of same material as housing. Variable mechanism terminating in single control lever with control shaft for double-width fans.
   f. Discharge Dampers: Assembly with parallel **OR** opposed, **as directed,** blades constructed of two plates formed around and to shaft, channel frame, and sealed ball bearings; with blades linked outside of airstream to single control lever of same material as housing.

g. Inlet Screens: Grid screen of same material as housing.
h. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
i. Spark-Resistant Construction: AMCA 99.
j. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.
k. Weather Cover: Enameled-steel sheet with ventilation slots, bolted to housing.

10. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
    a. Enclosure Type: Totally enclosed, fan cooled.

B. Backward-Inclined Centrifugal Fans
1. Description: Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure.
2. Housings: Formed panels to make curved-scroll housings with shaped cutoff; with doors or panels to allow access to internal parts and components.
    a. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
    b. Spun inlet cone with flange.
    c. Outlet flange.
3. Backward-Inclined Wheels: Single-width-single-inlet and double-width-double-inlet construction with curved inlet flange, backplate, backward-inclined blades welded or riveted to flange and backplate; cast-iron or cast-steel hub riveted to backplate, **as directed**, and fastened to shaft with set screws.
4. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.
    a. Turned, ground, and polished hot-rolled steel with keyway. Ship with a protective coating of lubricating oil.
    b. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
5. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings.
    a. Ball-Bearing Rating Life: ABMA 9, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
    b. Roller-Bearing Rating Life: ABMA 11, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
6. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing.
    a. Ball-Bearing Rating Life: ABMA 9, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
    b. Roller-Bearing Rating Life: ABMA 11, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
7. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing.
    a. Ball-Bearing Rating Life: ABMA 9, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
    b. Roller-Bearing Rating Life: ABMA 11, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
8. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.
    a. Service Factor Based on Fan Motor Size: 1.5 **OR** 1.4 **OR** 1.3 **OR** 1.2, **as directed**].
    b. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
    c. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
    d. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
    e. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
    f. Motor Mount: Adjustable for belt tensioning.
9. Accessories:

a. Scroll Access Doors: Shaped to conform to scroll, with quick-opening latches and gaskets.
b. Cleanout Door: Bolted **OR** Quick-opening, latch-type, **as directed,** gasketed door allowing access to fan scroll, of same material as housing.
c. Scroll Drain Connection: NPS 1 (DN 25) steel pipe coupling welded to low point of fan scroll.
d. Companion Flanges: Rolled flanges for duct connections of same material as housing.
e. Variable Inlet Vanes: With blades supported at both ends with two permanently lubricated bearings of same material as housing. Variable mechanism terminating in single control lever with control shaft for double-width fans.
f. Discharge Dampers: Assembly with parallel **OR** opposed, **as directed,** blades constructed of two plates formed around and to shaft, channel frame, and sealed ball bearings; with blades linked outside of airstream to single control lever of same material as housing.
g. Inlet Screens: Grid screen of same material as housing.
h. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
i. Spark-Resistant Construction: AMCA 99.
j. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.
k. Weather Cover: Enameled-steel sheet with ventilation slots, bolted to housing.

10. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
    a. Enclosure Type: Totally enclosed, fan cooled.

C. Forward-Curved Centrifugal Fans
1. Description: Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, **as directed**, drive assembly, and support structure.
2. Housings: Formed panels to make curved-scroll housings with shaped cutoff; with doors or panels to allow access to internal parts and components.
    a. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
    b. Horizontally split, bolted-flange housing.
    c. Spun inlet cone with flange.
    d. Outlet flange.
3. Forward-Curved Wheels: Black-enameled or galvanized steel construction with inlet flange, backplate, shallow blades with inlet and tip curved forward in direction of airflow, mechanically secured to flange and backplate; cast-steel hub swaged to backplate and fastened to shaft with set screws.
4. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.
    a. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
    b. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
5. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings.
    a. Ball-Bearing Rating Life: ABMA 9, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
    b. Roller-Bearing Rating Life: ABMA 11, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
6. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing.
    a. Ball-Bearing Rating Life: ABMA 9, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
    b. Roller-Bearing Rating Life: ABMA 11, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
7. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing.
    a. Ball-Bearing Rating Life: ABMA 9, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
    b. Roller-Bearing Rating Life: ABMA 11, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.

8. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.
   a. Service Factor Based on Fan Motor Size: 1.5.
   b. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
   c. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
   d. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
   e. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
   f. Motor Mount: Adjustable for belt tensioning.
9. Accessories:
   a. Scroll Access Doors: Shaped to conform to scroll, with quick-opening latches and gaskets.
   b. Cleanout Door: Bolted **OR** Quick-opening, latch-type, **as directed,** gasketed door allowing access to fan scroll, of same material as housing.
   c. Scroll Drain Connection: NPS 1 (DN 25) steel pipe coupling welded to low point of fan scroll.
   d. Companion Flanges: Rolled flanges for duct connections of same material as housing.
   e. Variable Inlet Vanes: With blades supported at both ends with two permanently lubricated bearings of same material as housing. Variable mechanism terminating in single control lever with control shaft for double-width fans.
   f. Discharge Dampers: Assembly with parallel **OR** opposed, **as directed,** blades constructed of two plates formed around and to shaft, channel frame, and sealed ball bearings; with blades linked outside of airstream to single control lever of same material as housing.
   g. Inlet Screens: Grid screen of same material as housing.
   h. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
   i. Spark-Resistant Construction: AMCA 99.
   j. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.
   k. Weather Cover: Enameled-steel sheet with ventilation slots, bolted to housing.
10. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   a. Enclosure Type: Totally enclosed, fan cooled.

D. Plenum Fans
1. Description: Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of wheel, fan shaft, bearings, motor and disconnect switch, **as directed**, drive assembly, and support structure.
2. Airfoil Wheels: Single-width-single-inlet construction with smooth-curved inlet flange; heavy backplate; hollow die-formed, airfoil-shaped blades continuously welded at tip flange and backplate; and cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws; and special coating.
3. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.
   a. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
   b. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
4. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings.
   a. Ball-Bearing Rating Life: ABMA 9, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
   b. Roller-Bearing Rating Life: ABMA 11, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
5. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing.

a. Ball-Bearing Rating Life: ABMA 9, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
b. Roller-Bearing Rating Life: ABMA 11, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.

6. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing.
   a. Ball-Bearing Rating Life: ABMA 9, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
   b. Roller-Bearing Rating Life: ABMA 11, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
7. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.
   a. Service Factor Based on Fan Motor Size: 1.5 **OR** 1.4 **OR** 1.3 **OR** 1.2, **as directed**.
   b. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
   c. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
   d. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
   e. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
   f. Motor Mount: Adjustable for belt tensioning.
8. Accessories:
   a. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
   b. Spark-Resistant Construction: AMCA 99.
   c. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.
9. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   a. Enclosure Type: Totally enclosed, fan cooled.

E. Plug Fans
1. Description: Factory-fabricated, -assembled, -tested, and -finished, belt-driven centrifugal fans consisting of wheel, fan shaft, bearings, motor and disconnect switch, **as directed**, drive assembly, and support structure.
2. Airfoil Wheels: Single-width-single-inlet construction with smooth-curved inlet flange; heavy backplate; hollow die-formed, airfoil-shaped blades continuously welded at tip flange and backplate; and cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws; and special coating, **as directed**.
3. Shafts: Statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.
   a. Turned, ground, and polished hot-rolled steel with keyway. Ship with protective coating of lubricating oil.
   b. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
4. Prelubricated and Sealed Shaft Bearings: Self-aligning, pillow-block-type ball bearings.
   a. Ball-Bearing Rating Life: ABMA 9, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
   b. Roller-Bearing Rating Life: ABMA 11, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
5. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, tapered roller bearings with double-locking collars and two-piece, cast-iron housing.
   a. Ball-Bearing Rating Life: ABMA 9, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
   b. Roller-Bearing Rating Life: ABMA 11, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
6. Grease-Lubricated Shaft Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing.
   a. Ball-Bearing Rating Life: ABMA 9, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
   b. Roller-Bearing Rating Life: ABMA 11, Ll0 at 50,000 hours **OR** 120,000 hours, **as directed**.
7. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation.

a. Service Factor Based on Fan Motor Size: 1.5 **OR** 1.4 **OR** 1.3 **OR** 1.2, **as directed**.
b. Fan Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
c. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
d. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
e. Belt Guards: Fabricate to comply with OSHA and SMACNA requirements of diamond-mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation. Include provisions for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
f. Motor Mount: Adjustable for belt tensioning.

8. Accessories:
a. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft.
b. Spark-Resistant Construction: AMCA 99.
c. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.

9. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
a. Enclosure Type: Totally enclosed, fan cooled.

F. Source Quality Control
1. Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Factory test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Label fans with the AMCA-Certified Ratings Seal.
2. Fan Performance Ratings: Establish flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests and ratings according to AMCA 210, "Laboratory Methods of Testing Fans for Rating."

1.3 EXECUTION

A. Installation
1. Install centrifugal fans level and plumb.
2. Support floor-mounting units using spring isolators **OR** restrained spring isolators, **as directed,** having a static deflection of 1 inch (25 mm). Vibration- and seismic-control devices are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
a. Secure vibration and seismic controls to concrete bases using anchor bolts cast in concrete base.
3. Install floor-mounting units on concrete bases. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-place Concrete".
4. Install floor-mounting units on concrete bases designed to withstand, without damage to equipment, the seismic force required by authorities having jurisdiction. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-place Concrete".
5. Support suspended units from structure using threaded steel rods and elastomeric hangers **OR** spring hangers **OR** spring hangers with vertical-limit stops, **as directed,** having a static deflection of 1 inch (25 mm). Vibration-control devices are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
6. Install units with clearances for service and maintenance.
7. Label fans according to requirements specified in Division 23 Section "Identification For Hvac Piping And Equipment".

B. Connections
1. Duct installation and connection requirements are specified in other Division 21. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with

flexible connectors. Flexible connectors are specified in Division 23 Section "Air Duct Accessories".

2. Install ducts adjacent to fans to allow service and maintenance.
3. Install line-sized piping from scroll drain connection, with trap with seal equal to 1.5 times specified static pressure, to nearest floor drain.
4. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
5. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

C. Field Quality Control

1. Perform the following field tests and inspections and prepare test reports:
   a. Verify that shipping, blocking, and bracing are removed.
   b. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
   c. Verify that cleaning and adjusting are complete.
   d. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
   e. Adjust belt tension.
   f. Adjust damper linkages for proper damper operation.
   g. Verify lubrication for bearings and other moving parts.
   h. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.
   i. Refer to Division 23 Section "Testing, Adjusting, And Balancing For Hvac" for testing, adjusting, and balancing procedures.
   j. Remove and replace malfunctioning units and retest as specified above.
2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

END OF SECTION 23 34 16 00

SECTION 23 34 16 00a - POWER VENTILATORS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for power ventilators. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following:
a. Utility set fans.
b. Centrifugal roof ventilators.
c. Axial roof ventilators.
d. Upblast propeller roof exhaust fans.
e. Centrifugal wall ventilators.
f. Ceiling-mounting ventilators.
g. In-line centrifugal fans.
h. Propeller fans.

C. Performance Requirements
1. Project Altitude: Base fan-performance ratings on actual Project site elevations **OR** sea level, **as directed**.
2. Operating Limits: Classify according to AMCA 99.

D. Submittals
1. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, and furnished specialties and accessories. Also include the following:
a. Certified fan performance curves with system operating conditions indicated.
b. Certified fan sound-power ratings.
c. Motor ratings and electrical characteristics, plus motor and electrical accessories.
d. Material thickness and finishes, including color charts.
e. Dampers, including housings, linkages, and operators.
f. Roof curbs.
g. Fan speed controllers.
2. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
a. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
b. Wiring Diagrams: For power, signal, and control wiring.
3. Delegated-Design Submittal: For unit hangars and supports indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
a. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
b. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
4. Field quality-control reports.
a. Operation and Maintenance Data: For power ventilators to include in emergency, operation, and maintenance manuals.

E. Quality Assurance

1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a testing agency, and marked for intended use.
2. AMCA Compliance: Fans shall have AMCA-Certified performance ratings and shall bear the AMCA-Certified Ratings Seal.
3. UL Standard: Power ventilators shall comply with UL 705. Power ventilators for use for restaurant kitchen exhaust shall also comply with UL 762.

1.2 PRODUCTS

A. Utility Set Fans
1. Description: Direct **OR** Belt, **as directed,**-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and accessories.
2. Housing: Fabricated of galvanized, **as directed**, steel with side sheets fastened with a deep lock seam or welded to scroll sheets.
   a. Housing Discharge Arrangement: Adjustable to eight standard positions.
3. Fan Wheels: Single-width, single inlet; welded to cast-iron or cast-steel hub and spun-steel inlet cone, with hub keyed to shaft.
   a. Blade Materials: Steel **OR** Aluminum, **as directed**.
   b. Blade Type: Backward inclined **OR** Forward curved **OR** Airfoil, **as directed**.
   c. Spark-Resistant Construction: AMCA 99, Type A **OR** B **OR** C, **as directed**.
4. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
5. Shaft Bearings: Prelubricated and sealed, self-aligning, pillow-block-type ball bearings with ABMA 9, L_{50} of 200,000 hours **OR** L_{10} of 80,000 hours, **as directed**.
6. Belt Drives:
   a. Factory mounted, with final alignment and belt adjustment made after installation.
   b. Service Factor Based on Fan Motor Size: 1.5 **OR** 1.4 **OR** 1.3 **OR** 1.2, **as directed**.
   c. Motor Pulleys: Adjustable pitch for use with motors through 5, **as directed**, hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
   d. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
   e. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.
7. Accessories:
   a. Inlet and Outlet: Flanged.
   b. Companion Flanges: Rolled flanges for duct connections of same material as housing.
   c. Backdraft Dampers: Gravity actuated with counterweight and interlocking aluminum blades with felt edges in steel frame installed on fan discharge.
   d. Access Door: Gasketed door in scroll with latch-type handles.
   e. Scroll Dampers: Single-blade damper installed at fan scroll top with adjustable linkage.
   f. Inlet Screens: Removable wire mesh.
   g. Drain Connections: NPS 3/4 (DN 20) threaded coupling drain connection installed at lowest point of housing.
   h. Weather Hoods: Weather resistant with stamped vents over motor and drive compartment.
   i. Discharge Dampers: Assembly with parallel **OR** opposed, **as directed,** blades constructed of two plates formed around and to shaft, channel frame, sealed ball bearings, with blades linked outside of airstream to single control lever of same material as housing.
   j. Variable Inlet Vanes: With blades supported at both ends with two permanently lubricated bearings of same material as housing. Variable mechanism terminating in single control lever with control shaft for double-width fans.
   k. Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.

B. Centrifugal Roof Ventilators
1. Description: Direct- or belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, curb base, and accessories.

2. Housing: Removable, spun-aluminum, dome top and outlet baffle **OR** extruded-aluminum, rectangular top **OR** galvanized steel, mushroom-domed top, **as directed**; square, one-piece, aluminum base with venturi inlet cone.
   a. Upblast Units: Provide spun-aluminum discharge baffle to direct discharge air upward, with rain and snow drains and grease collector, **as directed**.
   b. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.
3. Fan Wheels: Aluminum hub and wheel with backward-inclined blades.
4. Belt-Driven Drive:
   a. Resiliently mounted to housing.
   b. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
   c. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
   d. Pulleys: Cast-iron, adjustable-pitch motor pulley.
   e. Fan and motor isolated from exhaust airstream.
5. Accessories:
   a. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
   b. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted inside **OR** outside, **as directed,** fan housing, factory wired through an internal aluminum conduit.
   c. Bird Screens: Removable, 1/2-inch (13-mm) mesh, aluminum or brass wire.
   d. Dampers: Counterbalanced, parallel-blade, backdraft dampers mounted in curb base; factory set to close when fan stops.
   e. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.
6. Roof Curbs: Galvanized steel; mitered and welded corners; 1-1/2-inch- (40-mm-) thick, rigid, fiberglass insulation adhered to inside walls; and 1-1/2-inch (40-mm) wood nailer. Size as required to suit roof opening and fan base.
   a. Configuration: Self-flashing without a cant strip, with mounting flange **OR** Built-in cant and mounting flange **OR** Built-in raised cant and mounting flange, **as directed**.
   b. Overall Height: 8 inches (200 mm) **OR** 9-1/2 inches (240 mm) **OR** 12 inches (300 mm) **OR** 16 inches (400 mm) **OR** 18 inches (450 mm), **as directed**.
   c. Sound Curb: Curb with sound-absorbing insulation matrix.
   d. Pitch Mounting: Manufacture curb for roof slope.
   e. Metal Liner: Galvanized steel.
   f. Burglar Bars: 1/2-inch- (13-mm-) **OR** 5/8-inch- (16-mm-) **OR** 3/4-inch- (19-mm-), **as directed,** thick steel bars welded in place to form 6-inch (150-mm) squares.
   g. Mounting Pedestal: Galvanized steel with removable access panel.
   h. Vented Curb: Unlined with louvered vents in vertical sides.

C. Axial Roof Ventilators
1. Description: Direct- or belt-driven axial fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, curb base, and accessories.
2. Housing: Heavy-gage, removable, spun-aluminum, dome top and outlet baffle; square, one-piece, hinged, aluminum base.
   a. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.
3. Fan Wheel: Aluminum **OR** Steel, **as directed,** hub and blades.
4. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features:
   a. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
   b. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
   c. Pulleys: Cast-iron, adjustable-pitch motor pulley.
5. Accessories:
   a. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted inside **OR** outside, **as directed,** fan housing, factory wired through an internal aluminum conduit.
   b. Bird Screens: Removable, 1/2-inch (13-mm) mesh, aluminum or brass wire.

c. Dampers: Counterbalanced, parallel-blade, backdraft dampers mounted in curb base; factory set to close when fan stops.
d. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.

6. Roof Curbs: Galvanized steel; mitered and welded corners; 1-1/2-inch- (40-mm-) thick, rigid, fiberglass insulation adhered to inside walls; and 1-1/2-inch (40-mm) wood nailer. Size as required to suit roof opening and fan base.
   a. Configuration: Self-flashing without a cant strip, with mounting flange **OR** Built-in cant and mounting flange **OR** Built-in raised cant and mounting flange, **as directed**.
   b. Overall Height: 8 inches (200 mm) **OR** 9-1/2 inches (240 mm) **OR** 12 inches (300 mm) **OR** 16 inches (400 mm) **OR** 18 inches (450 mm), **as directed**.
   c. Sound Curb: Curb with sound-absorbing insulation matrix.
   d. Pitch Mounting: Manufacture curb for roof slope.
   e. Metal Liner: Galvanized steel.
   f. Burglar Bars: 1/2-inch- (13-mm-) **OR** 5/8-inch- (16-mm-) **OR** 3/4-inch- (19-mm-), **as directed,** thick steel bars welded in place to form 6-inch (150-mm) squares.
   g. Mounting Pedestal: Galvanized steel with removable access panel.

D. Upblast Propeller Roof Exhaust Fans
1. Description: Direct- or belt-driven propeller fans consisting of housing, wheel, butterfly-type discharge damper, fan shaft, bearings, motor and disconnect switch, drive assembly, curb base, and accessories.
2. Wind Band, Fan Housing, and Base: Reinforced and braced galvanized steel **OR** aluminum, **as directed**, containing galvanized-steel **OR** aluminum, **as directed,** butterfly dampers and rain trough, motor and drive assembly, and fan wheel.
   a. Damper Rods: Steel with bronze **OR** nylon, **as directed,** bearings.
   b. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.
3. Fan Wheel: Replaceable, cast **OR** extruded, **as directed,**-aluminum, airfoil blades fastened to cast-aluminum hub; factory set pitch angle of blades.
4. Belt-Driven Drive Assembly: Resiliently mounted to housing; weatherproof housing of same material as fan housing with the following features:
   a. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
   b. Shaft Bearings: Prelubricated and sealed, self-aligning, pillow-block-type ball bearings.
   c. Pulleys: Cast-iron, adjustable-pitch motor pulley.
   d. Motor Mount: On outside of fan cabinet, adjustable base for belt tensioning.
5. Roof Curbs: Galvanized steel; mitered and welded corners; 1-1/2-inch- (40-mm-) thick, rigid, fiberglass insulation adhered to inside walls; and 1-1/2-inch (40-mm) wood nailer. Size as required to suit roof opening and fan base.
   a. Configuration: Self-flashing without a cant strip, with mounting flange **OR** Built-in cant and mounting flange **OR** Built-in raised cant and mounting flange, **as directed**.
   b. Overall Height: 8 inches (200 mm) **OR** 9-1/2 inches (240 mm) **OR** 12 inches (300 mm) **OR** 16 inches (400 mm) **OR** 18 inches (450 mm), **as directed**.
   c. Sound Curb: Curb with sound-absorbing insulation matrix.
   d. Pitch Mounting: Manufacture curb for roof slope.
   e. Metal Liner: Galvanized steel.
   f. Burglar Bars: 1/2-inch- (13-mm-) **OR** 5/8-inch- (16-mm-) **OR** 3/4-inch- (19-mm-), **as directed,** thick steel bars welded in place to form 6-inch (150-mm) squares.
   g. Mounting Pedestal: Galvanized steel with removable access panel.

E. Centrifugal Wall Ventilators
1. Description: Direct- or belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and accessories.
2. Housing: Heavy-gage, removable, spun-aluminum, dome top and outlet baffle; venturi inlet cone.
3. Fan Wheel: Aluminum hub and wheel with backward-inclined blades.

4. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features:
   a. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
   b. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
   c. Pulleys: Cast-iron, adjustable-pitch motor pulley.
   d. Fan and motor isolated from exhaust airstream.
5. Accessories:
   a. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
   b. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted inside fan housing, factory wired through internal aluminum conduit.
   c. Bird Screens: Removable, 1/2-inch (13-mm) mesh, aluminum or brass wire.
   d. Wall Grille: Ring type for flush mounting.
   e. Dampers: Counterbalanced, parallel-blade, backdraft dampers mounted in wall sleeve; factory set to close when fan stops.
   f. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.

F. Ceiling-Mounting Ventilators
1. Description: Centrifugal fans designed for installing in ceiling or wall or for concealed in-line applications.
2. Housing: Steel, lined with acoustical insulation.
3. Fan Wheel: Centrifugal wheels directly mounted on motor shaft. Fan shrouds, motor, and fan wheel shall be removable for service.
4. Grille: Plastic **OR** Stainless steel **OR** Aluminum **OR** Painted aluminum, **as directed**, louvered grille with flange on intake and thumbscrew attachment to fan housing.
5. Electrical Requirements: Junction box for electrical connection on housing and receptacle for motor plug-in.
6. Accessories:
   a. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
   b. Manual Starter Switch: Single-pole rocker switch assembly with cover and pilot light.
   c. Time-Delay Switch: Assembly with single-pole rocker switch, timer, and cover plate.
   d. Motion Sensor: Motion detector with adjustable shutoff timer.
   e. Ceiling Radiation Damper: Fire-rated assembly with ceramic blanket, stainless-steel springs, and fusible link.
   f. Filter: Washable aluminum to fit between fan and grille.
   g. Isolation: Rubber-in-shear vibration isolators.
   h. Manufacturer's standard roof jack or wall cap, and transition fittings.

G. In-Line Centrifugal Fans
1. Description: In-line, direct **OR** belt, **as directed,**-driven centrifugal fans consisting of housing, wheel, outlet guide vanes, fan shaft, bearings, motor and disconnect switch, drive assembly, mounting brackets, and accessories.
2. Housing: Split, spun aluminum with aluminum straightening vanes, inlet and outlet flanges, and support bracket adaptable to floor, side wall, or ceiling mounting.
3. Direct-Driven Units: Motor mounted in airstream, factory wired to disconnect switch located on outside of fan housing; with wheel, inlet cone, and motor on swing-out service door, **as directed**.
4. Belt-Driven Units: Motor mounted on adjustable base, with adjustable sheaves, enclosure around belts within fan housing, and lubricating tubes from fan bearings extended to outside of fan housing.
5. Fan Wheels: Aluminum, airfoil blades welded to aluminum hub.
6. Accessories:
   a. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
   b. Volume-Control Damper: Manually operated with quadrant lock, located in fan outlet.
   c. Companion Flanges: For inlet and outlet duct connections.

d. Fan Guards: 1/2- by 1-inch (13- by 25-mm) mesh of galvanized steel in removable frame. Provide guard for inlet or outlet for units not connected to ductwork.
e. Motor and Drive Cover (Belt Guard): Epoxy-coated steel.

H. Propeller Fans
1. Description: Direct- or belt-driven propeller fans consisting of fan blades, hub, housing, orifice ring, motor, drive assembly, and accessories.
2. Housing: Galvanized-steel sheet with flanged edges and integral orifice ring with baked-enamel finish coat applied after assembly.
3. Steel Fan Wheels: Formed-steel blades riveted to heavy-gage steel spider bolted to cast-iron hub.
4. Fan Wheel: Replaceable, cast **OR** extruded, **as directed,**-aluminum, airfoil blades fastened to cast-aluminum hub; factory set pitch angle of blades.
5. Belt-Driven Drive Assembly: Resiliently mounted to housing, statically and dynamically balanced and selected for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.
   a. Service Factor Based on Fan Motor Size: 1.4.
   b. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
   c. Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
      1) Ball-Bearing Rating Life: ABMA 9, L_{10} of 100,000 hours.
   d. Pulleys: Cast iron with split, tapered bushing; dynamically balanced at factory.
   e. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
   f. Belts: Oil resistant, nonsparking, and nonstatic; matched sets for multiple belt drives.
   g. Belt Guards: Fabricate of steel for motors mounted on outside of fan cabinet.
6. Accessories:
   a. Gravity Shutters: Aluminum blades in aluminum frame; interlocked blades with nylon bearings.
   b. Motor-Side Back Guard: Galvanized steel, complying with OSHA specifications, removable for maintenance.
   c. Wall Sleeve: Galvanized steel to match fan and accessory size.
   d. Weathershield Hood: Galvanized steel to match fan and accessory size.
   e. Weathershield Front Guard: Galvanized steel with expanded metal screen.
   f. Variable-Speed Controller: Solid-state control to reduce speed from 100 to less than 50 percent.
   g. Disconnect Switch: Nonfusible type, with thermal-overload protection mounted inside fan housing, factory wired through an internal aluminum conduit.

I. Motors
1. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
2. Enclosure Type: Open dripproof **OR** Totally enclosed, fan cooled, **as directed**.

J. Source Quality Control
1. Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Factory test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Label fans with the AMCA-Certified Ratings Seal.
2. Fan Performance Ratings: Establish flow rate, pressure, power, air density, speed of rotation, and efficiency by factory tests and ratings according to AMCA 210, "Laboratory Methods of Testing Fans for Rating."

1.3 EXECUTION

A. Installation
1. Install power ventilators level and plumb.
2. Support units using elastomeric mounts **OR** restrained elastomeric mounts **OR** spring isolators **OR** restrained spring isolators, **as directed,** having a static deflection of 1 inch (25 mm). Vibration- and seismic-control devices are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   a. Secure vibration and seismic controls to concrete bases using anchor bolts cast in concrete base.
3. For projects not in seismic areas, install floor-mounting units on concrete bases. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-place Concrete".
4. For projects in seismic areas, install floor-mounting units on concrete bases designed to withstand, without damage to equipment, the seismic force required by code. Concrete, reinforcement, and formwork requirements are specified in Division 03 Section "Cast-in-place Concrete".
5. Secure roof-mounting fans to roof curbs with cadmium-plated hardware. Refer to Division 07 Section "Roof Accessories" for installation of roof curbs.
6. Ceiling Units: Suspend units from structure; use steel wire or metal straps.
7. Support suspended units from structure using threaded steel rods and elastomeric hangers **OR** spring hangers **OR** spring hangers with vertical-limit stops, **as directed,** having a static deflection of 1 inch (25 mm). Vibration-control devices are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
8. Install units with clearances for service and maintenance.
9. Label units according to requirements specified in Division 23 Section "Identification For Hvac Piping And Equipment".
10. Duct installation and connection requirements are specified in other Division 21. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Division 23 Section "Air Duct Accessories".
11. Install ducts adjacent to power ventilators to allow service and maintenance.
12. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
13. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

B. Field Quality Control
1. Perform the following field tests and inspections and prepare test reports:
   a. Verify that shipping, blocking, and bracing are removed.
   b. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
   c. Verify that cleaning and adjusting are complete.
   d. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
   e. Adjust belt tension.
   f. Adjust damper linkages for proper damper operation.
   g. Verify lubrication for bearings and other moving parts.
   h. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.
   i. Disable automatic temperature-control operators, energize motor and adjust fan to indicated rpm, and measure and record motor voltage and amperage.
   j. Shut unit down and reconnect automatic temperature-control operators.
   k. Remove and replace malfunctioning units and retest as specified above.

2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

END OF SECTION 23 34 16 00a

Task	Specification	Specification Description
23 34 16 00	01 22 16 00	No Specification Required
23 34 23 00	23 34 16 00a	Power Ventilators

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SECTION 23 34 33 00 - AIR CURTAINS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for air curtains. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes air curtains with hot-water heat, steam heat, electric heat, and gas-fired heater.

C. Submittals
1. Product Data: Include rated capacities, furnished specialties, and accessories for each unit indicated.
2. Shop Drawings: For air curtains. Include plans, elevations, sections, details, and attachments to other work.
   a. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   b. Wiring Diagrams: Power, signal, and control wiring.
3. Delegated-Design Submittal: For air curtains indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
   a. Detail fabrication and assembly of air-curtain mounting assemblies.
   b. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints.
4. Operation and maintenance data: For air curtains to include in maintenance manuals.
5. Warranties: Sample of special warranties.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified and marked for intended location and application.
2. Comply with AMCA 220, "Laboratory Methods of Testing Air Curtains for Aerodynamic Performance Ratings," for airflow, outlet velocity, and power consumption.
3. Comply with ARI 410, "Forced-Circulation Air-Cooling and Air-Heating Coils," for components, construction, and rating.
   a. Certify coils according to ARI 410.
4. Comply with NSF 37, "Air Curtains for Entranceways in Food and Food Service Establishments."

E. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of air curtains that fail in materials or workmanship within specified warranty period.
   a. Warranty Period (Nonheating Units): 24 months.
   b. Warranty Period (Water or Steam Heating Units): 18 **OR** 24 months, **as directed**.
   c. Warranty Period (Gas Heating Units): 18 **OR** 24 months, **as directed**.

1.2 PRODUCTS

A. Air-Curtain Unit
1. Housing:

a. Materials: Galvanized steel with electrostatically applied epoxy enamel finish over powdered mirror
b. Materials: One-piece, molded, high-impact, white polymer material
c. Materials: Heavy-gage, electroplated-zinc steel with welded construction and polyester-coated finish.
d. Materials: Heavy-gage, aluminum construction.
   1) Anodized Finish: Match finish and color of adjacent architectural metals. Comply with NAAMM's "Metal Finishes Manual for Architectural and Metal Products" for recommendations for applying and designating finishes.
   2) Finish designations prefixed by AA comply with the system established by the Aluminum Association for designating aluminum finishes.
      a) Class II, Clear Anodic Finish: AA-M12C22A31 (Mechanical Finish: Nonspecular as fabricated; Chemical Finish: Etched, medium matte; Anodic Coating: Architectural Class II, clear coating 0.010 mm or thicker) complying with AAMA 611.
      b) Class II, Color Anodic Finish: AA-M12C22A32/A34 (Mechanical Finish: Nonspecular as fabricated; Chemical Finish: Etched, medium matte; Anodic Coating: Architectural Class II, integrally colored or electrolytically deposited color coating 0.010 mm or thicker).
e. Materials: Stainless steel.
f. Discharge Nozzle: Integral part of the housing, containing fixed air-directional vanes.
g. Discharge Nozzle: Integral part of the housing, containing adjustable air-directional vanes with 40 **OR** 20 **OR** 15-degree sweep front to back, **as directed**.
h. Discharge Nozzle: Integral part of the housing, containing air-directional vanes adjustable in 5-degree increments through a 45-degree sweep front to back.

2. Mounting Brackets: Steel, for wall **OR** ceiling mounting, **as directed**.
3. Air-Intake Louvers: Comply with requirements in Division 08 Section "Louvers And Vents".
4. Air-Intake Louvers **OR** Grille**, as directed.**
   a. Louvers: Integral part of the housing, mechanically field adjustable and capable of reducing air-outlet velocity by 60 percent with louver in totally closed position.
   b. Grille: Integral part of and same material as the housing.
   c. Insect Scrren: Aluminum **OR** Stainless steel**, as directed**, removable.
5. Fans
   a. Centrifugal, forward curved, double width, double inlet **OR** Vane axial, **as directed**.
   b. Galvanized steel **OR** Painted steel **OR** Aluminum, **as directed.**
   c. Statically and dynamically balanced.
   d. Direct drive **OR** Belt drive and equipped with belt guards and adjustable sheaves and pulleys for adjusting air-outlet velocity, **as directed**.
6. Motors: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
   b. Single speed **OR** Two speed Multispeed, **as directed**.
   c. Resiliently mounted.
   d. Continuous duty.
   e. Totally enclosed, air over **OR** totally enclosed, fan cooled, **OR**, open, dripproof **OR** explosion proof, **as directed.**
   f. Integral thermal-overload protection.
   g.
   h. Bearings: Permanently sealed, lifetime, prelubricated, ball bearings.
   i. Disconnect: Internal power cord with plug and receptacle.
7. Water Coils
   a. Type: Continuous-circuit **OR** Self-draining **OR** Cleanable, **as directed**.
   b. Piping Connections: Threaded on same end **OR** opposite ends, **as directed**.

c. Tubes: Copper, complying with ASTM B 75 (ASTM B 75M).
   1) Tube Diameter: 0.625 inch (15.9 mm).
d. Fins: Aluminum **OR** Copper, **as directed** with fin spacing 0.167 inch (4.23 mm) **OR** 0.125 inch (3.18 mm) **OR** 0.091 inch (2.31 mm) **OR** 0.071 inch (1.80 mm) **OR** 0.067 inch (1.70 mm) **OR** 0.056 inch (1.42 mm) **OR** 0.0075 inch (0.19 mm), **as directed**.
e. Fin and Tube Joint: Mechanical bond **OR** Silver brazed, **as directed**.
f. Headers: Cast iron with drain and air vent tappings **OR** Cast iron with cleaning plugs, and drain and air vent tappings **OR** Seamless copper tube with brazed joints, prime coated **OR** Fabricated steel with brazed joints, prime coated, **as directed**.
g. Frames: Galvanized-steel channel frame 0.052 inch (1.3 mm) **OR** 0.064 inch (1.6 mm) **OR** 0.079 inch (2.0 mm) **OR** 0.0625 inch (1.59 mm), **as directed**.
h. Ratings: According to ASHRAE 33.
i. Working-Pressure Ratings: 200 psig (1380 kPa), 325 deg F (163 deg C).

8. Steam Coils Distribution header coil **OR** Single-tube coil, **as directed** with threaded steam supply and condensate connections.
   a. Piping Connections: Same end **OR** Opposite ends **OR** Steam supply on both ends; condensate on one end, **as directed**.
   b. Tube Material: Copper, complying with ASTM B 75 (ASTM B 75M).
   c. Tube Diameter: 0.625 inch (15.9 mm).
   d. Fins: Aluminum **OR** Copper, **as directed** 0.167 inch (4.23 mm) **OR** 0.125 inch (3.18 mm) **OR** 0.091 inch (2.31 mm) **OR** 0.071 inch (1.80 mm) **OR** 0.067 inch (1.70 mm) **OR** 0.056 inch (1.42 mm) **OR** 0.0075 inch (0.19 mm), **as directed**.
   e. Fin and Tube Joint: Mechanical bond **OR** Silver brazed, **as directed**.
   f. Headers: Cast iron with drain and air vent tappings **OR** Cast iron with cleaning plugs, and drain and air vent tappings **OR** Seamless copper tube with brazed joints, prime coated **OR** Fabricated steel with brazed joints, prime coated, **as directed**.
   g. Frames: Galvanized-steel channel frame, 0.052 inch (1.3 mm) **OR** 0.064 inch (1.6 mm) **OR** 0.079 inch (2.0 mm) **OR** 0.0625 inch (1.59 mm) , **as directed**.
   h. Pressure and Temperature Ratings: 100 psig (690 kPa), 400 deg F (205 deg C) according to ASHRAE 33.

9. Electric-Resistance Coils:
   a. Coil Assembly: Comply with UL 1995.
   b. Frame: Galvanized-steel frame.
   c. Heating Elements: Coiled resistance wire of 80 percent nickel and 20 percent chromium; surrounded by compacted magnesium-oxide powder in tubular-steel sheath; with spiral-wound, copper-plated, steel fins continuously brazed to sheath.
   d. Heating Elements: Open-coil resistance wire of 80 percent nickel and 20 percent chromium, supported and insulated by floating ceramic bushings recessed into casing openings, fastened to supporting brackets, and mounted in galvanized-steel frame.
   e. Overtemperature Protection: Disk-type, automatically reset, thermal-cutout, safety device; serviceable through terminal box without removing heater from duct or unit.
      1) Secondary Protection: Load-carrying, manually reset or manually replaceable, thermal cutouts; factory wired in series with each heater stage.
   f. Control Panel: Unit **OR** Remote, **as directed**, mounted with disconnecting means and overcurrent protection. Include the following controls:
      1) Magnetic contactor.
      2) Mercury contactor.
      3) Solid-state stepless pulse controller.
      4) Toggle switches; one per step.
      5) Step controller.
      6) Time-delay relay.
      7) Pilot lights; one per step.
      8) Airflow proving switch.

10. Gas-Fired Heaters:
   a. Comply with ANSI Z83.8/CSA, "Gas Unit Heaters and Gas-Fired Duct Furnaces."
      1) CSA Approval: Bear AGA label.

2) Type of Gas: Natural **OR** LP, **as directed**.
b. Assembly and Wiring: Heaters factory assembled, piped, wired, and tested for 120-V ac.
c. Housing: Steel, with integral draft hood and inserts for suspension-mounting rods.
d. External Casings and Cabinets: Baked enamel over corrosion-resistant-treated surface.
e. Heat Exchanger: Aluminized **OR** Stainless, **as directed**, steel.
f. Burners: Cast iron or aluminized steel with stainless-steel inserts.
g. Gravity vent.
h. Power Venter: 120-V ac, with stainless-steel shaft.
i. Automatic Gas Control: Single **OR** 2-stage, **as directed**, 24-V ac valve.
j. Ignition: Standing pilot **OR** Electronically controlled spark with flame sensor, **as directed**.

11. Filters:
    a. Disposable Panel Filters: Factory-fabricated, viscous-coated, flat-panel-type, disposable air filters with glass-fiber media sprayed with nonflammable adhesive in cardboard **OR** galvanized-steel, **as directed**, frame.
    b. Washable Panel Filters: Removable, stainless-steel, baffle-type filters with spring-loaded fastening; with minimum 0.0781-inch- (1.984-mm-) thick, stainless-steel filter frame.
    c. Mounting Frames: Welded, galvanized steel with gaskets and fasteners and suitable for bolting together into built-up filter banks.
12. Controls:
    a. Built-in **OR** Field-Installed, **as directed**, Thermostat: Line voltage, factory installed and wired to the junction box on air curtain **OR** motor-control panel**, as directed.**
    b. Automatic Door Switch: Plunger type installed in door area to activate air curtain when door opens and to deactivate air curtain when door closes.
    c. Start-Stop, Push-Button Switch: Manually activates and deactivates air curtain.
    d. Three-Speed Switch: Manually activates, deactivates, and controls air-curtain fan speed.
    e. Time-Delay Relay: Factory installed and adjustable to allow air curtain to operate from 0.5 seconds to 10 hours.
    f. Motor-Control Panel: Complete with motor starter, 115-V ac transformer with primary and secondary fuses, terminal strip, and NEMA 250, Type 1 **OR** 12, **as directed**, enclosure.
13. Accessories:
    a. Mounting Brackets: Adjustable mounting brackets for drum-type roll-up doors.
    b. Discharge Extension Neck: For ceiling-recessed installation.

B. Source Quality Control
1. Source Quality Control: Test to 300 psig (2070 kPa) and to 200 psig (1380 kPa) underwater.
2. Testing: Test and inspect steam coils according to ASHRAE 33.
3. Steam coils will be considered defective if it does not pass tests and inspections.
4. Prepare test and inspection reports.

1.3 EXECUTION

A. Examination
1. Examine areas and conditions for compliance with requirements for installation tolerances and other conditions affecting performance.
2. Examine roughing-in for hot-water **OR** steam **OR** gas, **as directed**, piping systems to verify actual locations of piping connections before air-curtain installation.
3. Proceed with installation only after unsatisfactory conditions have been corrected.

B. Installation
1. Install air curtains with clearance for equipment service and maintenance.
2. Equipment Installation: Install air curtains with seismic-restraint devices. Comply with requirements for seismic-restraint devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".

3. Comply with requirements for hangers and supports specified in Division 23 Section "Hangers And Supports For Hvac Piping And Equipment".

C. Connections
1. Comply with requirements for piping specified in Division 26 Section "Grounding And Bonding For Electrical Systems" and Division 26 Section "Low-voltage Electrical Power Conductors And Cables".
2. Where installing piping adjacent to equipment, allow space for service and maintenance of equipment.
3. Breaching: Comply with applicable requirements in Division 23 Section "Breechings, Chimneys, And Stacks". Connect breaching to full size at flue outlet.

D. Field Quality Control
1. Perform tests ad inspections.
   a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
2. Tests and Inspections:
   a. After installing air curtains completely, perform visual and mechanical check of individual components.
   b. After electrical circuitry has been energized, start unit to confirm motor rotation and unit operation. Certify compliance with test parameters.
   c. Inspect for water leaks.
   d. Test gas train and verify that there are no gas leaks.
   e. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
3. Air-curtain unit will be considered defective if it does not pass tests and inspections.
4. Prepare test and inspection reports.

E. Adjusting
1. Adjust belt tension.
2. Adjust motor and fan speed to achieve specified airflow.
3. Adjust discharge louver and dampers to regulate airflow.
4. Adjust air-directional vanes.

END OF SECTION 23 34 33 00

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Task	Specification	Specification Description
23 35 13 00	01 22 16 00	No Specification Required

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SECTION 23 36 13 00 - DIFFUSERS, REGISTERS, AND GRILLES

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for diffusers, registers and grilles. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Round ceiling diffusers.
b. Rectangular and square ceiling diffusers.
c. Perforated diffusers.
d. Louver face diffusers.
e. Linear bar diffusers.
f. Linear slot diffusers.
g. Ceiling-integral continuous diffusers.
h. Light troffer diffusers.
i. Round induction diffusers.
j. Linear floor diffuser plenums.
k. Drum louvers.
l. Modular core supply grilles.
m. Continuous tubular diffusers.
n. Adjustable bar registers and grilles.
o. Security registers and grilles.
p. Fixed face registers and grilles.
q. Linear bar grilles.

C. Submittals
1. Product Data: For each type of product indicated, include the following:
a. Data Sheet: Indicate materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.
b. Diffuser, Register, and Grille Schedule: Indicate drawing designation, room location, quantity, model number, size, and accessories furnished.
2. Samples: For each exposed product and for each color and texture specified.

1.2 PRODUCTS

A. Ceiling Diffusers
1. Round Ceiling Diffuser:
a. Devices shall be specifically designed for variable-air-volume flows.
b. Material: Steel **OR** Aluminum, **as directed**.
c. Finish: Baked enamel, white **OR** Baked enamel, color selected **OR** Anodized aluminum, **as directed**.
d. Face Style: Four **OR** Three **OR** Two, **as directed**, cone.
e. Mounting: Duct connection.
f. Pattern: Fully adjustable **OR** Two-position horizontal, **as directed**.
g. Dampers: Radial opposed blade **OR** Butterfly **OR** Combination damper and grid, **as directed**.
h. Accessories:
1) Equalizing grid.

2) Plaster ring.
3) Safety chain.
4) Wire guard.
5) Sectorizing baffles.
6) Operating rod extension.

2. Rectangular and Square Ceiling Diffusers:
   a. Devices shall be specifically designed for variable-air-volume flows.
   b. Material: Steel **OR** Aluminum, **as directed**.
   c. Finish: Baked enamel, white **OR** Baked enamel, color selected **OR** Anodized aluminum, **as directed**.
   d. Face Size: 24 by 24 inches (600 by 600 mm) **OR** 20 by 20 inches (500 by 500 mm) **OR** 12 by 12 inches (300 by 300 mm), **as directed**.
   e. Face Style: Three cone **OR** Four cone **OR** Plaque, **as directed**.
   f. Mounting: Surface **OR** T-bar **OR** Snap in **OR** Spline **OR** Mounting panel, **as directed**.
   g. Pattern: Fixed **OR** Two position **OR** Adjustable, **as directed**.
   h. Dampers: Radial opposed blade **OR** Butterfly **OR** Combination damper and grid, **as directed**.
   i. Accessories:
      1) Equalizing grid.
      2) Plaster ring.
      3) Safety chain.
      4) Wire guard.
      5) Sectorizing baffles.
      6) Operating rod extension.
3. Perforated Diffuser:
   a. Devices shall be specifically designed for variable-air-volume flows.
   b. Material: Steel backpan and pattern controllers, with steel **OR** aluminum, **as directed**, face.
   c. Finish: Baked enamel, white **OR** Baked enamel, color selected **OR** Anodized aluminum, **as directed**.
   d. Face Size: 12 by 12 inches (300 by 300 mm) **OR** 24 by 12 inches (600 by 300 mm) **OR** 36 by 12 inches (900 by 300 mm) **OR** 48 by 12 inches (1200 by 300 mm) **OR** 16 by 16 inches (400 by 400 mm) **OR** 20 by 20 inches (500 by 500 mm) **OR** 24 by 24 inches (600 by 600 mm) **OR** 36 by 24 inches (900 by 600 mm) **OR** 48 by 24 inches (1200 by 600 mm), **as directed**.
   e. Duct Inlet: Round **OR** Square, **as directed**.
   f. Face Style: Flush **OR** Drop extended, **as directed**.
   g. Mounting: Surface **OR** T-bar **OR** Snap in **OR** Spline **OR** Mounting panel, **as directed**.
   h. Pattern Controller: Four louvered deflector patches **OR** Fixed with curved blades at inlet **OR** Adjustable with louvered pattern modules at inlet **OR** None, **as directed**.
   i. Dampers: Opposed blade **OR** Radial opposed blade **OR** Butterfly **OR** Combination damper and grid **OR** Combination volume and fire, **as directed**.
   j. Accessories:
      1) Equalizing grid.
      2) Plaster ring.
      3) Safety chain.
      4) Wire guard.
      5) Sectorizing baffles.
      6) Operating rod extension.
4. Louver Face Diffuser:
   a. Devices shall be specifically designed for variable-air-volume flows.
   b. Material: Steel **OR** Aluminum, **as directed**.
   c. Finish: Baked enamel, white **OR** Baked enamel, color selected **OR** Anodized aluminum, **as directed**.
   d. Face Size: as directed by the Owner.

e. Mounting: Surface **OR** Surface with beveled frame **OR** T-bar **OR** Snap in **OR** Spline **OR** Mounting panel, **as directed**.
f. Pattern: One-way **OR** Two-way **OR** Two-way corner **OR** Three-way **OR** Four-way **OR** Adjustable, **as directed**, core style.
g. Dampers: Radial opposed blade **OR** Butterfly **OR** Combination damper and grid, **as directed**.
h. Accessories:
1) Square to round neck adaptor.
2) Adjustable pattern vanes.
3) Throw reducing vanes.
4) Equalizing grid.
5) Plaster ring.
6) Safety chain.
7) Wire guard.
8) Sectorizing baffles.
9) Operating rod extension.

B. Ceiling Linear Slot Outlets
1. Linear Bar Diffuser:
a. Devices shall be specifically designed for variable-air-volume flows.
b. Material: Steel **OR** Aluminum **OR** Stainless steel, **as directed**.
c. Finish: Baked enamel, white **OR** Baked enamel, color selected, **as directed**.
d. Narrow Core Spacing Arrangement: 1/8-inch- (3-mm-) thick blades spaced 1/4 inch (6 mm) apart, zero **OR** 15, **as directed**,-degree deflection.
e. Wide Core Spacing Arrangement: 1/8-inch- (3-mm-) thick blades spaced 1/2 inch (13 mm) apart, zero **OR** 15, **as directed**,-degree deflection.
f. Wide Core Spacing Arrangement: 3/16-inch- (5-mm-) thick blades spaced 1/2 inch (13 mm) apart, zero **OR** 15 **OR** 30, **as directed**,-degree deflection.
g. Pencil-Proof Core Spacing Arrangement: 3/16-inch- (5-mm-) thick blades spaced 7/16 inch (11 mm) apart, zero **OR** 15 **OR** 30, **as directed**,-degree deflection.
h. One **OR** Two, **as directed**,-Way Deflection Vanes: Extruded construction fixed louvers with removable core.
i. Frame: 1-1/4 inches (32 mm) **OR** 1 inch (25 mm) **OR** 3/4 inch (19 mm) **OR** 1/2 inch (13 mm) **OR** 3/16 inch (5 mm), **as directed**, wide.
j. Mounting Frame: Filter.
k. Mounting: Countersunk screw **OR** Concealed bracket **OR** Spring clip, **as directed**.
l. Damper Type: Adjustable opposed-blade assembly **OR** Hinged single blade, **as directed**.
m. Accessories: Plaster frame **OR** Directional vanes **OR** Alignment pins **OR** Core clips **OR** Blank-off strips, **as directed**.
2. Linear Slot Diffuser:
a. Devices shall be specifically designed for variable-air-volume flows.
b. Material - Shell: Steel **OR** Aluminum, **as directed**, insulated **OR** noninsulated, **as directed**.
c. Material - Pattern Controller and Tees: Aluminum.
d. Finish - Face and Shell: Baked enamel, black.
e. Finish - Pattern Controller: Baked enamel, black.
f. Finish - Tees: Baked enamel, white **OR** Baked enamel, color selected, **as directed**.
g. Slot Width: 1/2 inch (13 mm) **OR** 3/4 inch (19 mm) **OR** 1 inch (25 mm) **OR** 1-1/2 inches (38 mm), **as directed**.
h. Number of Slots: One **OR** Two **OR** Three **OR** Four, **as directed**.
i. Length: 24 inches (600 mm) **OR** 30 inches (750 mm) **OR** 36 inches (900 mm) **OR** 48 inches (1200 mm) **OR** 60 inches (1500 mm), **as directed**.
j. Accessories: Plaster frame **OR** T-bar slot **OR** Center notch **OR** T-bar on inlet side **OR** T-bar on both sides **OR** T-bar clip on one side **OR** T-bar clips on both sides, **as directed**.
3. Ceiling-Integral Continuous Diffuser:

a. Slot Width: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm) **OR** 2-1/2 inches (63 mm) **OR** 3 inches (76 mm), **as directed**.
b. Section Length: 12 feet (3.7 m).
c. Straight and curved sections as required to accommodate layout.
d. Mitered tees and corners.
e. Pattern Controllers: 24 inches (600 mm) o.c.
f. Material: Aluminum, extruded, heavy wall.
g. Finishes:
1) Exterior: Standard white.
2) Interior: Standard black.
h. Throw: Standard **OR** High, **as directed**.
i. Mounting: Ceiling **OR** Sidewall, **as directed**.
j. Plenum: Noninsulated **OR** Insulated, **as directed**.
k. Other Features:
1) Painted interior.
2) Blank-offs.

4. Light Troffer Diffuser:
a. Devices shall be specifically designed for variable-air-volume flows.
b. Material: Steel with external insulation, **as directed**.
c. Finish: None **OR** Black enamel on visible surfaces, **as directed**.
d. Slot Width: 1/2 inch (13 mm) **OR** 3/4 inch (19 mm) **OR** 1 inch (25 mm) **OR** 1-1/2 inches (38 mm), **as directed**.
e. Number of Sides: One **OR** Two, **as directed**.
f. Length: 24 inches (600 mm) **OR** 36 inches (900 mm) **OR** 48 inches (1200 mm), **as directed**.
g. Pattern: Fixed **OR** Adjustable, **as directed**.
h. Inlet: Top **OR** Side, **as directed**.
i. Inlet Size: 5 inches (125 mm) **OR** 6 inches (150 mm) **OR** 8 inches (200 mm), **as directed**.

C. Underfloor Air Distribution Diffusers
1. Round Induction Diffusers:
a. Airflow Principle: Swirl-pattern induction.
b. Material: Plastic, high impact, and resistant to cart and foot traffic.
c. Color: Gray **OR** Black, **as directed**.
d. Components:
1) Diffuser core.
2) Flow regulator.
3) Dirt and liquid catch pan.
4) Spacer flange.
5) Gasketed, underfloor compression ring.

2. Linear Floor Diffuser Plenums:
a. Material: Steel.
b. Finish: White baked acrylic.
c. Deflection: Zero **OR** 15, **as directed**, degrees.
d. Components:
1) Aluminum diffuser core.
2) Diffuser frame.
3) Plenum, 0.034-inch (0.85-mm) steel.

D. High-Capacity Diffusers
1. Drum Louver:
a. Airflow Principle: Extended distance for high airflow rates.
b. Material: Aluminum, heavy gage extruded.
c. Finish: White baked acrylic.
d. Border: 1-1/4-inch (32-mm) width with countersunk screw holes.

e. Gasket between drum and border.
f. Body: Drum shaped; adjustable vertically.
g. Blades: Individually adjustable horizontally.
h. Mounting: Surface to duct **OR** wall, **as directed**.
i. Inlet Width: 6 inches (150 mm) **OR** 10 inches (250 mm) **OR** 12 inches (300 mm) **OR** 15 inches (380 mm), **as directed**.
j. Inlet Length: 12 inches (300 mm) **OR** 24 inches (600 mm) **OR** 36 inches (900 mm) **OR** 60 inches (1500 mm), **as directed**.
k. Accessories:
1) Opposed-blade steel damper.
2) Duct-mounting collars with countersunk screw holes.

2. Modular Core Supply Grilles:
a. Throw: Extended distance for airflow rates.
b. Material: Steel.
c. Grilles per Unit: One **OR** Two **OR** Three **OR** Four, **as directed**.
d. Finish: White baked acrylic.
e. Border: 1-1/2-inch (38-mm) width with countersunk screw holes.
f. Blades:
1) Airfoil, individually adjustable horizontally.
2) Double deflection.
3) Set in modules.
g. Modules: Removable; rotatable.
h. Mounting: Surface.
i. Accessory: Opposed-blade steel damper.

E. Flexible Diffusion Outlets
1. Continuous Tubular Diffuser:
a. Material: Flame-retardant, woven polyethylene fabric **OR** Flame-retardant, coated polyester and fiberglass fabric **OR** Flame-retardant, permeable polyester and fiberglass fabric **OR** Polyethylene, **as directed**.
b. Duct Connection: Round.
c. Duct Connection Size: as directed by the Owner.
d. Diffusion Hole Size: as directed by the Owner.
e. Diffusion Hole Frequency - Number per 100 Feet (30 m): <**Insert number**>.
f. Accessories:
1) Quick-connect joint.
2) Snap hooks.
3) Cleanout zipper.
4) Condensate drain.

F. Registers And Grilles
1. Adjustable Bar Register:
a. Material: Steel **OR** Aluminum **OR** Stainless steel, **as directed**.
b. Finish: Baked enamel, white **OR** Baked enamel, color selected, **as directed**.
c. Face Blade Arrangement: Horizontal **OR** Vertical, **as directed**, spaced 3 inches (76 mm) **OR** 1-1/2 inches (38 mm) **OR** 3/4 inch (19 mm) **OR** 1/2 inch (13 mm), **as directed**, apart.
d. Core Construction: Integral **OR** Removable, **as directed**.
e. Rear-Blade Arrangement: Horizontal **OR** Vertical, **as directed**, spaced 3/4 inch (19 mm) **OR** 1/2 inch (13 mm), **as directed**, apart.
f. Frame: 1-1/4 inches (32 mm) **OR** 1 inch (25 mm), **as directed**, wide.
g. Mounting Frame: Filter.
h. Mounting: Countersunk screw **OR** Concealed **OR** Lay in, **as directed**.
i. Damper Type: Adjustable opposed blade **OR** NRTL listed, opposed blade, spring closing, and with fusible link for 160 deg F (71 deg C), **as directed**.
j. Accessories:
1) Front **OR** Rear, **as directed**,-blade gang operator.

2) Filter.

2. Adjustable Bar Grille:
   a. Material: Steel **OR** Aluminum **OR** Stainless steel, **as directed**.
   b. Finish: Baked enamel, white **OR** Baked enamel, color selected, **as directed**.
   c. Face Blade Arrangement: Horizontal **OR** Vertical, **as directed**, spaced 3 inches (76 mm) **OR** 1-1/2 inches (38 mm) **OR** 3/4 inch (19 mm) **OR** 1/2 inch (13 mm), **as directed**, apart.
   d. Core Construction: Integral **OR** Removable, **as directed**.
   e. Rear-Blade Arrangement: Horizontal **OR** Vertical, **as directed**, spaced 3/4 inch (19 mm) **OR** 1/2 inch (13 mm), **as directed**, apart.
   f. Frame: 1-1/4 inches (32 mm) **OR** 1 inch (25 mm), **as directed**, wide.
   g. Mounting Frame: Filter.
   h. Mounting: Countersunk screw **OR** Concealed **OR** Lay in, **as directed**.
3. Security Register:
   a. Security Level: Maximum **OR** Medium **OR** Minimum, **as directed**, and suicide deterrent, **as directed**.
   b. Application: Ducted return **OR** Air transfer **OR** Barrier, **as directed**.
   c. Material: Steel **OR** Aluminum, **as directed**.
   d. Material Thickness: 0.19 inch (4.8 mm).
   e. Finish: Baked enamel, white **OR** Baked enamel, color selected, **as directed**.
   f. Face Arrangement:
      1) Shape: Square **OR** Rectangular **OR** Round, **as directed**.
      2) Design: Fixed bar **OR** Perforated **OR** Lattice, **as directed**.
      3) Frame: Yes **OR** No, **as directed**.
      4) Deflection: Zero **OR** 38, **as directed**, degrees.
      5) Core: None **OR** Louvered, **as directed**.
      6) 3/16-inch- (5-mm-) thick, front lattice plate with 2-by-2-inch- (50-by-50-mm-) square holes and 1-inch (25-mm) frets, 0.135-inch (3.43-mm) wire mesh, and 1/4-inch- (6-mm-) thick backer plate.
      7) 3/16-inch- (5-mm-) thick, perforated faceplate with 5/16-inch- (8-mm-) diameter holes spaced 7/16 inch (11 mm) o.c., staggered at 60 degrees.
      8) 1-1/2-inch (38-mm) bars and mandrel tubes and rods with zero **OR** 15, **as directed**,-degree deflection in 1-1/4-by-1-1/4-by-3/16-inch (32-by-32-by-5-mm) angle border.
      9) 1-3/8-inch (35-mm) bars and double mandrel tubes with zero **OR** 15, **as directed**,-degree deflection in 1-3/4-inch (45-mm) angle border.
   g. Damper Operation: None **OR** Face operated **OR** Rear operated, **as directed**.
   h. Damper Type: Adjustable opposed blade **OR** NRTL listed, opposed blade, spring closing, and with fusible link for 160 deg F (71 deg C), **as directed**.
   i. Wall Sleeve: 3/16 inch (5 mm) welded to face **OR** 1/8 inch (3 mm) welded to face **OR** Mechanically fastened to border, **as directed**.
   j. Mounting: 1-by-1-by-3/16-inch (25-by-25-by-5-mm) retaining angle frame **OR** 1-1/4-by-1-1/4-by-3/16-inch (32-by-32-by-5-mm) retaining angle frame **OR** 1-1/4-by-1-1/4-by-3/16-inch (32-by-32-by-5-mm) cast-in-place frame and tamperproof machine screws, **as directed**.
4. Security Grille:
   a. Security Level: Maximum **OR** Medium **OR** Minimum, **as directed**, and suicide deterrent, **as directed**.
   b. Application: Ducted return **OR** Air transfer **OR** Barrier, **as directed**.
   c. Material: Steel **OR** Aluminum, **as directed**.
   d. Material Thickness: 0.19 inch (4.8 mm).
   e. Finish: Baked enamel, white **OR** Baked enamel, color selected, **as directed**.
   f. Face Arrangement:
      1) Shape: Square **OR** Rectangular **OR** Round, **as directed**.
      2) Design: Fixed bar **OR** Perforated **OR** Lattice, **as directed**.
      3) Frame: Yes **OR** No, **as directed**.
      4) Deflection: Zero **OR** 38, **as directed**, degrees.
      5) Core: None **OR** Louvered, **as directed**.

6) 3/16-inch- (5-mm-) thick, front lattice plate with 2-by-2-inch- (50-by-50-mm-) square holes and 1-inch (25-mm) frets, 0.135-inch (3.43-mm) wire mesh, and 1/4-inch- (6-mm-) thick backer plate.
7) 3/16-inch- (5-mm-) thick perforated faceplate with 5/16-inch- (8-mm-) diameter holes spaced 7/16 inch (11 mm) o.c., staggered at 60 degrees.
8) 1-1/2-inch (38-mm) bars and mandrel tubes and rods with zero **OR** 15, **as directed**,-degree deflection in 1-1/4-by-1-1/4-by-3/16-inch (32-by-32-by-5-mm) angle border.
9) 1-3/8-inch (35-mm) bars and double mandrel tubes with zero **OR** 15, **as directed**,-degree deflection in 1-3/4-inch (45-mm) angle border.

g. Wall Sleeve: 3/16 inch (5 mm) welded to face **OR** 1/8 inch (3 mm) welded to face **OR** Mechanically fastened to border, **as directed**.
h. Mounting: 1-by-1-by-3/16-inch (25-by-25-by-5-mm) retaining angle frame **OR** 1-1/4-by-1-1/4-by-3/16-inch (32-by-32-by-5-mm) retaining angle frame **OR** 1-1/4-by-1-1/4-by-3/16-inch (32-by-32-by-5-mm) cast-in-place frame and tamperproof machine screws, **as directed**.

5. Fixed Face Register:
a. Material: Steel **OR** Aluminum, **as directed**.
b. Finish: Baked enamel, white **OR** Baked enamel, color selected, **as directed**.
c. Face Arrangement: 1/2-by-1/2-by-1/2-inch (13-by-13-by-13-mm) grid **OR** Perforated, **as directed**, core.
d. Core Construction: Integral **OR** Removable, **as directed**.
e. Frame: 1-1/4 inches (32 mm) **OR** 1 inch (25 mm), **as directed**, wide.
f. Mounting Frame: Filter.
g. Mounting: Countersunk screw **OR** Concealed **OR** Lay in, **as directed**.
h. Damper Type: Adjustable opposed blade **OR** NRTL listed, opposed blade, spring closing, and with fusible link for 160 deg F (71 deg C), **as directed**.
i. Accessory: Filter.

6. Fixed Face Grille:
a. Material: Steel **OR** Aluminum, **as directed**.
b. Finish: Baked enamel, white **OR** Baked enamel, color selected.
c. Face Arrangement: 1/2-by-1/2-by-1/2-inch (13-by-13-by-13-mm) grid **OR** Perforated, **as directed**, core.
d. Core Construction: Integral **OR** Removable, **as directed**.
e. Frame: 1-1/4 inches (32 mm) **OR** 1 inch (25 mm), **as directed**, wide.
f. Mounting Frame: Filter.
g. Mounting: Countersunk screw **OR** Concealed **OR** Lay in, **as directed**.
h. Accessory: Filter.

7. Linear Bar Grille:
a. Material: Steel **OR** Aluminum, **as directed**.
b. Finish: Baked enamel, white **OR** Baked enamel, color selected, **as directed**.
c. Face Arrangement: 1/2-by-1/2-by-1/2-inch (13-by-13-by-13-mm) grid **OR** Perforated, **as directed**, core.
d. Distribution plenum.
1) Internal insulation.
2) Inlet damper.
e. Frame: 1-1/4 inches (32 mm) **OR** 1 inch (25 mm), **as directed**, wide.
f. Mounting Frame: Filter.
g. Mounting: Countersunk screw **OR** Concealed **OR** Lay in, **as directed**.
h. Damper Type: Adjustable opposed blade **OR** NRTL listed, opposed blade, spring closing, and with fusible link for 160 deg F (71 deg C), **as directed**.

G. Source Quality Control
1. Verification of Performance: Rate diffusers, registers, and grilles according to ASHRAE 70, "Method of Testing for Rating the Performance of Air Outlets and Inlets."

1.3 EXECUTION

A. Installation
   1. Install diffusers, registers, and grilles level and plumb.
   2. Ceiling-Mounted Outlets and Inlets: Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations where indicated, as much as practical. For units installed in lay-in ceiling panels, locate units in the center of panel. Where architectural features or other items conflict with installation, notify the Owner for a determination of final location.
   3. Install diffusers, registers, and grilles with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

B. Adjusting
   1. After installation, adjust diffusers, registers, and grilles to air patterns indicated, or as directed, before starting air balancing.

END OF SECTION 23 36 13 00

SECTION 23 36 16 00 - AIR TERMINAL UNITS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for air terminal units. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Bypass, single-duct air terminal units.
b. Dual-duct air terminal units.
c. Fan-powered air terminal units.
d. Induction air terminal units.
e. Shutoff, single-duct air terminal units.
f. Diffuser-type air terminal units.

C. Performance Requirements
1. Structural Performance: Hangers and supports and seismic restraints, **as directed**, shall withstand the effects of gravity and seismic, **as directed**, loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and ASCE/SEI 7 **OR** SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems", **as directed**.
a. Seismic Hazard Level A: Seismic force to weight ratio, 0.48.
b. Seismic Hazard Level B: Seismic force to weight ratio, 0.30.
c. Seismic Hazard Level C: Seismic force to weight ratio, 0.15.

D. Submittals
1. Product Data: For each type of product indicated.
2. LEED Submittal:
a. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1-2004, Section 5 - "Systems and Equipment."
3. Shop Drawings: For air terminal units. Include plans, elevations, sections, details, and attachments to other work.
a. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
b. Wiring Diagrams: For power, signal, and control wiring.
c. Hangers and supports, including methods for duct and building attachment, seismic restraints, and vibration isolation.
4. Delegated-Design Submittal:
a. Materials, fabrication, assembly, and spacing of hangers and supports.
b. Design Calculations: Calculations, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation, **as directed**, for selecting hangers and supports and seismic restraints, **as directed**.
5. Field quality-control reports.
6. Operation and maintenance data.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1-2004, Section 5 - "Systems and Equipment" and Section 7 - "Construction and System Start-Up."

1.2 PRODUCTS

A. Bypass, Single-Duct Air Terminal Units
1. Configuration: Diverting-damper assembly inside unit casing with control components inside a protective metal shroud.
2. Casing: 0.034-inch (0.85-mm) steel **OR** 0.032-inch (0.8-mm) aluminum, **as directed**, single **OR** double, **as directed**, wall.
   a. Casing Lining: Adhesive attached, 1/2-inch- (13-mm-) **OR** 3/4-inch- (19-mm-) **OR** 1-inch- (25-mm-), **as directed**, thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
      1) Cover liner with nonporous foil.
      OR
      Cover liner with nonporous foil and perforated metal.

      OR
      Casing Lining: Adhesive attached, 1/2-inch- (13-mm-) **OR** 3/4-inch- (19-mm-) **OR** 1-inch- (25-mm-), **as directed**, thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
   b. Air Inlet: Round stub connection for duct attachment.
   c. Air Outlet: S-slip and drive connections.
   d. Access: Removable panels for access to diverting damper and other parts requiring service, adjustment, or maintenance; with airtight gasket.
   e. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.
3. Diverter Assembly: Galvanized-steel gate, with polyethylene linear bearings **OR** Aluminum blade, with nylon-fitted pivot points, **as directed**.
4. Multioutlet Attenuator Section: With two **OR** three **OR** four, **as directed**, 6-inch- (150-mm-) **OR** 8-inch- (200-mm-) **OR** 10-inch- (250-mm-), **as directed**, diameter collars, each with locking butterfly balancing damper.
5. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), and rated for a minimum working pressure of 200 psig (1380 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain valve.
   OR
   Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware.
   a. Access door interlocked disconnect switch.
   b. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable.)
   c. Nickel chrome 80/20 heating elements.
   d. Airflow switch for proof of airflow.
   e. Fuses in terminal box for overcurrent protection (for coils more than 48 A).
   f. Mercury contactors.
   g. Pneumatic-electric switches and relays.
   h. Magnetic contactor for each step of control (for three-phase coils).
6. Electric Controls: Damper actuator and thermostat.
   a. Damper Actuator: 24 V, powered closed, powered open with microswitch to energize heating control circuit, **as directed**.
   b. Thermostat: Wall-mounted electric type with temperature display in Fahrenheit and Celsius, and space temperature set point.

c. Changeover Thermostat: Duct-mounted, field-adjustable, electric type reverses action of zone thermostat when air temperature reaches 70 deg F (21 deg C).

OR

Electronic Controls: Bidirectional damper operator and microprocessor-based thermostat. Control devices shall be compatible with temperature controls specified in Division 23 Section "Instrumentation And Control For Hvac" and shall have the following features:

d. Damper Actuator: 24 V, powered closed, powered open.

e. Thermostat: Wall-mounted electronic type with the following features:

1) Temperature set-point display in Fahrenheit and Celsius.

2) Auxiliary switch to energize heating control circuit.

3) Changeover thermistor to reverse action.

B. Dual-Duct Air Terminal Units

1. Configuration: Two volume dampers inside unit casing with mixing attenuator section and control components inside a protective metal shroud with a third primary air inlet with volume damper, **as directed**.

2. Casing: 0.034-inch (0.85-mm) steel **OR** 0.032-inch (0.8-mm) aluminum, **as directed**, single **OR** double, **as directed**, wall.

a. Casing Lining: Adhesive attached, 1/2-inch- (13-mm-) **OR** 3/4-inch- (19-mm-) **OR** 1-inch- (25-mm-), **as directed**, thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.

1) Cover liner with nonporous foil.

OR

Cover liner with nonporous foil and perforated metal.

OR

Casing Lining: Adhesive attached, 1/2-inch- (13-mm-) **OR** 3/4-inch- (19-mm-) **OR** 1-inch- (25-mm-), **as directed**, thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.

b. Air Inlets: Round stub connections or S-slip and drive connections for duct attachment.

c. Air Outlet: S-slip and drive connections.

d. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket.

e. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.

3. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.

a. Maximum Damper Leakage: ARI 880 rated, 3 percent of nominal airflow at 3-inch wg (750-Pa) **OR** 6-inch wg (1500-Pa), **as directed**, inlet static pressure.

4. Velocity Sensors: Multipoint array with velocity sensors in cold- and hot-deck air inlets and air outlets.

5. Attenuator Section: 0.034-inch (0.85-mm) steel **OR** 0.032-inch (0.8-mm) aluminum, **as directed**, sheet.

a. Lining: Adhesive attached, 1/2-inch- (13-mm-) **OR** 3/4-inch- (19-mm-) **OR** 1-inch- (25-mm-), **as directed**, thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.

1) Cover liner with nonporous foil.

OR

Cover liner with nonporous foil and perforated metal.

OR

Lining: Adhesive attached, 3/4-inch- (19-mm-) thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index

of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.

b. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.

6. Multioutlet Attenuator Section: With two **OR** three **OR** four, **as directed**, 6-inch- (150-mm-) **OR** 8-inch- (200-mm-) **OR** 10-inch- (250-mm-) **OR** 12-inch- (300-mm-), **as directed**, diameter collars, each with locking butterfly balancing damper.

7. Pneumatic Controls: Damper operator, velocity controllers, and thermostat. Control devices shall be compatible with temperature controls specified in Division 23 Section "Instrumentation And Control For Hvac" and shall have the following features:

a. Pneumatic Damper Operator: 0- to 13-psig (0- to 90-kPa) spring range.

b. Velocity Controllers: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor. Locate velocity sensors in cold- and hot-deck **OR** cold-, hot-, and ventilation- deck **OR** cold-deck, **as directed**, air inlets and supply air outlets.

c. Thermostat: Wall-mounted pneumatic type with appropriate mounting hardware.

OR

Electronic Controls: Bidirectional damper operator and microprocessor-based thermostat with integral airflow transducer and room sensor. Control devices shall be compatible with temperature controls specified in Division 23 Section "Instrumentation And Control For Hvac" and shall have the following features:

a. Damper Actuator: 24 V, powered closed, spring return open **OR** powered open, **as directed**.

b. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor. Locate velocity sensors in cold-deck air inlets and air outlets.

c. Thermostat: Wall-mounted electronic type with temperature set-point display in Fahrenheit and Celsius, **as directed**.

OR

Direct Digital Controls: Single-package unitary controller and actuator specified in Division 23 Section "Instrumentation And Control For Hvac"

OR

Direct Digital Controls: Bidirectional damper operators and microprocessor-based controller and room sensor. Control devices shall be compatible with controls specified in Division 23 Section "Instrumentation And Control For Hvac" and shall have the following features:

d. Damper Actuators: 24 V, powered closed, spring return open **OR** powered open, **as directed**.

e. Terminal Unit Controller: Pressure-independent, variable-air **OR** constant, **as directed**,-volume controller with electronic airflow transducers factory calibrated to minimum and maximum air volumes, and having the following features:

1) Occupied and unoccupied operating mode.

2) Remote reset of airflow or temperature set points.

3) Adjusting and monitoring with portable terminal.

4) Communication with temperature-control system specified in Division 23 Section "Instrumentation And Control For Hvac".

f. Room Sensor: Wall mounted with temperature set-point adjustment and access for connection of portable operator terminal.

8. Control Sequence:

a. Modulate cold-air damper to maintain room temperature.

b. Modulate warm-air damper to maintain constant airflow.

C. Parallel Fan-Powered Air Terminal Units

1. Configuration: Volume-damper assembly and fan in parallel arrangement inside unit casing with control components inside a protective metal shroud.
2. Casing: 0.034-inch (0.85-mm) steel **OR** 0.032-inch (0.8-mm) aluminum, **as directed**, single **OR** double, **as directed**, wall.
   a. Casing Lining: Adhesive attached, 1/2-inch- (13-mm-) **OR** 3/4-inch- (19-mm-) **OR** 1-inch- (25-mm-), **as directed**, thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
      1) Cover liner with nonporous foil.
         OR
         Cover liner with nonporous foil and perforated metal.

      OR

      Casing Lining: Adhesive attached, 1/2-inch- (13-mm-) **OR** 3/4-inch- (19-mm-) **OR** 1-inch- (25-mm-), **as directed**, thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
   b. Air Inlets: Round stub connections or S-slip and drive connections for duct attachment.
   c. Air Outlet: S-slip and drive connections.
   d. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket and quarter-turn latches.
   e. Fan: Forward-curved centrifugal, located at plenum air inlet.
   f. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.
3. Volume Damper: Galvanized steel with flow-sensing ring and peripheral gasket and self-lubricating bearings.
   a. Maximum Damper Leakage: ARI 880 rated, 2 **OR** 3, **as directed**, percent of nominal airflow at 3-inch wg (750-Pa) **OR** 6-inch wg (1500-Pa), **as directed**, inlet static pressure.
   b. Damper Position: Normally open **OR** closed, **as directed**.
4. Velocity Sensors: Multipoint array with velocity sensors in cold- and hot-deck air inlets and air outlets.
5. Motor:
   a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   b. Type: Permanent-split capacitor with SCR for speed adjustment **OR** Electronically commutated motor, **as directed**.
   c. Fan-Motor Assembly Isolation: Rubber isolators.
   d. Enclosure: Open dripproof **OR** Totally enclosed, fan cooled **OR** Totally enclosed, air over **OR** Open, externally ventilated **OR** Totally enclosed, nonventilated **OR** Severe duty **OR** Explosion proof **OR** Dust-ignition-proof machine, **as directed**.
   e. Enclosure Materials: Cast iron **OR** Cast aluminum **OR** Rolled steel, **as directed**.
6. Filters: Minimum arrestance according to ASHRAE 52.1 and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.
   a. Material: Polyurethane foam having 70 percent arrestance and 3 MERV.
      OR
      Material: Glass fiber treated with adhesive; having 80 percent arrestance and 5 MERV.
      OR
      Material: Pleated cotton-polyester media having 90 percent arrestance and 7 MERV.
   b. Thickness: 2 inches (50 mm) **OR** 1 inch (25 mm), **as directed**.
7. Attenuator Section: 0.034-inch (0.85-mm) steel **OR** 0.032-inch (0.8-mm) aluminum, **as directed**, sheet.
   a. Lining: Adhesive attached, 1/2-inch- (13-mm-) **OR** 3/4-inch- (19-mm-) **OR** 1-inch- (25-mm-), **as directed**, thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and

having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.

1) Cover liner with nonporous foil.

OR

Cover liner with nonporous foil and perforated metal.

b. Lining: Adhesive attached, 3/4-inch- (19-mm-) thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.

c. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.

8. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), and rated for a minimum working pressure of 200 psig (1380 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain valve.

a. Location: Plenum air inlet.

OR

Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware.

a. Location: Plenum air inlet.

b. Stage(s): 1 **OR** 2 **OR** 3, **as directed**.

c. Access door interlocked disconnect switch.

d. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable.)

e. Nickel chrome 80/20 heating elements.

f. Airflow switch for proof of airflow.

g. Fan interlock contacts.

h. Fuses in terminal box for overcurrent protection (for coils more than 48 A).

i. Mercury contactors.

j. Pneumatic-electric switches and relays.

k. Magnetic contactor for each step of control (for three-phase coils).

9. Factory-Mounted and -Wired Controls: Electrical components mounted in control box with removable cover. Incorporate single-point electrical connection to power source.

a. Control Transformer: Factory mounted for control voltage on electric and electronic control units with terminal strip in control box for field wiring of thermostat and power source.

b. Wiring Terminations: Fan and controls to terminal strip. Terminal lugs to match quantities, sizes, and materials of branch-circuit conductors. Enclose terminal lugs in terminal box that is sized according to NFPA 70.

c. Disconnect Switch: Factory-mounted, fuse type.

10. Control Panel Enclosure: NEMA 250, Type 1, with access panel sealed from airflow and mounted on side of unit.

11. Electric Controls: 24-V damper actuator with wall-mounted electric thermostat and appropriate mounting hardware.

OR

Pneumatic Controls: Damper operator, velocity controller, and thermostat. Control devices shall be compatible with temperature controls specified in Division 23 Section "Instrumentation And Control For Hvac" and shall have the following features:

a. Pneumatic Damper Operator: 0- to 13-psig (0- to 90-kPa) spring range.

b. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while pressure independent up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor at air inlet.

c. Thermostat: Wall-mounted pneumatic type with appropriate mounting hardware.

OR

Electronic Controls: Bidirectional damper operator and microprocessor-based controller with integral airflow transducer and room sensor. Control devices shall be compatible with temperature controls specified in Division 23 Section "Instrumentation And Control For Hvac" and shall have the following features:

a. Occupied and unoccupied operating mode.
b. Remote reset of airflow or temperature set points.
c. Adjusting and monitoring with portable terminal.
d. Communication with temperature-control system specified in Division 23 Section "Instrumentation And Control For Hvac".

12. Control Sequence:
    a. Occupied (Primary Airflow On):
        1) Operate as throttling control for cooling.
        2) As cooling requirement decreases, control valve throttles toward minimum airflow.
        3) As heating requirement increases, fan energizes to draw in warm plenum air and electric heat is energized in steps, **as directed**.
    b. Unoccupied (Primary Airflow Off):
        1) When pressure at primary inlet is zero or less, fan is de-energized.
        2) As heating requirement increases, fan energizes to draw in warm plenum air and electric heat is energized in steps, **as directed**.

D. Series Fan-Powered Air Terminal Units

1. Configuration: Volume-damper assembly and fan in series arrangement inside unit casing with control components inside a protective metal shroud for installation above a ceiling and within a raised access floor, **as directed**.
2. Casing: 0.034-inch (0.85-mm) steel **OR** 0.032-inch (0.8-mm) aluminum, **as directed**, single **OR** double, **as directed**, wall.
    a. Casing Lining: Adhesive attached, 1/2-inch- (13-mm-) **OR** 3/4-inch- (19-mm-) **OR** 1-inch- (25-mm-), **as directed**, thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
        1) Cover liner with nonporous foil.
        OR
        Cover liner with nonporous foil and perforated metal.

        OR
        Casing Lining: Adhesive attached, 1/2-inch- (13-mm-) **OR** 3/4-inch- (19-mm-) **OR** 1-inch- (25-mm-), **as directed**, thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
    b. Air Inlets: Round stub connections or S-slip and drive connections for duct attachment.
    c. Air Outlet: S-slip and drive connections.
    d. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket and quarter-turn latches.
    e. Fan: Forward-curved centrifugal.
    f. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.
3. Volume Damper: Galvanized steel with flow-sensing ring and peripheral gasket and self-lubricating bearings.
    a. Maximum Damper Leakage: ARI 880 rated, 2 **OR** 3, **as directed**, percent of nominal airflow at 3-inch wg (750-Pa) **OR** 6-inch wg (1500-Pa), **as directed**, inlet static pressure.
    b. Damper Position: Normally open **OR** closed, **as directed**.
4. Velocity Sensors: Multipoint array with velocity sensors in cold- and hot-deck air inlets and air outlets.
5. Motor:

a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
b. Type: Permanent-split capacitor with SCR for speed adjustment **OR** Electronically commutated motor, **as directed**.
c. Fan-Motor Assembly Isolation: Rubber isolators.
d. Enclosure: Open dripproof **OR** Totally enclosed, fan cooled **OR** Totally enclosed, air over **OR** Open, externally ventilated **OR** Totally enclosed, nonventilated **OR** Severe duty **OR** Explosion proof **OR** Dust-ignition-proof machine, **as directed**.
e. Enclosure Materials: Cast iron **OR** Cast aluminum **OR** Rolled steel, **as directed**.

6. Filters: Minimum arrestance according to ASHRAE 52.1 and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.
   a. Material: Polyurethane foam having 70 percent arrestance and 3 MERV.
      OR
      Material: Glass fiber treated with adhesive; having 80 percent arrestance and 5 MERV.
      OR
      Material: Pleated cotton-polyester media having 90 percent arrestance and 7 MERV.
   b. Thickness: 2 inches (50 mm) **OR** 1 inch (25 mm), **as directed**.
7. Attenuator Section: 0.034-inch (0.85-mm) steel **OR** 0.032-inch (0.8-mm) aluminum, **as directed**, sheet.
   a. Lining: Adhesive attached, 1/2-inch- (13-mm-) **OR** 3/4-inch- (19-mm-) **OR** 1-inch- (25-mm-), **as directed**, thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
      1) Cover liner with nonporous foil.
         OR
         Cover liner with nonporous foil and perforated metal.

      OR
      Lining: Adhesive attached, 3/4-inch- (19-mm-) thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
   b. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.
8. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), and rated for a minimum working pressure of 200 psig (1380 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain valve.
   OR
   Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware.
   a. Stage(s): 1 **OR** 2 **OR** 3, **as directed**.
   b. Access door interlocked disconnect switch.
   c. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable.)
   d. Nickel chrome 80/20 heating elements.
   e. Airflow switch for proof of airflow.
   f. Fan interlock contacts.
   g. Fuses in terminal box for overcurrent protection (for coils more than 48 A).
   h. Mercury contactors.
   i. Pneumatic-electric switches and relays.
   j. Magnetic contactor for each step of control (for three-phase coils).
9. Factory-Mounted and -Wired Controls: Electrical components mounted in control box with removable cover. Incorporate single-point electrical connection to power source.

a. Control Transformer: Factory mounted for control voltage on electric and electronic control units with terminal strip in control box for field wiring of thermostat and power source.
b. Wiring Terminations: Fan and controls to terminal strip. Terminal lugs to match quantities, sizes, and materials of branch-circuit conductors. Enclose terminal lugs in terminal box that is sized according to NFPA 70.
c. Disconnect Switch: Factory-mounted, fuse type.

10. Control Panel Enclosure: NEMA 250, Type 1, with access panel sealed from airflow and mounted on side of unit.
11. Electric Controls: 24-V damper actuator with wall-mounted electric thermostat and appropriate mounting hardware.

OR

Pneumatic Controls: Damper operator, velocity controller, and thermostat. Control devices shall be compatible with temperature controls specified in Division 23 Section "Instrumentation And Control For Hvac" and shall have the following features:
a. Pneumatic Damper Operator: 0- to 13-psig (0- to 90-kPa) spring range.
b. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while pressure independent up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor at air inlet.
c. Thermostat: Wall-mounted pneumatic type with appropriate mounting hardware.

OR

Electronic Controls: Bidirectional damper operator and microprocessor-based controller with integral airflow transducer and room sensor. Control devices shall be compatible with temperature controls specified in Division 23 Section "Instrumentation And Control For Hvac" and shall have the following features:
a. Occupied and unoccupied operating mode.
b. Remote reset of airflow or temperature set points.
c. Adjusting and monitoring with portable terminal.
d. Communication with temperature-control system specified in Division 23 Section "Instrumentation And Control For Hvac".

12. Control Sequence:
a. Occupied (Primary Airflow On):
1) When pressure at inlet is at least 1.2-inch wg (300 Pa).
2) As cooling requirement decreases, control valve throttles toward minimum airflow.
b. Unoccupied (Primary Airflow Off):
1) When pressure at primary inlet is zero or less, fan is de-energized.

E. Induction Air Terminal Units
1. Configuration: Volume-damper assembly inside unit casing with mechanical induction damper mounted on casing and control components inside a protective metal shroud.
2. Casing: 0.034-inch (0.85-mm) steel **OR** 0.032-inch (0.8-mm) aluminum, **as directed**, single **OR** double, **as directed**, wall.
a. Casing Lining: Adhesive attached, 1/2-inch- (13-mm-) **OR** 3/4-inch- (19-mm-) **OR** 1-inch- (25-mm-), **as directed**, thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
1) Cover liner with nonporous foil.
OR
Cover liner with nonporous foil and perforated metal.

OR

Casing Lining: Adhesive attached, 1/2-inch- (13-mm-) **OR** 3/4-inch- (19-mm-) **OR** 1-inch- (25-mm-), **as directed**, thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.

b. Air Inlet: Round stub connection for duct attachment.
c. Air Outlet: S-slip and drive connections, size matching inlet size, **as directed**.
d. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket.
e. Fan: Forward-curved centrifugal.
f. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.

3. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.
   a. Maximum Damper Leakage: ARI 880 rated, 2 **OR** 3, **as directed**, percent of nominal airflow at 3-inch wg (750-Pa) **OR** 6-inch wg (1500-Pa), **as directed**, inlet static pressure.
   b. Damper Position: Normally open **OR** closed, **as directed**.
4. Induction Damper: Galvanized-steel, multiblade assembly with self-lubricating bearings.
5. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), and rated for a minimum working pressure of 200 psig (1380 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain valve.

   OR

   Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware.
   a. Access door interlocked disconnect switch.
   b. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable.)
   c. Nickel chrome 80/20 heating elements.
   d. Airflow switch for proof of airflow.
   e. Fan interlock contacts.
   f. Fuses in terminal box for overcurrent protection (for coils more than 48 A).
   g. Mercury contactors.
   h. Pneumatic-electric switches and relays.
   i. Magnetic contactor for each step of control (for three-phase coils).
6. Pneumatic Controls: Damper operator, velocity controller, and induction damper operator. Control devices shall be compatible with temperature controls specified in Division 23 Section "Instrumentation And Control For Hvac" and shall have the following features:
   a. Damper Operator: Pneumatic, 0- to 13-psig (0- to 90-kPa) spring range.
   b. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor at air inlet.
   c. Induction Damper Operator: Pneumatic, spring range matching reset range of controller.
   d. Thermostat: Wall-mounted pneumatic type with appropriate mounting hardware.

   OR

   Electronic Controls: Pneumatic damper operators, electronic controller integral airflow transducer, and electronic thermostat. Control devices shall be compatible with temperature controls specified in Division 23 Section "Instrumentation And Control For Hvac" and shall have the following features:
   a. Damper Actuator: Pneumatic, 0- to 13-psig (0- to 90-kPa) spring range.
   b. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor at air inlet.
   c. Induction Damper Operator: Pneumatic, spring range matching reset range of controller.
   d. Thermostat: Wall-mounted electronic type with the following features:
      1) Proportional, plus integral control of room temperature.
      2) Time-proportional reheat-coil control.
      3) Temperature set-point display in Fahrenheit and Celsius.

F. Shutoff, Single-Duct Air Terminal Units
1. Configuration: Volume-damper assembly inside unit casing with control components inside a protective metal shroud.
2. Casing: 0.034-inch (0.85-mm) steel **OR** 0.032-inch (0.8-mm) aluminum, **as directed**, single **OR** double, **as directed**, wall.
   a. Casing Lining: Adhesive attached, 1/2-inch- (13-mm-) **OR** 3/4-inch- (19-mm-) **OR** 1-inch- (25-mm-), **as directed**, thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
      1) Cover liner with nonporous foil.
         OR
         Cover liner with nonporous foil and perforated metal.

      OR
      Casing Lining: Adhesive attached, 1/2-inch- (13-mm-) **OR** 3/4-inch- (19-mm-) **OR** 1-inch- (25-mm-), **as directed**, thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
   b. Air Inlet: Round stub connection or S-slip and drive connections for duct attachment.
   c. Air Outlet: S-slip and drive connections, size matching inlet size, **as directed**.
   d. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with airtight gasket.
   e. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.
3. Regulator Assembly: System-air-powered bellows section incorporating polypropylene bellows for volume regulation and thermostatic control. Bellows shall operate at temperatures from 0 to 140 deg F (minus 18 to plus 60 deg C), shall be impervious to moisture and fungus, shall be suitable for 10-inch wg (2500-Pa) static pressure, and shall be factory tested for leaks.
4. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.
   a. Maximum Damper Leakage: ARI 880 rated, 2 **OR** 3, **as directed**, percent of nominal airflow at 3-inch wg (750-Pa) **OR** 6-inch wg (1500-Pa), **as directed**, inlet static pressure.
   b. Damper Position: Normally open **OR** closed, **as directed**.
5. Attenuator Section: 0.034-inch (0.85-mm) steel **OR** 0.032-inch (0.8-mm) aluminum, **as directed**, sheet.
   a. Lining: Adhesive attached, 1/2-inch- (13-mm-) **OR** 3/4-inch- (19-mm-) **OR** 1-inch- (25-mm-), **as directed**, thick, coated, fibrous-glass duct liner complying with ASTM C 1071, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
      1) Cover liner with nonporous foil.
         OR
         Cover liner with nonporous foil and perforated metal.

      OR
      Lining: Adhesive attached, 3/4-inch- (19-mm-) thick, polyurethane foam insulation complying with UL 181 erosion requirements, and having a maximum flame-spread index of 25 and a maximum smoke-developed index of 50, for both insulation and adhesive, when tested according to ASTM E 84.
   b. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.
6. Multioutlet Attenuator Section: With two **OR** three **OR** four, **as directed**, 6-inch- (150-mm-) **OR** 8-inch- (200-mm-) **OR** 10-inch- (250-mm-), **as directed**, diameter collars, each with locking butterfly balancing damper.
7. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), and rated for a minimum working pressure of 200 psig (1380 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain valve.
   OR

Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware.

a. Access door interlocked disconnect switch.
b. Downstream air temperature sensor with local connection to override discharge-air temperature to not exceed a maximum temperature set point (adjustable.)
c. Nickel chrome 80/20 heating elements.
d. Airflow switch for proof of airflow.
e. Fan interlock contacts.
f. Fuses in terminal box for overcurrent protection (for coils more than 48 A).
g. Mercury contactors.
h. Pneumatic-electric switches and relays.
i. Magnetic contactor for each step of control (for three-phase coils).

8. Electric Controls: Damper actuator and thermostat.
   a. Damper Actuator: 24 V, powered closed, spring return open **OR** powered open, **as directed**.
   b. Thermostat: Wall-mounted electronic type with clock display, temperature display in Fahrenheit and Celsius, and space temperature set point.

OR

Pneumatic Controls: Damper operator and velocity controller. Control devices shall be compatible with temperature controls specified in Division 23 Section "Instrumentation And Control For Hvac" and shall have the following features:

a. Pneumatic Damper Operator: 0- to 13-psig (0- to 90-kPa) spring range.
b. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor at air inlet.
c. Thermostat: Wall-mounted pneumatic type with appropriate mounting hardware.

OR

Electronic Controls: Bidirectional damper operator and microprocessor-based thermostat with integral airflow transducer and room sensor. Control devices shall be compatible with temperature controls specified in Division 23 Section "Instrumentation And Control For Hvac" and shall have the following features:

a. Damper Actuator: 24 V, powered closed, spring return open **OR** powered open, **as directed**.
b. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor at air inlet.
c. Thermostat: Wall-mounted electronic type with temperature set-point display in Fahrenheit and Celsius.

OR

Direct Digital Controls: Single-package unitary controller and actuator specified in Division 23 Section "Instrumentation And Control For Hvac".

OR

Direct Digital Controls: Bidirectional damper operators and microprocessor-based controller and room sensor. Control devices shall be compatible with temperature controls specified in Division 23 Section "Instrumentation And Control For Hvac" and shall have the following features:

a. Damper Actuator: 24 V, powered closed, spring return open **OR** powered open, **as directed**.
b. Terminal Unit Controller: Pressure-independent, variable-air-volume controller with electronic airflow transducer with multipoint velocity sensor at air inlet, factory calibrated to minimum and maximum air volumes, and having the following features:
   1) Occupied and unoccupied operating mode.

2) Remote reset of airflow or temperature set points.
3) Adjusting and monitoring with portable terminal.
4) Communication with temperature-control system specified in Division 23 Section "Instrumentation And Control For Hvac".

c. Room Sensor: Wall mounted with temperature set-point adjustment and access for connection of portable operator terminal.

9. Control Sequence:
   a. Suitable for operation with duct pressures between 0.25- and 3.0-inch wg (60- and 750-Pa) inlet static pressure.
   b. System-powered, wall-mounted thermostat.

G. Diffuser-Type Air Terminal Units
1. Configuration: Volume-damper, diffuser, controller assembly and electric heater, **as directed**, and wall-mounted thermostat with master-slave capability, **as directed**.
2. Volume Damper: Galvanized steel with peripheral gasket and self-lubricating bearings.
   a. Damper Position: Normally open **OR** closed, **as directed**.
3. Diffuser: Galvanized steel with white baked-enamel finish.
4. Electronic Controls: Bidirectional damper operator and microprocessor-based thermostat with integral airflow transducer and room sensor. Control devices shall be compatible with temperature controls specified in Division 23 Section "Instrumentation And Control For Hvac" and shall have the following features:
   a. Damper Actuator: 24 V, powered closed, spring return open **OR** powered open, **as directed**.
   b. Velocity Controller: Factory calibrated and field adjustable to minimum and maximum air volumes; shall maintain constant airflow dictated by thermostat within 5 percent of set point while compensating for inlet static-pressure variations up to 4-inch wg (1000 Pa); and shall have a multipoint velocity sensor at air inlet.
   c. Thermostat: Wall-mounted electronic type with the following features:
      1) Proportional, plus integral control of room temperature.
      2) Temperature set-point display in Fahrenheit and Celsius.
5. Integral thermally powered actuators control diffusion dampers based on duct and room temperature.

H. Hangers And Supports
1. Hanger Rods for Noncorrosive Environments: Cadmium-plated steel rods and nuts.
2. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.
3. Steel Cables: Galvanized steel complying with ASTM A 603 **OR** Stainless steel complying with ASTM A 492, **as directed**.
4. Steel Cable End Connections: Cadmium-plated steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.
5. Air Terminal Unit Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.
6. Trapeze and Riser Supports: Steel shapes and plates for units with steel casings; aluminum for units with aluminum casings.

I. Seismic-Restraint Devices
1. General Requirements for Restraint Components: Rated strengths, features, and applications shall be as defined in reports by an evaluation service member of the ICC Evaluation Service **OR** the Office of Statewide Health Planning and Development for the State of California **OR** an agency acceptable to authorities having jurisdiction, **as directed**.
   a. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least four times the maximum seismic forces to which they will be subjected.
2. Channel Support System: Shop- or field-fabricated support assembly made of slotted steel channels rated in tension, compression, and torsion forces and with accessories for attachment to

braced component at one end and to building structure at the other end. Include matching components and corrosion-resistant coating.

3. Restraint Cables: ASTM A 603, galvanized **OR** ASTM A 492, stainless, **as directed**,-steel cables with end connections made of cadmium-plated steel assemblies with brackets, swivel, and bolts designed for restraining cable service; with an automatic-locking and clamping device or double-cable clips.
4. Hanger Rod Stiffener: Steel tube or steel slotted-support-system sleeve with internally bolted connections **OR** Reinforcing steel angle clamped, **as directed**, to hanger rod.
5. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

J. Source Quality Control
1. Factory Tests, as directed: Test factory-assembled air terminal units according to ARI 880.
   a. Label each air terminal unit with plan number, nominal airflow, maximum and minimum factory-set airflows, coil type, **as directed**, and ARI certification seal.

1.3 EXECUTION

A. Installation
1. Install air terminal units according to NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems."
2. Install air terminal units level and plumb. Maintain sufficient clearance for normal service and maintenance.
3. Install wall-mounted thermostats.

B. Hanger And Support Installation
1. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 4, "Hangers and Supports."
2. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.
   a. Where practical, install concrete inserts before placing concrete.
   b. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
   c. Use powder-actuated concrete fasteners for standard-weight aggregate concretes and for slabs more than 4 inches (100 mm) thick.
   d. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes and for slabs less than 4 inches (100 mm) thick.
   e. Do not use powder-actuated concrete fasteners for seismic restraints.
3. Hangers Exposed to View: Threaded rod and angle or channel supports.
4. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

C. Seismic-Restraint-Device Installation
1. Install hangers and braces designed to support the air terminal units and to restrain against seismic forces required by applicable building codes. Comply with SMACNA's "Seismic Restraint Manual: Guidelines for Mechanical Systems" **OR** ASCE/SEI 7, **as directed**.
2. Select seismic-restraint devices with capacities adequate to carry present and future static and seismic loads.
3. Install cables so they do not bend across edges of adjacent equipment or building structure.
4. Install cable restraints on air terminal units that are suspended with vibration isolators.
5. Install seismic-restraint devices using methods approved by an evaluation service member of the ICC Evaluation Service **OR** the Office of Statewide Health Planning and Development for the State of California **OR** an agency acceptable to authorities having jurisdiction, **as directed**.
6. Attachment to Structure: If specific attachment is not indicated, anchor bracing and restraints to structure, to flanges of beams, to upper truss chords of bar joists, or to concrete members.

7. Drilling for and Setting Anchors:

8. Identify position of reinforcing steel and other embedded items before drilling holes for anchors. Do not damage existing reinforcement or embedded items during drilling. Notify the the Owner if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
9. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
10. Wedge Anchors: Protect threads from damage during anchor installation. Install heavy-duty sleeve anchors with sleeve fully engaged in the structural element to which anchor is to be fastened.
11. Set anchors to manufacturer's recommended torque, using a torque wrench.
12. Install zinc-coated steel anchors for interior applications and stainless-steel anchors for applications exposed to weather.

D. Connections
1. Install piping adjacent to air terminal unit to allow service and maintenance.
2. Hot-Water Piping: In addition to requirements in Division 23 Section "Hydronic Piping", connect heating coils to supply with shutoff valve, strainer, control valve, and union or flange; and to return with balancing valve and union or flange.
3. Connect ducts to air terminal units according to Division 23 Section(s) "Metal Ducts" OR "Nonmetal Ducts", **as directed**.
4. Make connections to air terminal units with flexible connectors complying with requirements in Division 23 Section "Air Duct Accessories".

E. Identification
1. Label each air terminal unit with plan number, nominal airflow, and maximum and minimum factory-set airflows. Comply with requirements in Division 23 Section "Identification For Hvac Piping And Equipment" for equipment labels and warning signs and labels.

F. Field Quality Control
1. Perform tests and inspections.
   a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
2. Tests and Inspections:
   a. After installing air terminal units and after electrical circuitry has been energized, test for compliance with requirements.
   b. Leak Test: After installation, fill water coils and test for leaks. Repair leaks and retest until no leaks exist.
   c. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   d. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
3. Air terminal unit will be considered defective if it does not pass tests and inspections.
4. Prepare test and inspection reports.

G. Startup Service
1. Perform startup service.
   a. Complete installation and startup checks according to manufacturer's written instructions.
   b. Verify that inlet duct connections are as recommended by air terminal unit manufacturer to achieve proper performance.
   c. Verify that controls and control enclosure are accessible.
   d. Verify that control connections are complete.
   e. Verify that nameplate and identification tag are visible.
   f. Verify that controls respond to inputs as specified.

H. Demonstration
   1. Train Owner's maintenance personnel to adjust, operate, and maintain air terminal units.

END OF SECTION 23 36 16 00

Task	Specification	Specification Description
23 37 13 00	23 31 13 33	Duct Accessories
23 37 13 00	23 36 13 00	Diffusers, Registers, And Grilles
23 38 13 16	01 22 16 00	No Specification Required
23 38 13 16	11 21 63 00	Food Service Equipment
23 38 13 16	23 31 13 13	Metal Ducts
23 38 13 16	07 72 13 00a	Intake and Relief Ventilators

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SECTION 23 41 13 00 - AIR FILTERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for particulate air infiltration. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Metal panel filters.
b. Flat panel filters.
c. Pleated panel filters.
d. Ring panel filters.
e. Nonsupported bag filters.
f. Supported bag filters.
g. Rigid cell box filters.
h. V-bank cell filters.
i. Self-supported pocket filters.
j. Automatic roll filters.
k. Bulk media.
l. Front- and rear-access filter frames.
m. Side-service housings.
n. Filter gages.

C. Submittals
1. Product Data: For each type of product indicated. Include dimensions; operating characteristics; required clearances and access; rated flow capacity, including initial and final pressure drop at rated airflow; efficiency and test method; fire classification; furnished specialties; and accessories for each model indicated.
2. LEED Submittals:
a. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
b. Product Data for Credit EQ 4.1: For adhesives and sealants, including printed statement of VOC content.
3. Shop Drawings: For air filters. Include plans, elevations, sections, details, and attachments to other work.
a. Show filter rack assembly, dimensions, materials, and methods of assembly of components.
b. Include setting drawings, templates, and requirements for installing anchor bolts and anchorages.
c. Wiring Diagrams: For power, signal, and control wiring.
4. Operation and Maintenance Data: For each type of filter and rack to include in emergency, operation, and maintenance manuals.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. ASHRAE Compliance:
a. Comply with applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality"; Section 5 - "Systems and Equipment"; and Section 7 - "Construction and Startup."

b. Comply with ASHRAE 52.1 for arrestance and ASHRAE 52.2 for MERV for methods of testing and rating air-filter units.

3. Comply with NFPA 90A and NFPA 90B.

E. Coordination

1. Coordinate sizes and locations of concrete bases. Cast anchor-bolt inserts into bases.

1.2 PRODUCTS

A. Metal Panel Filters

1. Description: Factory-fabricated, self-supported, cleanable, all-metal, impingement-type, panel-type, permanent air filters with holding frames.
2. Media: Four **OR** Six, **as directed**, alternate layers of galvanized-steel **OR** aluminum **OR** stainless-steel, **as directed**, flat and herringbone-crimp screen.
   a. Nonoiled for grease removal application.
   b. Adhesive coating.
      1) Adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
3. Filter-Media Frame: Galvanized steel **OR** Hot-dip galvanized steel **OR** Aluminum **OR** Stainless steel, **as directed**, hinged, and with pull and retaining handles fastened to the media.
   a. Drain holes.

B. Flat Panel Filters

1. Description: Factory-fabricated, self-supported, flat, nonpleated, panel-type, disposable air filters with holding frames.
2. Filter Unit Class: UL 900, Class 1 **OR** Class 2, **as directed**.
3. Media: Interlaced glass or synthetic fibers **OR** Cotton and synthetic fibers, **as directed**, coated with nonflammable adhesive.
   a. Adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
   b. Media shall be coated with an antimicrobial agent.
   c. Metal Retainer: Upstream side and downstream side.
4. Filter-Media Frame: Cardboard with perforated metal retainer **OR** Galvanized steel with metal grid on outlet side and steel rod grid on inlet side, hinged, with pull and retaining handles, **as directed**, sealed or bonded to the media.
5. Mounting Frames: Welded galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.

C. Pleated Panel Filters

1. Description: Factory-fabricated, self-supported, extended-surface, pleated, panel-type, disposable air filters with holding frames.
2. Filter Unit Class: UL 900, Class 1 **OR** Class 2, **as directed**.
3. Media: Interlaced glass or synthetic fibers **OR** Cotton and synthetic fibers, **as directed**, coated with nonflammable adhesive.
   a. Adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
   b. Media shall be coated with an antimicrobial agent.
   c. Separators shall be bonded to the media to maintain pleat configuration.
   d. Welded wire grid shall be on downstream side to maintain pleat.
   e. Media shall be bonded to frame to prevent air bypass.
   f. Support members on upstream and downstream sides to maintain pleat spacing.
4. Filter-Media Frame: Cardboard frame with perforated metal retainer **OR** Galvanized steel **OR** Aluminized steel, **as directed**, with metal grid on outlet side and steel rod grid on inlet side, hinged, with pull and retaining handles, **as directed**, sealed or bonded to the media.

5. Mounting Frames: Welded galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.

D. Ring Panel Filters
1. Description: Internally supported, flat panel filters for installation in a filter track.
2. Filter Unit Class: UL 900, Class 1 **OR** Class 2, **as directed**.
3. Media: Two **OR** Three **OR** Four, **as directed**,-ply polyester with sealed edges.
   a. Panel Construction: Single with one edge unsealed for support removal, **as directed**, **OR** Linked, **as directed**.
   b. Media shall be coated with an antimicrobial agent.
4. Internal Support: 9-gage steel wire frame.

E. Nonsupported Bag Filters
1. Description: Factory-fabricated, dry, extended-surface, nonsupported filters with header frames.
2. Filter Unit Class: UL 900, Class 1 **OR** Class 2, **as directed**.
3. Media: Glass-fiber **OR** Synthetic, **as directed**, material constructed so individual pockets are maintained in tapered form under rated-airflow conditions by flexible internal supports.
   a. Media shall be coated with an antimicrobial agent.
4. Filter-Media Frame: Galvanized steel **OR** Hard polyurethane foam, **as directed**.
5. Mounting Frames: Welded galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.

F. Supported Bag Filters
1. Description: Factory-fabricated, dry, extended-surface, self-supported filters with holding frames in steel, basket-type retainers.
2. Filter Unit Class: UL 900, Class 1 **OR** Class 2, **as directed**.
3. Media: Fibrous material constructed so individual pleats are maintained in tapered form under rated-airflow conditions by flexible internal supports.
   a. Media shall be coated with an antimicrobial agent.
4. Filter-Media Frame: Galvanized steel **OR** Hard polyurethane foam, **as directed**.
5. Mounting Frames: Welded galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.

G. Rigid Cell Box Filters
1. Description: Factory-fabricated, adhesive-coated, **as directed**, disposable, packaged air filters with media perpendicular to airflow, and with holding frames.
2. Filter Unit Class: UL 900, Class 1 **OR** Class 2, **as directed**.
3. Media: Fibrous material constructed so individual pleats are maintained in tapered form under rated-airflow conditions by flexible internal supports.
   a. Adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
   b. Media shall be coated with an antimicrobial agent.
4. Filter-Media Frames: Galvanized steel **OR** Hard polyurethane foam, **as directed**.
5. Mounting Frames: Welded galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.

H. V-Bank Cell Filters
1. Description: Factory-fabricated, adhesive-coated, **as directed**, disposable, packaged air filters with media angled to airflow, and with holding frames.
2. Filter Unit Class: UL 900, Class 1 **OR** Class 2, **as directed**.
3. Media: Fibrous material constructed so individual pleats are maintained in tapered form under rated-airflow conditions by flexible internal supports.
   a. Adhesive shall have a VOC content of 80 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
   b. Media shall be coated with an antimicrobial agent.
4. Filter-Media Frames: Galvanized steel **OR** Hard polyurethane foam, **as directed**.

5. Mounting Frames: Welded galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.

I. Self-Supported Pocket Filters
1. Description: Factory-fabricated, panel-type, disposable air filters with contoured media for extended surface.
2. Filter Unit Class: UL 900, Class 1 **OR** Class 2, **as directed**.
3. Media: Fibrous material constructed so individual pleats are maintained in tapered form under rated-airflow conditions by flexible internal supports.
   a. Media shall be coated with an antimicrobial agent.
4. Configuration: Single-pocket cube **OR** Multipocket, **as directed**.
5. Filter-Media Frame: Galvanized steel **OR** Hard polyurethane foam, **as directed**.
6. Mounting Frames: Welded galvanized steel, with gaskets and fasteners; suitable for bolting together into built-up filter banks.

J. Automatic Roll Filters
1. Description: Factory-fabricated, automatic, motor-driven, roll-type filters with holding casing.
2. Arrangement: Horizontal **OR** Vertical, **as directed**.
3. Filter Unit Class: UL 900, Class 1 **OR** Class 2, **as directed**.
4. Media: Compressed and rolled, fibrous-glass material; viscous coated.
   a. Media shall be coated with an antimicrobial agent.
5. Holding Frame: Galvanized steel with enclosed, clean media roll arranged to allow upstream replacement of filter media.
   a. Auxiliary Frame: Locate on downstream side of unit with downstream **OR** side, **as directed**, access.
   b. Final Filter: Extended-surface, retained **OR** nonsupported, **as directed**, media.
6. Control and Drive: Electric, gear-reducer, motor-driven, feed-control mechanism equipped with manual media advance and runout switches for stopping media movement of filter bank and operating remote warning signal lights.
   a. Manual Control: Manual switch to advance media, and wired to override automatic controls.
   b. Automatic Control: Prewired control package to advance media when filter resistance exceeds preselected high limit **OR** after preselected operating time, **as directed**.

K. Bulk Media
1. Description: Air-filter media, factory custom cut or rolled.
2. Filter Unit Class: UL 900, Class 1 **OR** Class 2, **as directed**.
3. Media: Spun glass **OR** Synthetic **OR** Polyester, **as directed**, in a roll **OR** cut into pads, **as directed**.

L. Front- And Rear-Access Filter Frames
1. Framing System: Galvanized-steel **OR** Aluminum, **as directed**, framing members with access for either upstream (front) or downstream (rear) filter servicing, cut to size and prepunched for assembly into modules. Vertically support filters to prevent deflection of horizontal members without interfering with either filter installation or operation.
2. Prefilters: Incorporate a separate track with spring clips, **as directed**, removable from front or back, **as directed**.
3. Sealing: Factory-installed, positive-sealing device for each row of filters, to ensure seal between gasketed filter elements and to prevent bypass of unfiltered air.

M. Side-Service Housings
1. Description: Factory-assembled, side-service housings, constructed of galvanized steel **OR** aluminum, **as directed**, with flanges to connect to duct or casing system.
2. Prefilters: Integral tracks to accommodate 2-inch- (50-mm-) deep, disposable or washable, **as directed**, filters.

3. Access Doors: Hinged, with continuous **OR** Continuous, **as directed**, gaskets on perimeter and positive-locking devices, and arranged so filter cartridges can be loaded from either access door.
4. Sealing: Incorporate positive-sealing gasket material on channels to seal top and bottom of filter cartridge frames and to prevent bypass of unfiltered air.

N. Filter Gages
1. Diaphragm-type gage with dial and pointer in metal case, vent valves, black figures on white background, and front recalibration adjustment.
   a. Diameter: 4-1/2 inches (115 mm) **OR** 2 inches (50 mm), **as directed**.
   b. Scale Range for Filter Media Having a Recommended Final Resistance of 0.5-Inch wg (125 Pa) or Less: 0- to 0.5-inch wg (0 to 125 Pa).
   c. Scale Range for Filter Media Having a Recommended Final Resistance of 0.5- to 1.0-Inch wg (125 to 250 Pa) or Less: 0- to 1.0-inch wg (0 to 250 Pa).
   d. Scale Range for Filter Media Having a Recommended Final Resistance of 1.0- to 2.0-Inch wg (250 to 500 Pa) or Less: 0- to 2.0-inch wg (0 to 500 Pa).
   e. Scale Range for Filter Media Having a Recommended Final Resistance of 2.0- to 3.0-Inch wg (500 to 750 Pa) or Less: 0- to 3.0-inch wg (0 to 750 Pa).
   f. Scale Range for Filter Media Having a Recommended Final Resistance of 3.0- to 4.0-Inch wg (750 to 1000 Pa) or Less: 0- to 4.0-inch wg (0 to 1000 Pa).
2. Manometer-Type Filter Gage: Molded plastic, with epoxy-coated aluminum scale and logarithmic-curve tube gage with integral leveling gage, graduated to read from 0- to 3.0-inch wg (0 to 750 Pa), and accurate within 3 percent of the full scale range.
3. Accessories: Static-pressure tips, tubing, gage connections, and mounting bracket.

1.3 EXECUTION

A. Installation
1. Position each filter unit with clearance for normal service and maintenance. Anchor filter holding frames to substrate.
2. Install filters in position to prevent passage of unfiltered air.
3. Install filter gage for each filter bank.
4. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing with new, clean filters.
5. Install filter-gage, static-pressure taps upstream and downstream from filters. Install filter gages on filter banks with separate static-pressure taps upstream and downstream from filters. Mount filter gages on outside of filter housing or filter plenum in an accessible position. Adjust and level inclined gages.
6. Coordinate filter installations with duct and air-handling-unit installations.

B. Field Quality Control
1. Perform tests and inspections.
2. Tests and Inspections:
   a. Operate automatic roll filters to demonstrate compliance with requirements.
   b. Test for leakage of unfiltered air while system is operating.
3. Air filter will be considered defective if it does not pass tests and inspections.
4. Prepare test and inspection reports.

C. Cleaning
1. After completing system installation and testing, adjusting, and balancing of air-handling and air-distribution systems, clean filter housings and install new filter media.

END OF SECTION 23 41 13 00

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SECTION 23 41 13 00a - ELECTRONIC AIR CLEANERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for electronic air cleaners. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Electronic air cleaners.
b. Side-service housings.
c. Front- and rear-access filter frames.
d. Filter gages.

C. Submittals
1. Product Data: For each type of product indicated. Include dimensions; operating characteristics; required clearances and access; rated flow capacity, including initial and final pressure drop at rated airflow; efficiency and test method; fire classification; furnished specialties; and accessories for each model indicated.
2. LEED Submittal:
a. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
3. Shop Drawings: For each electronic air cleaner. Include plans, elevations, sections, details, and attachments to other work.
a. Show filter assembly, dimensions, materials, and methods of assembly of components.
b. Include setting drawings, templates, and requirements for installing anchor bolts and anchorages.
c. Wiring Diagrams: For power, signal, and control wiring.
4. Field quality-control reports.
5. Operation and Maintenance Data: For each type of filter and housing to include in emergency, operation, and maintenance manuals.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. ASHRAE Compliance:
a. Comply with applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality," Section 5 - "Systems and Equipment," and Section 7 - "Construction and Startup."
b. Comply with ASHRAE 52.1 for arrestance and with ASHRAE 52.2 for MERV for methods of testing and rating air-filter units.
3. Comply with NFPA 90A and NFPA 90B.
4. Comply with ARI 850.
5. Comply with UL 867.

1.2 PRODUCTS

A. Electronic Air Cleaners
1. Description: Factory-fabricated electronic air cleaner operating by electrostatic precipitation principles.

2. Prefilter Media: Four **OR** Six, **as directed**, alternate layers of galvanized-steel **OR** aluminum **OR** stainless-steel, **as directed**, flat and herringbone-crimp screen.
3. Prefilter: Comply with requirements in Division 23 Section "Particulate Air Filtration" for flat **OR** pleated **OR** ring, **as directed**, panel. Size and airflow capacity shall match those of electronic air cleaners.
   a. Depth: 1 inch (25 mm) **OR** 2 inches (50 mm) **OR** 4 inches (100 mm), **as directed**.
   b. Filter Unit Class: UL 900, Class 1 **OR** Class 2, **as directed**.
   c. Arrestance: 85 percent when tested according to ASHRAE 52.1.
   d. MERV: 8 when tested according to ASHRAE 52.2.
4. Final Filter: Comply with requirements in Division 23 Section "Particulate Air Filtration" for supported bag **OR** unsupported bag **OR** rigid-cell box **OR** V-bank cell **OR** self-supported pocket, **as directed**. Size and airflow capacity shall match those of gas-phase filters.
   a. Depth: 12 inches (300 mm) **OR** 18 inches (450 mm) **OR** 24 inches (600 mm),**as directed**.
   b. Filter Unit Class: UL 900, Class 1 **OR** Class 2, **as directed**.
   c. Arrestance: 85 percent when tested according to ASHRAE 52.1.
   d. MERV: 13 when tested according to ASHRAE 52.2.
5. Collection Cells: Aluminum, independently supported and nested.
   a. Ionizing Section: Alternately spaced grounded struts and charged ionizing wires.
   b. Collecting Section: Alternately grounded and charged plates, with insulators located out of airstream.
6. Power Pack: Self-contained, prewired rectifying unit to convert 120 **OR** 208/240 **OR** 480, **as directed**,-V ac, single-phase, 60-Hz power to approximately 12,000-V dc for ionizer and 6000-V dc for collector; include overload protection, on-off switch, pilot light showing operating status, and access door interlock.
7. Safety Accessories: Manual-reset safety switches and warning lights for filter plenum access doors, signal lights and safety switching upstream and downstream from unit within duct, and enameled high-voltage warning signs.
8. Collection Section Cleaning System:
   a. Detergent Reservoir Tank: 30 gal. (110 L) **OR** 55 gal. (200 L), **as directed**, with pump, motor, solenoid valve, level sensor, backflow preventer, wye-strainer, and ball valve.
   b. Detergent.
   c. Dispensing System: Motor-driven oscillating copper manifolds with brass spray nozzles on each side of the collector.
9. Mist Eliminators: Upstream **OR** Upstream and downstream **OR** Downstream, **as directed**.
10. Controls: Programmable logic controller in remotely mounted NEMA 250, Type 12 enclosure; with integral time clock and manual override.
    a. Contacts for enable-disable control by building automation system.
11. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

B. Fan Section
1. Fan: Forward curved, belt driven.
2. Motor:
   a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   b. Type: Permanent-split capacitor with SCR for speed adjustment **OR** Electronically commutated motor, **as directed**.
   c. Fan-Motor Assembly Isolation: Rubber isolators.
   d. Enclosure: Totally enclosed, fan cooled, and explosion proof **OR** dust-ignition proof, **as directed**.
   e. Enclosure Materials: Cast iron **OR** Cast aluminum **OR** Rolled steel, **as directed**.
   f. Motor Bearings: Sealed ball.
   g. Unusual Service Conditions:
      1) Ambient Temperature: <**Insert deg F (deg C)**>.

2) Altitude: <**Insert feet (m)**> above sea level.
3) High humidity.

h. Efficiency: Premium efficient.
i. NEMA Design: <**Insert designation**>.
j. Service Factor: <**Insert value**>.
k. Motor Speed: Single speed **OR** Multispeed, **as directed**.
1) Speed Control: Infinitely adjustable with pneumatic-electric and electronic controls.

C. Cabinet
1. Description: 16-gage galvanized steel with epoxy powder finish for suspended, wall, frame, or duct mounting.

D. Side-Service Housings
1. Description: Factory-assembled, side-service housings, with bottom drain, **as directed**, constructed of galvanized steel **OR** aluminum, **as directed**, and configured for stacking, with flanges to connect to duct or casing system.
2. Access Doors: Hinged with continuous **OR** Continuous, **as directed**, gaskets on perimeter and positive-locking devices.
3. Sealing: Incorporate positive-sealing gasket material on channels to seal top and bottom of filter cartridge frames to prevent bypass of unfiltered air.
4. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

E. Front- And Rear-Access Filter Frames
1. Framing System: Galvanized-steel **OR** Aluminum, **as directed**, framing members with access for either upstream (front) or downstream (rear) filter servicing, cut to size and prepunched for assembly into modules with bottom drain, **as directed**, and configured for stacking. Vertically support filters to prevent deflection of horizontal members without interfering with either filter installation or operation.
2. Prefilters: Incorporate a separate track with spring clips, **as directed**, removable from front or back, **as directed**.
3. Final Filters: Integral tracks to accommodate particulate **OR** gas-phase, **as directed**, disposable filters.
4. Sealing: Factory-installed, positive-sealing device for each row of filters to ensure seal between gasketed filter elements to prevent bypass of unfiltered air.
5. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

F. Filter Gages
1. Diaphragm type, with dial and pointer in metal case, vent valves, black figures on white background, and front recalibration adjustment.
a. Diameter: 4-1/2 inches (115 mm) **OR** 2 inches (50 mm), **as directed**.
b. Scale Range for Filter Media Having a Recommended Final Resistance of 0.5-Inch wg (125 Pa) or Less: 0- to 0.5-inch wg (0 to 125 Pa).
c. Scale Range for Filter Media Having a Recommended Final Resistance of 0.5- to 1-Inch wg (125 to 250 Pa) or Less: 0- to 1.0-inch wg (0 to 250 Pa).
d. Scale Range for Filter Media Having a Recommended Final Resistance of 1.0- to 2.0-Inch wg (250 to 500 Pa) or Less: 0- to 2.0-inch wg (0 to 500 Pa).
e. Scale Range for Filter Media Having a Recommended Final Resistance of 2.0- to 3.0-Inch wg (500 to 750 Pa) or Less: 0- to 3.0-inch wg (0 to 750 Pa).
f. Scale Range for Filter Media Having a Recommended Final Resistance of 3.0- to 4.0-Inch wg (750 to 1000 Pa) or Less: 0- to 4.0-inch wg (0 to 1000 Pa).
2. Manometer-Type Filter Gage: Molded plastic, with epoxy-coated aluminum scale, logarithmic-curve tube gage, with integral leveling indicator, graduated to read from 0- to 3.0-inch wg (0 to 750 Pa), and accurate within 3 percent of full-scale range.
3. Accessories: Static-pressure tips, tubing, gage connections, and mounting bracket.

1.3 EXECUTION

A. Installation
1. Position each filter unit with clearance for normal service and maintenance. Anchor filter holding frames to substrate.
2. Install filters in position to prevent passage of unfiltered air.
3. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing with new, clean filters.
4. Operate electronic air cleaners for 24 hours as part of startup before filters are put into operation.
5. Install filter-gage, static-pressure taps upstream and downstream from filters. Install filter gages on filter banks with separate static-pressure taps upstream and downstream from filters. Mount filter gages on outside of filter housing or filter plenum in an accessible position. Adjust and level inclined gages.
6. Install and connect water-supply and drainage piping.
7. Coordinate filter installations with duct and air-handling-unit installations.

B. Field Quality Control
1. Perform tests and inspections.
2. Tests and Inspections: Test for leakage of unfiltered air while system is operating.
3. Air filter will be considered defective if it does not pass tests and inspections.
4. Prepare test and inspection reports.

C. Cleaning
1. After completing system installation and testing, adjusting, and balancing air-handling and air-distribution systems, clean filter housings and install new prefilter and final-filter media.

END OF SECTION 23 41 13 00a

Task	Specification	Specification Description
23 41 16 00	23 41 13 00	Air Filters
23 41 16 00	23 41 13 00a	Electronic Air Cleaners
23 41 19 00	23 41 13 00	Air Filters
23 41 19 00	23 41 13 00a	Electronic Air Cleaners
23 41 33 00	23 41 13 00	Air Filters
23 41 33 00	22 13 19 00	High-Efficiency Particulate Filtration

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SECTION 23 42 13 00 - GAS-PHASE AIR FILTRATION

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for gas-phase air infiltration. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Activated-carbon panel filters.
b. Activated-carbon, deep-V filters.
c. Activated carbon, V-cell filters.
d. Cylindrical-canister filters.
e. Permanganate filters.
f. Supported adsorber bag filters.
g. Front-access filter housings.
h. Side-service housings.
i. Filter gages.

C. Submittals
1. Product Data: For each type of product indicated. Include dimensions; operating characteristics; required clearances and access; rated flow capacity, including initial and final pressure drop at rated airflow; efficiency and test method; fire classification; furnished specialties; and accessories for each model indicated.
2. LEED Submittal:
a. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with applicable requirements in ASHRAE 62.1, Section 5, "Systems and Equipment."
3. Shop Drawings: For air filters. Include plans, elevations, sections, details, and attachments to other work.
a. Show filter rack assembly, dimensions, materials, and methods of assembly of components.
b. Include setting drawings, templates, and requirements for installing anchor bolts and anchorages.
4. Field quality-control reports.
5. Operation and Maintenance Data: For each type of filter and rack to include in emergency, operation, and maintenance manuals.

D. Quality Assurance
1. ASHRAE Compliance:
a. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
2. Comply with NFPA 90A and NFPA 90B.

1.2 PRODUCTS

A. Activated-Carbon Panel Filters
1. Description: Factory-fabricated unit with activated-carbon media.
2. Media: Flat-panel, disposable multilayer filter with an inlet layer of polyester fibers, a layer of activated-carbon granules bonded to fibers, and a layer of polyurethane foam; housed in a cardboard frame.

3. Media: Flat-panel, disposable honeycombed cellulose with cells filled with activated-carbon granules and a perforated mesh grid; housed in a cardboard frame.
4. Media: Pleated, multilayer filter with an inlet layer of cotton and synthetic fibers and a layer of activated-carbon granules bonded to synthetic fibers; media formed into deep-V-shaped pleats, held by self-wire grid, and housed in a cardboard frame.
5. Mounting Frames: Welded, galvanized, sheet-steel frame and galvanized-steel fasteners with polyurethane, **as directed**, gaskets; capable of bolting together into built-up filter banks.

B. Activated-Carbon, Deep-V Filters
1. Description: Factory-fabricated unit with activated-carbon trays in deep-V arrangement with disposable panel prefilter, **as directed**, and final filter, **as directed**.
2. Module Housing: 0.064-inch- (1.6-mm-) thick, galvanized steel **OR** stainless steel **OR** double-wall casing with 1-inch- (25-mm-) thick insulation, **as directed**, to hold media-filled panels; with side servicing through gasketed access doors on both sides and able to connect to other housings. Equip housings with metal slide channel tracks to hold activated-carbon trays and particulate prefilter, **as directed**, and final filter, **as directed**.
   a. Finish: Factory primed **OR** primed and painted, **as directed**, outside **OR** inside and outside **OR** inside, **as directed**.
   b. Pressure tap and fitting.
3. Media-Holding Panels: 1-inch- (25-mm-) thick, perforated polystyrene to allow airflow through contained loose-fill media; with removable service cap for recharging.
   OR
   Media-Holding Panels: 1 inch (25 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**, deep and containing granular carbon bonded into a briquette form with a galvanized **OR** stainless, **as directed**,-steel frame.
4. Media: 45 lb (20.3 kg) per 1000 cfm (470 L/s) of loose-fill **OR** loose-fill or bonded-briquette **OR** bonded-briquette, **as directed**, coconut-shell activated carbon.
   a. Ash Content: 2 to 3 percent.
   b. Percent Carbon Tetrachloride Activity: 35 to 70 percent when tested according to ASTM D 3467.
   c. Bulk Density: 32 lb/cu. ft. (510 kg/cu. m).
   d. Mesh Size: 4 by 6 inches (100 by 150 mm), 90 percent minimum.
   e. Hardness Factor: 95 when tested according to ASTM D 3802.
5. Media: loose-fill **OR** loose-fill or bonded-briquette **OR** bonded-briquette, **as directed**, activated alumina impregnated with potassium permanganate.
   a. Ash Content: 2 to 3 percent.
   b. Percent Carbon Tetrachloride Activity: 35 to 70 percent when tested according to ASTM D 3467.
   c. Bulk Density: 32 lb/cu. ft. (510 kg/cu. m).
   d. Mesh Size: 4 by 6 inches (100 by 150 mm), 90 percent minimum.
   e. Hardness Factor: 95 when tested according to ASTM D 3802.
6. Media: loose-fill **OR** loose-fill or bonded-briquette **OR** bonded-briquette, **as directed**, impregnated carbon.
   a. Ash Content: 2 to 3 percent.
   b. Percent Carbon Tetrachloride Activity: 35 to 70 percent when tested according to ASTM D 3467.
   c. Bulk Density: 32 lb/cu. ft. (510 kg/cu. m).
   d. Mesh Size: 4 by 6 inches (100 by 150 mm), 90 percent minimum.
   e. Hardness Factor: 95 when tested according to ASTM D 3802.
7. Media: loose-fill **OR** loose-fill or bonded-briquette **OR** bonded-briquette, **as directed**, blended carbon and alumina impregnated with potassium permanganate.
   a. Ash Content: 2 to 3 percent.
   b. Percent Carbon Tetrachloride Activity: 35 to 70 percent when tested according to ASTM D 3467.
   c. Bulk Density: 32 lb/cu. ft. (510 kg/cu. m).

d. Mesh Size: 4 by 6 inches (100 by 150 mm), 90 percent minimum.
e. Hardness Factor: 95 when tested according to ASTM D 3802.

C. Activated-Carbon, V-Cell Filters
1. Description: Factory-fabricated, dry, V-shaped cartridges containing loose-fill media with holding frames.
2. Cartridges: V-cell configuration, plastic enclosure caps, galvanized-steel frame with vertical galvanized-steel channel supports. Integral, 1-inch- (25-mm-) deep panels constructed of honeycombed paper and nylon mesh.
3. Fill Media: Coconut-shell activated carbon; 45 lb (20.3 kg) of activated carbon per 1000 cfm (470 L/s) of airflow.
   a. Ash Content: 2 to 3 percent.
   b. Percent Carbon Tetrachloride Activity: 35 to 70 percent when tested according to ASTM D 3467.
   c. Bulk Density: 32 lb/cu. ft. (510 kg/cu. m).
   d. Mesh Size: 4 by 6 inches (100 by 150 mm), 90 percent minimum.
   e. Hardness Factor: 95 when tested according to ASTM D 3802.
4. Fill Media: Activated alumina impregnated with potassium permanganate; 10.5 lb (4.8 kg) of adsorbent per 500 cfm (236 L/s) of airflow.
   a. Ash Content: 2 to 3 percent.
   b. Percent Carbon Tetrachloride Activity: 35 to 70 percent when tested according to ASTM D 3467.
   c. Bulk Density: 32 lb/cu. ft. (510 kg/cu. m).
   d. Mesh Size: 4 by 6 inches (100 by 150 mm), 90 percent minimum.
   e. Hardness Factor: 95 when tested according to ASTM D 3802.
5. Fill Media: Impregnated carbon; 8.0 lb (3.6 kg) of adsorbent per 500 cfm (236 L/s) of airflow.
   a. Ash Content: 2 to 3 percent.
   b. Percent Carbon Tetrachloride Activity: 35 to 70 percent when tested according to ASTM D 3467.
   c. Bulk Density: 32 lb/cu. ft. (510 kg/cu. m).
   d. Mesh Size: 4 by 6 inches (100 by 150 mm), 90 percent minimum.
   e. Hardness Factor: 95 when tested according to ASTM D 3802.
6. Fill Media: Blended carbon and alumina impregnated with potassium permanganate; 7.0 lb (3.1 kg) of adsorbent per 500 cfm (236 L/s) of airflow.
   a. Ash Content: 2 to 3 percent.
   b. Percent Carbon Tetrachloride Activity: 35 to 70 percent when tested according to ASTM D 3467.
   c. Bulk Density: 32 lb/cu. ft. (510 kg/cu. m).
   d. Mesh Size: 4 by 6 inches (100 by 150 mm), 90 percent minimum.
   e. Hardness Factor: 95 when tested according to ASTM D 3802.
7. Mounting Frames: Welded, galvanized, sheet-steel frame and galvanized-steel fasteners with gaskets; capable of bolting together into built-up filter banks.

D. Cylindrical-Canister Filters
1. Description: Factory-fabricated, dry, cylindrical canisters containing loose-fill adsorbent with holding frames.
2. Cylinders: 0.0455-inch- (1.2-mm-) thick, perforated, electroplated **OR** stainless, **as directed**, steel, with end plate.
3. Fill Media: 5.0 lb (2.3 kg) **OR** 6.7 lb (3.0 kg), **as directed**, of coconut-shell activated carbon **OR** activated alumina impregnated with potassium permanganate **OR** impregnated carbon **OR** blended carbon and alumina impregnated with potassium permanganate, **as directed**, per canister.
   a. Ash Content: 2 to 3 percent.
   b. Percent Carbon Tetrachloride Activity: 35 to 70 percent when tested according to ASTM D 3467.
   c. Bulk Density: 32 lb/cu. ft. (510 kg/cu. m).

d. Mesh Size: 4 by 6 inches (100 by 150 mm), 90 percent minimum.
e. Hardness Factor: 95 when tested according to ASTM D 3802.

4. Mounting Frames: Welded galvanized, sheet steel with galvanized-steel fasteners **OR** stainless steel with stainless-steel fasteners, **as directed**, with gaskets; designed for bolting together into built-up filter banks.

E. Permanganate Filters
1. Description: Factory-fabricated modules containing loose-fill adsorbent with holding frames.
2. Modules: Permanent type, 24 inches wide by 24 inches high by 24 inches deep (600 mm wide by 600 mm high by 600 mm deep); shall hold both potassium permanganate and activated carbon. Manufactured in two pieces, each 12 inches (300 mm) wide for ease of installation.
3. Media: Porous spherical pellets formed from a combination of powdered, activated carbon and other binders, impregnated with potassium permanganate.
   a. Leach Test: 180 minutes.
   b. Potassium Permanganate Content: 4 percent minimum.
   c. Moisture Content: 20 percent maximum.
   d. Bulk Density: 34 lb/cu. ft. (0.54 g/mL) **OR** 50 lb/cu. ft. (0.8 g/mL), **as directed**.
   e. Crush Strength: 40 **OR** 50 **OR** 60, **as directed**, percent maximum.
   f. Abrasion: 4 percent maximum.
   g. Nominal Pellet Diameter: 0.125 inch (3.175 mm).
   h. Percent of Pellet Sizes: 80 to 85 percent after screening.
4. Media: High-grade carbon, manufactured from coconut shells, bituminous coal, or a combination of both.
   a. Ash Content: 2 to 3 percent.
   b. Percent Carbon Tetrachloride Activity: 35 to 70 percent when tested according to ASTM D 3467.
   c. Bulk Density: 32 lb/cu. ft. (510 kg/cu. m).
   d. Mesh Size: 4 by 6 inches (100 by 150 mm), 90 percent minimum.
   e. Hardness Factor: 95 when tested according to ASTM D 3802.
5. Frame: Galvanized steel **OR** Hot-dip galvanized steel **OR** Aluminum **OR** Stainless steel, **as directed**, hinged, and with pull and retaining handles fastened to the media.

F. Supported Adsorber Bag Filters
1. Description: Factory-fabricated, dry, extended-surface, self-supporting filters with holding frames.
2. Media: Carbon-filled fibrous material constructed so individual pleats are maintained under rated-airflow conditions in tapered form by flexible internal supports.
3. Filter-Media Frame: Galvanized steel.
4. Mounting Frames: Welded, galvanized, sheet-steel frame and galvanized-steel fasteners with gaskets; capable of bolting together into built-up filter banks.

G. Front-Access Filter Frames
1. Framing System: Galvanized-steel **OR** Aluminum, **as directed**, framing members with access for upstream (front) filter servicing, cut to size and prepunched for assembly into modules. Vertically support filters to prevent deflection of horizontal members without interfering with either filter installation or operation.
2. Prefilters: Incorporate a separate track with spring clips, **as directed**, removable from front or back, **as directed**.
3. Sealing: Factory-installed, positive-sealing device for each row of filters to ensure seal between gasketed filter elements to prevent bypass of unfiltered air.

H. Side-Service Housings
1. Description: Factory-assembled, side-service housings constructed of galvanized steel **OR** aluminum, **as directed**, with flanges to connect to duct or casing system.
2. Prefilters: Integral tracks to accommodate 2-inch- (50-mm-) thick, disposable or washable, **as directed**, filters.

3. Access Doors: Hinged with continuous **OR** Continuous, **as directed**, gaskets on perimeter and with positive-locking devices. Arrange so filter cartridges can be loaded from either access door.
4. Sealing: Incorporate positive-sealing gasket material on channels to seal top and bottom of filter cartridge frames to prevent bypass of unfiltered air.

I. Filter Gages
1. Diaphragm type, with dial and pointer in metal case, vent valves, black figures on white background, and front recalibration adjustment.
   a. Diameter: 4-1/2 inches (115 mm) **OR** 2 inches (50 mm),**as directed** .
   b. Scale Range for Filter Media Having a Recommended Final Resistance of 0.5-Inch wg (125 Pa) or Less: 0- to 0.5-inch wg (0 to 125 Pa).
   c. Scale Range for Filter Media Having a Recommended Final Resistance of 0.5- to 1.0-Inch wg (125 to 250 Pa) or Less: 0- to 1.0-inch wg (0 to 250 Pa).
   d. Scale Range for Filter Media Having a Recommended Final Resistance of 1.0- to 2.0-Inch wg (250 to 500 Pa) or Less: 0- to 2.0-inch wg (0 to 500 Pa).
   e. Scale Range for Filter Media Having a Recommended Final Resistance of 2.0- to 3.0-Inch wg (500 to 750 Pa) or Less: 0- to 3.0-inch wg (0 to 750 Pa).
   f. Scale Range for Filter Media Having a Recommended Final Resistance of 3.0- to 4.0-Inch wg (750 to 1000 Pa) or Less: 0- to 4.0-inch wg (0 to 1000 Pa).
2. Manometer-Type Filter Gage: Molded plastic, with epoxy-coated aluminum scale, logarithmic-curve tube gage with integral leveling gage; graduated to read from 0- to 3.0-inch wg (0 to 750 Pa) and accurate within 3 percent of full-scale range.
3. Accessories: Static-pressure tips, tubing, gage connections, and mounting bracket.

1.3 EXECUTION

A. Installation
1. Position each filter unit with clearance for normal service and maintenance. Anchor filter holding frames to substrate.
2. Install filters in position to prevent passage of unfiltered air.
3. Install filter gage for each filter bank.
4. Do not operate fan system until particulate filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing with new, clean filters.
5. Do not install gas-phase filters until fan system is clean and there is no risk of construction debris loading the filter.
6. Install filter-gage, static-pressure taps upstream and downstream from filters. Install filter gages on filter banks with separate static-pressure taps upstream and downstream of filters. Mount filter gages on outside of filter housing or filter plenum in an accessible position. Adjust and level inclined gages.
7. Coordinate filter installations with duct and air-handling unit installations.

B. Field Quality Control
1. Perform tests and inspections.
2. Tests and Inspections:
   a. Test for leakage of unfiltered air while system is operating.
3. Air filter will be considered defective if it does not pass tests and inspections.
4. Prepare test and inspection reports.

C. Cleaning
1. After completing system installation and testing, adjusting, and balancing air-handling and air-distribution systems, clean filter housings and install new particulate filter media.

END OF SECTION 23 42 13 00

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Task	Specification	Specification Description
23 42 13 00	23 41 13 00	Air Filters

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SECTION 23 51 13 00 - BREECHINGS, CHIMNEYS, AND STACKS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for breechings, chimneys, and stacks. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following:
a. Listed chimney liners.
b. Listed single-wall and double-wall vents and chimneys.
c. Listed, refractory-lined breechings and stacks.
d. Field-fabricated metal breechings and chimneys.
e. Listed grease and dishwasher ducts.

C. Submittals
1. Product Data: For the following:
a. Chimney liners.
b. Type B and BW vents.
c. Type L vents.
d. Special gas vents.
e. Building-heating-appliance chimneys.
f. Grease ducts.
g. Refractory-lined metal breechings and chimneys.
h. Guy wires and connectors.
2. Shop Drawings: For vents, breechings, chimneys, and stacks. Include plans, elevations, sections, details, and attachments to other work.
3. Welding certificates.
4. Manufacturer Seismic Qualification Certification: Submit certification that factory-fabricated breeching, chimneys, and stacks; accessories; and components will withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
5. Warranty: Warranty specified in this Section.

D. Quality Assurance
1. Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code--Steel," for hangers and supports and AWS D9.1/D9.1M, "Sheet Metal Welding Code," for shop and field welding of joints and seams in vents, breechings, and stacks.

E. Warranty
1. Manufacturer's standard form in which manufacturer agrees to repair or replace components of venting system that fail in materials or workmanship within 10 **OR** 15 **OR** 25, **as directed**, years from date of Final Completion. Failures include, but are not limited to, structural failures caused by expansion and contraction.

1.2 PRODUCTS

A. Listed Chimney Liners
1. Description: Straight **OR** Corrugated, **as directed**, single-wall chimney liner tested according to UL 1777 and rated for 1000 deg F (538 deg C) continuously, or 2100 deg F (1150 deg C) for 10 minutes; with negative or positive flue pressure complying with NFPA 211.

2. Straight Liner Materials: ASTM A 666, Type 304 **OR** Type 316, **as directed**, stainless steel.
3. Corrugated Liner Materials: ASTM A 240/A 240M, Type 321 **OR** ASTM A 240/A 240M, Type 430 **OR** ASTM A 959, Type 29-4C, **as directed**, stainless steel.
4. Accessories:
   a. Fittings: Tees, elbows, increasers, draft-hood connectors, metal caps with bird barriers, adjustable roof flashings, storm collars, support assemblies, thimbles, firestop spacers, and fasteners; fabricated from similar or compatible materials and designs.
   b. Sealant: Manufacturer's standard high-temperature sealant.
   c. Insulating Fill: Manufacturer's standard high-temperature insulation fill material in annular space surrounding chimney liner including high-temperature, ceramic-fiber insulation required to seal chimney at top and bottom.

B. Listed Type B And BW Vents
1. Description: Double-wall metal vents tested according to UL 441 and rated for 480 deg F (248 deg C) continuously for Type B, or 550 deg F (288 deg C) continuously for Type BW; with neutral or negative flue pressure complying with NFPA 211.
2. Construction: Inner shell and outer jacket separated by at least a 1/4-inch (6-mm) airspace.
3. Inner Shell: ASTM B 209 (ASTM B 209M), Type 1100 aluminum **OR** ASTM B 209 (ASTM B 209M), Type 3003 aluminum **OR** ASTM B 209 (ASTM B 209M), Type 3105 aluminum **OR** ASTM A 666, Type 430 stainless steel, **as directed**.
4. Outer Jacket: Galvanized **OR** Aluminized, **as directed**, steel.
5. Accessories: Tees, elbows, increasers, draft-hood connectors, terminations, adjustable roof flashings, storm collars, support assemblies, thimbles, firestop spacers, and fasteners; fabricated from similar materials and designs as vent-pipe straight sections; all listed for same assembly.
   a. Termination:
      1) Stack cap designed to exclude minimum 90 percent of rainfall.
      OR
      Round chimney top designed to exclude minimum 98 percent of rainfall.
      OR
      Exit cone with drain section incorporated into riser.
      OR
      Antibackdraft.

C. Listed Type L Vents
1. Description: Double-wall metal vents tested according to UL 641 and rated for 570 deg F (300 deg C) continuously, or 1700 deg F (926 deg C) for 10 minutes; with neutral or negative flue pressure complying with NFPA 211.
2. Construction: Inner shell and outer jacket separated by at least a 1/4-inch (6-mm) **OR** 1-inch (25-mm) **OR** 2-inch (50-mm) **OR** 4-inch (100-mm), **as directed**, airspace filled with high-temperature, ceramic-fiber **OR** mineral-wool, **as directed**, insulation.
3. Inner Shell: ASTM A 666, Type 304 **OR** Type 316, **as directed**, stainless steel.
4. Outer Jacket: Galvanized **OR** Aluminized **OR** Stainless, **as directed**, steel.
5. Accessories: Tees, elbows, increasers, draft-hood connectors, terminations, adjustable roof flashings, storm collars, support assemblies, thimbles, firestop spacers, and fasteners; fabricated from similar materials and designs as vent-pipe straight sections; all listed for same assembly.
   a. Termination:
      1) Stack cap designed to exclude 90 percent of rainfall.
      OR
      Round chimney top designed to exclude 98 percent of rainfall.
      OR
      Exit cone with drain section incorporated into riser.

D. Listed Special Gas Vents
1. Description: Double-wall metal vents tested according to UL 1738 and rated for 480 deg F (248 deg C) continuously, with positive or negative flue pressure complying with NFPA 211.

2. Construction: Inner shell and outer jacket separated by at least a 1/2-inch (13-mm) airspace.
3. Inner Shell: ASTM A 959, Type 29-4C stainless steel.
4. Outer Jacket: Aluminized **OR** Stainless, **as directed**, steel.
5. Accessories: Tees, elbows, increasers, draft-hood connectors, terminations, adjustable roof flashings, storm collars, support assemblies, thimbles, firestop spacers, and fasteners; fabricated from similar materials and designs as vent-pipe straight sections; all listed for same assembly.
   a. Termination:
      1) Stack cap designed to exclude minimum 90 percent of rainfall.
         OR
         Round chimney top designed to exclude minimum 98 percent of rainfall.
         OR
         Exit cone with drain section incorporated into riser.

E. Listed Building-Heating-Appliance Chimneys
1. Description for building-heating-appliance chimneys suitable for dual-fuel boilers, oven vents, water heaters, or exhaust for engines: Double-wall metal vents tested according to UL 103 and rated for 1000 deg F (538 deg C) continuously, or 1700 deg F (926 deg C) for 10 minutes; with neutral or negative flue pressure complying with NFPA 211.
   a. Construction: Inner shell and outer jacket separated by at least a 1/2-inch (25-mm) **OR** 1-inch (50-mm) **OR** 2-inch (50-mm) **OR** 3-inch (75-mm) **OR** 4-inch (100-mm), **as directed**, annular space filled with high-temperature, ceramic-fiber insulation, **as directed**.
   b. Inner Shell: ASTM A 666, Type 304 **OR** Type 316, **as directed**, stainless steel.
2. Description for 1400 deg F (760 deg C) chimneys suitable for dual-fuel boilers, oven vents, water heaters, or exhaust for engines: Double-wall metal vents tested according to UL 103 and UL 959 and rated for 1400 deg F (760 deg C) continuously, or 1800 deg F (982 deg C) for 10 minutes; with positive or negative flue pressure complying with NFPA 211.
   a. Construction: Inner shell and outer jacket separated by at least a 1-inch (25-mm) **OR** 2-inch (50-mm) **OR** 3-inch (75-mm) **OR** 4-inch (100-mm), **as directed**, annular space filled with high-temperature, ceramic-fiber insulation.
   b. Inner Shell: ASTM A 666, Type 304 **OR** Type 316, **as directed**, stainless steel.
3. Description for Type HT chimneys suitable for fireplaces and other solid-fuel-burning appliances: Double-wall metal vents tested according to UL 103 and rated for 1000 deg F (538 deg C) continuously, or 2100 deg F (1150 deg C) for 10 minutes; with neutral or negative flue pressure complying with NFPA 211.
   a. Construction: Inner shell and outer jacket separated by at least a 1-inch (25-mm) **OR** 1-1/2-inch (38-mm) **OR** 2-inch (50-mm) **OR** 4-inch (100-mm), **as directed**, annular space filled with high-temperature, ceramic-fiber insulation.
   b. Inner Shell: ASTM A 666, Type 304 **OR** ASTM A 666, Type 316 **OR** ASTM A 240/A 240M, Type 430, **as directed**, stainless steel.
4. Outer Jacket: Galvanized **OR** Aluminized **OR** Stainless, **as directed**, steel.
5. Accessories: Tees, elbows, increasers, draft-hood connectors, terminations, adjustable roof flashings, storm collars, support assemblies, thimbles, firestop spacers, and fasteners; fabricated from similar materials and designs as vent-pipe straight sections; all listed for same assembly.
   a. Termination:
      1) Stack cap designed to exclude minimum 90 percent of rainfall.
         OR
         Round chimney top designed to exclude minimum 98 percent of rainfall.
         OR
         Exit cone with drain section incorporated into riser.

F. Listed Grease Ducts
1. Description: Double-wall metal vents tested according to UL 1978 and rated for 500 deg F (260 deg C) continuously, or 2000 deg F (1093 deg C) for 30 minutes; with positive or negative duct pressure and complying with NFPA 211.

2. Construction: Inner shell and outer jacket separated by at least a 1-inch (25-mm) **OR** 2-inch (50-mm) **OR** 3-inch (75-mm) **OR** 4-inch (100-mm), **as directed**, annular space filled with high-temperature, ceramic-fiber insulation.
3. Inner Shell: ASTM A 666, Type 304 **OR** Type 316, **as directed**, stainless steel.
4. Outer Jacket: Aluminized **OR** Stainless, **as directed**, steel where concealed. Stainless steel where exposed.
5. Accessories: Tees, elbows, increasers, hood connectors, terminations, adjustable roof flashings, storm collars, support assemblies, thimbles, firestop spacers, and fasteners; fabricated from similar materials and designs as vent-pipe straight sections; all listed for same assembly. Include unique components required to comply with NFPA 96 including cleanouts, transitions, adapters and drain fittings.

G. Listed, Refractory-Lined Metal Breechings And Chimneys
1. Comply with ASME STS-1.
2. Design Wind Loads: 150 mph (241 km/h), **as directed**.
3. Design for seismic conditions at Project site.
4. Chimney Outer Jacket: Aluminized **OR** Galvanized, **as directed**, steel with riveted **OR** welded, **as directed**, seams.
5. Refractory Lining: Tested according to UL 959 for temperature and acid resistance, and bearing the testing laboratory label.
   a. Temperature Rating: 1800 deg F (982 deg C) continuously, and 2000 deg F (1093 deg C) intermittently.
   b. Acid Extraction: Maximum of 0.2 percent.
   c. Cold Crushing Strength: Minimum of 3200 psig (22 MPa).
   d. Thickness: Minimum of 2 inches (50 mm).
6. Finish: Factory-applied, high-heat-resistant paint; color as selected.
7. Base Section: Acid-resistant-coated, cast-iron anchor lugs for securing stack to foundation with anchorage designed by manufacturer, **as directed**.
8. Reinforced Cleanout Section: Smoke-tight connection, with gasketed and bolt-tightened inspection plate; neck shall be welded to stack section.
9. T or Y Sections: Smoke-tight connection, with welded joints and refractory lining; finished with smooth transition and with no exposed metal on inside.
10. Spark Screen: ASTM A 666, Type 316 stainless steel, 0.0625 inch (1.6 mm) thick, maximum 1/2-by-1/2-inch (13-by-13-mm) mesh, with ASTM A 666, Type 304 stainless-steel rolled angle and drawband.
11. Guy Bands: 8-inch- (200-mm-) wide bands of same material as jacket, with bolted fasteners.
12. Roof Penetration: Factory-fabricated thimbles, flashings, and counterflashings.
13. Fabricate sections, fittings, and accessories as individual pieces or in combination lengths for field handling.
14. Fabricate components with centrifugally cast refractory lining in lengths suitable for connection with drawbands.
15. Bond refractory to steel jacket with calcium aluminate cement to prevent separation in finished product during shipping, handling, and installation.
16. Fabricate stacks with anchor lugs; cleanout; T sections; flashings and counterflashings; and provisions for support, expansion, and contraction.

H. Field-Fabricated Metal Breechings And Chimneys
1. Fabricate freestanding chimneys according to SMACNA's "Guide for Steel Stack Design and Construction."
2. Fabricate breechings and chimneys from ASTM A 1011/A 1011M hot-rolled steel with continuously welded joints, complying with NFPA 211 for minimum metal thickness.
   a. Equal to or Less Than 1.069 Sq. Ft. (0.099 Sq. m.) or 14 Inches (356 mm) in Diameter: 0.053 inch (1.35 mm).
   b. Up to 1.396 Sq. Ft. (0.129 Sq. m) or 16 Inches (406 mm) in Diameter: 0.067 inch (1.7 mm).

c. Up to 1.764 Sq. Ft. (0.164 Sq. m.) or 18 Inches (457 mm) in Diameter: 0.093 inch (2.36 mm).
d. Larger Than Above: 0.123 inch (3.12 mm).

3. Fabricate chimneys and vent connectors from galvanized steel, complying with NFPA 211 for minimum metal thickness.
   a. Equal to or Less Than 6 Inches (152 mm) in Diameter: 0.019 inch (0.48 mm).
   b. Up to 10 Inches (254 mm) in Diameter: 0.024 inch (0.61 mm).
   c. Up to 16 Inches (406 mm) in Diameter: 0.029 inch (0.74 mm).
   d. Larger Than Above: 0.056 inch (1.42 mm).
4. Fabricate chimneys and vent connectors from ASTM B 209 (ASTM B 209M), Type 1100 or 3003, aluminum or stainless steel, complying with NFPA 211 for the following minimum metal thicknesses:
   a. Aluminum: 0.027 inch (0.69 mm).
   b. Stainless Steel: 0.012 inch (0.31 mm).
5. Fabricate cleanout doors from compatible material, same thickness as breeching, bolted and gasketed.
6. Fabricate engine exhaust from ASTM A 53/A 53M, Type E (electric-resistance welded), Grade B; or ASTM A 106, Type S, Grade B, Schedule 40 **OR** Schedule 80, **as directed**, pipe; with welded joints and carbon-steel fittings and flanges.
   a. Wrought-Steel Fittings: ASME B16.9, wall thickness to match adjoining pipe.
   b. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, Class 150, including bolts, nuts, and gaskets.

I. Guying And Bracing Materials
1. Cable: Three **OR** Four, **as directed**, galvanized, stranded wires of the following thickness:
   a. Minimum Size: 1/4 inch (6 mm) in diameter.
   b. For ID Sizes 4 to 15 Inches (100 to 381 mm): 5/16 inch (8 mm).
   c. For ID Sizes 18 to 24 Inches (457 to 610 mm): 3/8 inch (9.5 mm).
   d. For ID Sizes 27 to 30 Inches (685 to 762 mm): 7/16 inch (11 mm).
   e. For ID Sizes 33 to 36 Inches (838 to 915 mm): 1/2 inch (13 mm).
   f. For ID Sizes 39 to 48 Inches (990 to 1220 mm): 9/16 inch (14.3 mm).
   g. For ID Sizes 51 to 60 Inches (1295 to 1524 mm): 5/8 inch (16 mm).
2. Pipe: Two **OR** Three, **as directed**, galvanized steel, NPS 1-1/4 (DN 32).
3. Angle Iron: Two **OR** Three, **as directed**, galvanized steel, 2 by 2 by 0.25 inch (50 by 50 by 6 mm).

1.3 EXECUTION

A. Application
1. Listed Chimney Liners: High-efficiency boiler or furnace vents in masonry chimney, dishwasher exhaust, or Type II commercial kitchen hood.
2. Listed Type B and BW Vents: Vents for certified gas appliances.
3. Listed Type L Vents: Vents for low-heat appliances.
4. Listed Special Gas Vents: Condensing gas appliances.
5. Listed Building-Heating-Appliance Chimneys: Dual-fuel boilers, oven vents, water heaters, and exhaust for engines. Fireplaces and other solid-fuel-burning appliances.
6. Listed Grease Ducts: Type I commercial kitchen grease duct.
7. Listed, Refractory-Lined Metal Breechings and Chimneys: Freestanding dual-fuel boiler vents, oven vents, water heaters, exhaust for engines, fireplaces, and other solid-fuel-burning appliances.
8. Field-Fabricated Metal Breechings and Chimneys: Dual-fuel boilers, oven vents, water heaters, exhaust for engines, fireplaces, and other solid-fuel-burning appliances.
9. Field-Fabricated Metal Breechings and Chimneys: Steel pipe for use with engine exhaust.

B. Installation Of Listed Vents And Chimneys

1. Locate to comply with minimum clearances from combustibles and minimum termination heights according to product listing or NFPA 211, whichever is most stringent.
2. Seal between sections of positive-pressure vents and grease exhaust ducts according to manufacturer's written installation instructions, using sealants recommended by manufacturer.
3. Support vents at intervals recommended by manufacturer to support weight of vents and all accessories, without exceeding appliance loading.
4. Slope breechings down in direction of appliance, with condensate drain connection at lowest point piped to nearest drain.
5. Lap joints in direction of flow.
6. Connect base section to foundation using anchor lugs of size and number recommended by manufacturer.
7. Join sections with acid-resistant joint cement to provide continuous joint and smooth interior finish.
8. Erect stacks plumb to finished tolerance of no more than 1 inch (25 mm) out of plumb from top to bottom.

C. Installation Of Unlisted, Field-Fabricated Breechings And Chimneys
1. Suspend breechings and chimneys independent of their appliance connections.
2. Install, support, and restrain according to seismic requirements.
3. Align breechings at connections, with smooth internal surface and a maximum 1/8-inch (3-mm) misalignment tolerance.
4. Slope breechings down in direction of appliance, with condensate drain connection at lowest point piped to nearest drain.
5. Lap joints in direction of flow.
6. Support breechings and chimneys from building structure with bolts, concrete inserts, steel expansion anchors, welded studs, C-clamps, or beam clamps according to manufacturer's written instructions.

D. Cleaning
1. After completing system installation, including outlet fittings and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.
2. Clean breechings internally, during and after installation, to remove dust and debris. Clean external surfaces to remove welding slag and mill film. Grind welds smooth and apply touchup finish to match factory or shop finish.
3. Provide temporary closures at ends of breechings, chimneys, and stacks that are not completed or connected to equipment.

END OF SECTION 23 51 13 00

Task	Specification	Specification Description
23 51 16 00	23 51 13 00	Breechings, Chimneys, And Stacks

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SECTION 23 52 16 00 - CONDENSING BOILERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for condensing boilers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes packaged, factory-fabricated and -assembled, gas-fired, pulse-combustion, fire-tube, water-tube, and water-jacketed condensing boilers, trim, and accessories for generating hot water or steam.

C. Submittals
1. Product Data: Include performance data, operating characteristics, furnished specialties, and accessories.
2. Shop Drawings: For boilers, boiler trim, and accessories. Include plans, elevations, sections, details, and attachments to other work.
   a. Design calculations and vibration isolation base details, signed and sealed by a qualified professional engineer.
      1) Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
      2) Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails and equipment mounting frames.
   b. Wiring Diagrams: Power, signal, and control wiring.
3. Manufacturer Seismic Qualification Certification: Submit certification that boiler, accessories, and components will withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment". Include the following:
4. Source quality-control test reports.
5. Field quality-control test reports.
6. Operation and maintenance data.
7. Warranty: Special warranty specified in this Section.
8. Other Informational Submittals:
   a. ASME Stamp Certification and Report: Submit "A," "S," or "PP" stamp certificate of authorization, as required by authorities having jurisdiction, and document hydrostatic testing of piping external to boiler.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. ASME Compliance: Fabricate and label boilers to comply with ASME Boiler and Pressure Vessel Code.
3. ASHRAE/IESNA 90.1 Compliance: Boilers shall have minimum efficiency according to "Gas and Oil Fired Boilers - Minimum Efficiency Requirements."
4. DOE Compliance: Minimum efficiency shall comply with 10 CFR 430, Subpart B, Appendix N, "Uniform Test Method for Measuring the Energy Consumption of Furnaces and Boilers."
5. UL Compliance: Test boilers for compliance with UL 795, "Commercial-Industrial Gas Heating Equipment." Boilers shall be listed and labeled by a testing agency acceptable to authorities having jurisdiction.

E. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of boilers that fail in materials or workmanship within specified warranty period.
   a. Warranty Period for Pulse-Combustion Boilers:
      1) Heat Exchanger Damaged by Thermal Shock: 10 years from date of Final Completion.
      2) Heat-Exchanger Corrosion: Prorated **OR** Nonprorated, **as directed**, for five years from date of Final Completion.
   b. Warranty Period for Fire-Tube Condensing Boilers:
      1) Leakage and Materials: 10 years from date of Final Completion.
      2) Heat Exchanger Damaged by Thermal Stress and Corrosion: Prorated **OR** Nonprorated for five years from date of Final Completion.
   c. Warranty Period for Water-Tube Condensing Boilers: 20 years from date of Final Completion.
   d. Warranty Period for Water-Jacketed Condensing Boilers:
      1) Leakage and Materials: Eight years from date of Final Completion.
      2) Heat Exchanger Damaged by Thermal Stress and Corrosion: Prorated **OR** Nonprorated, **as directed**, for five years from date of Final Completion.

1.2 PRODUCTS

A. Manufactured Units: Pulse-Combustion Condensing Boilers.
1. Description: Factory-fabricated, -assembled, and -tested, pulse-combustion condensing boiler with heat exchanger sealed pressure tight, built on a steel base; including insulated jacket; flue-gas vent; combustion-air intake connections; water supply, return, and condensate drain connections; and controls.
2. Heat Exchanger: Type 316L, stainless-steel **OR** Carbon-steel, **as directed**, primary and secondary combustion chamber.
3. Pressure Vessel: Carbon steel with welded heads and tube connections.
4. Exhaust Decoupler: Fiberglass composite material in a corrosion-resistant steel box.
5. Burner: Natural **OR** Propane, **as directed**, gas, self-aspirating and self-venting after initial start.
6. Blower: Centrifugal fan to operate only during start of each burner sequence.
   a. Motors: Comply with requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
      1) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
7. Gas Train: Combination gas valve with manual shutoff and pressure regulator.
8. Ignition: Spark ignition with 100 percent main-valve shutoff with electronic flame supervision.
9. Casing:
   a. Jacket: Sheet metal, with snap-in or interlocking closures.
   b. Control Compartment Enclosure: NEMA 250, Type 1A.
   c. Finish: Baked-enamel **OR** Powder-coated, **as directed**, protective finish.
   d. Insulation: Minimum 2-inch- (50-mm-) thick, mineral-fiber insulation surrounding the heat exchanger.
   e. Draft Hood: Integral **OR** External, **as directed**.
   f. Combustion-Air Connection: Inlet duct collar and sheet metal closure over burner compartment.
   g. Mounting base to secure boiler to concrete base.
      1) Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler pressure vessel, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" when mounting base is anchored to building structure.

10. Mufflers: Carbon-steel intake muffler and stainless-steel exhaust.
11. Condensate Trap: Cast-iron body with stainless-steel internal parts.

B. Manufactured Units: Fire-Tube Condensing Boilers.
1. Description: Factory-fabricated, -assembled, and -tested, fire-tube condensing boiler with heat exchanger sealed pressure tight, built on a steel base; including insulated jacket; flue-gas vent; combustion-air intake connections; water supply, return, and condensate drain connections; and controls. Water heating service only.
2. Heat Exchanger: Nonferrous, corrosion-resistant combustion chamber.
3. Pressure Vessel: Carbon steel with welded heads and tube connections.
4. Burner: Natural **OR** Propane, **as directed**, gas, forced draft.
5. Blower: Centrifugal fan to operate during each burner firing sequence and to prepurge and postpurge the combustion chamber.
   a. Motors: Comply with requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
      1) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
6. Gas Train: Combination gas valve with manual shutoff and pressure regulator.
7. Ignition: Spark ignition with 100 percent main-valve shutoff with electronic flame supervision.
8. Casing:
   a. Jacket: Sheet metal **OR** Plastic, **as directed**, with snap-in or interlocking closures.
   b. Control Compartment Enclosures: NEMA 250, Type 1A.
   c. Finish: Baked-enamel **OR** Powder-coated, **as directed**, protective finish for sheet metal jacket.
   d. Insulation: Minimum 2-inch- (50-mm-) thick, mineral-fiber **OR** polyurethane-foam, **as directed**, insulation surrounding the heat exchanger.
   e. Combustion-Air Connections: Inlet and vent duct collars.
   f. Mounting base to secure boiler.
      1) Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler pressure vessel, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" when mounting base is anchored to building structure.

C. Manufactured Units: Water-Tube Condensing Boilers.
1. Description: Factory-fabricated, -assembled, and -tested, water-tube condensing boiler with heat exchanger sealed pressure tight, built on a steel base; including insulated jacket; flue-gas vent; combustion-air intake connections; water supply, return, and condensate drain connections; and controls. Water heating service only.
2. Heat Exchanger: Finned-copper primary and stainless-steel secondary heat exchangers.
3. Combustion Chamber: Stainless steel, sealed.
4. Burner: Natural **OR** Propane, **as directed**, gas, forced draft drawing from gas premixing valve.
5. Blower: Centrifugal fan to operate during each burner firing sequence and to prepurge and postpurge the combustion chamber.
   a. Motors: Comply with requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
      1) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
6. Gas Train: Combination gas valve with manual shutoff and pressure regulator.
7. Ignition: Silicone carbide hot-surface ignition that includes flame safety supervision and 100 percent main-valve shutoff.
8. Integral Circulator: Cast-iron body and stainless-steel impeller sized for minimum flow required in heat exchanger.
9. Casing:
   a. Jacket: Sheet metal, with snap-in or interlocking closures.
   b. Control Compartment Enclosures: NEMA 250, Type 1A.

c. Finish: Textured epoxy.
d. Insulation: Minimum 1-inch- (25-mm-) **OR** 2-inch- (50-mm-), **as directed**, thick, mineral-fiber insulation surrounding the heat exchanger.
e. Combustion-Air Connections: Inlet and vent duct collars.
f. Mounting base to secure boiler.
1) Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler pressure vessel, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" when mounting base is anchored to building structure.

D. Manufactured Units: Water-Jacketed Condensing Boilers.
1. Description: Factory-fabricated, -assembled, and -tested, water-jacketed condensing boiler with heat exchanger sealed pressure tight, built on a steel base; including insulated jacket; flue-gas vent; water supply, return, and condensate drain connections; and controls. Water heating service only.
2. Heat Exchanger: Stainless-steel primary and secondary combustion chamber.
3. Pressure Vessel: Carbon steel with welded heads and tube connections where not in contact with combustion or flue gases.
4. Burner: Natural **OR** Propane, **as directed**, gas, forced draft; swing-open front and burner observation port.
5. Blower: Centrifugal fan, forced draft. Include prepurge and postpurge of the combustion chamber.
a. Motors: Comply with requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
1) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
6. Gas Train: Combination gas valve with manual shutoff and pressure regulator. Include 100 percent safety shutoff with electronic flame supervision.
7. Ignition: Electric-spark ignition with 100 percent main-valve shutoff with electronic flame supervision.
8. Casing:
a. Jacket: Sheet metal, with snap-in or interlocking closures.
b. Control Compartment Enclosures: NEMA 250, Type 1A.
c. Finish: Powder-coated protective finish.
d. Insulation: Minimum 4-inch- (100-mm-) thick, mineral-fiber insulation surrounding the heat exchanger.
e. Combustion-Air Connections: Inlet and vent duct collars.
f. Mounting base to secure boiler.
1) Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler pressure vessel, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" when mounting base is anchored to building structure.

E. Trim: For Hot-Water Boilers.
1. Include devices sized to comply with ANSI B31.1, "Power Piping **OR** ANSI B31.9, "Building Services Piping", **as directed**.
2. Aquastat Controllers: Operating, firing rate, **as directed**, and high limit.
3. Safety Relief Valve: ASME rated.
4. Pressure and Temperature Gage: Minimum 3-1/2-inch- (89-mm-) diameter, combination water-pressure and -temperature gage. Gages shall have operating-pressure and -temperature ranges so normal operating range is about 50 percent of full range.
5. Boiler Air Vent: Automatic **OR** Manual, **as directed**.
6. Drain Valve: Minimum NPS 3/4 (DN 20) hose-end gate valve.

7. Circulation Pump: Non-overloading, in-line pump with split-capacitor motor having thermal-overload protection and lubricated bearings; designed to operate at specified boiler pressures and temperatures.

F. Trim: For Steam Boilers.
1. Include devices sized to comply with ANSI B31.1, "Power Piping **OR** ANSI B31.9, "Building Services Piping", **as directed**.
2. Pressure Controllers: Operating, firing rate, **as directed**, and high limit.
3. Safety Relief Valve:
   a. Size and Capacity: As required for equipment according to ASME Boiler and Pressure Vessel Code.
   b. Description: Fully enclosed steel spring with adjustable pressure range and positive shutoff; factory set and sealed.
      1) Drip-Pan Elbow: Cast iron and having threaded inlet and outlet with threads complying with ASME B1.20.1.
4. Pressure Gage: Minimum 3-1/2-inch (89-mm) diameter. Gage shall have normal operating pressure about 50 percent of full range.
5. Water Column: Minimum 12-inch (300-mm) glass gage with shutoff cocks.
6. Drain Valves: Minimum NPS 3/4 (DN 20) or nozzle size with hose-end connection.
7. Blowdown Valves: Factory-installed bottom and surface, slow-acting blowdown valves same size as boiler nozzle. Blowdown valves shall be combination of slow and quick acting as required by ANSI B31.1, **as directed**.
8. Stop Valves: Boiler inlets and outlets, except safety relief valves or preheater inlet and outlet, shall be equipped with stop valve in an accessible location as near as practical to boiler nozzle and same size or larger than nozzle. Valves larger than NPS 2 (DN 50) shall have rising stem.
9. Stop-Check Valves: Factory-installed, stop-check valve and stop valve at boiler outlet with free-blow drain valve factory installed between the two valves and visible when operating stop-check valve.

G. Controls
1. Refer to Division 23 Section "Instrumentation And Control For Hvac".
   OR
   Boiler operating controls shall include the following devices and features:
   a. Operating Pressure Control for Steam Boilers: Factory wired and mounted to cycle burner.
   b. Low-Water Cutoff and Pump Control for Steam Boilers: Cycle feedwater pump(s) for makeup water control.
   c. Sequence of Operation for Hot-Water Boilers: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain space temperature in response to thermostat with heat anticipator located in heated space.
      OR
      Sequence of Operation for Hot-Water Boilers: Electric, factory-fabricated and field-installed panel to control burner firing rate to reset supply-water temperature inversely with outside-air temperature. At 0 deg F (minus 17 deg C) outside-air temperature, set supply-water temperature at 200 deg F (93 deg C); at 60 deg F (15 deg C) outside-air temperature, set supply-water temperature at 140 deg F (60 deg C).
   d. Sequence of Operation for Steam Boilers: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain a constant steam pressure. Maintain pressure set point plus or minus 10 percent.
      1) Include automatic, alternating-firing sequence for multiple boilers to ensure maximum system efficiency throughout the load range and to provide equal runtime for boilers.
2. Burner Operating Controls: To maintain safe operating conditions, burner safety controls limit burner operation.
   a. High Cutoff: Manual **OR** Automatic, **as directed**, reset stops burner if operating conditions rise above maximum boiler design temperature for hot-water boiler or pressure for steam boiler.

b. Low-Water Cutoff Switch: Electronic for hot-water boilers or Float and electronic for steam boilers probe shall prevent burner operation on low water. Cutoff switch shall be manual **OR** automatic, **as directed**,-reset type.
c. Blocked Inlet Safety Switch: Manual-reset pressure switch field mounted on boiler combustion-air inlet.
d. Audible Alarm: Factory mounted on control panel with silence switch; shall sound alarm for above conditions.

3. Building Automation System Interface: Factory install hardware and software to enable building automation system to monitor, control, and display boiler status and alarms.
   a. Hardwired Points:
      1) Monitoring: On/off status, common trouble alarm **OR** low water level alarm, **as directed**.
      2) Control: On/off operation, hot water supply temperature set-point adjustment **OR** steam pressure adjustment, **as directed**.
   b. A communication interface with building automation system shall enable building automation system operator to remotely control and monitor the boiler from an operator workstation. Control features available, and monitoring points displayed, locally at boiler control panel shall be available through building automation system.

H. Electrical Power
1. Controllers, Electrical Devices, and Wiring: Electrical devices and connections are specified in Division 22.
   OR
   Single-Point Field Power Connection: Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to boiler.
   a. House in NEMA 250, Type 1 enclosure.
   b. Wiring shall be numbered and color-coded to match wiring diagram.
   c. Install factory wiring outside of an enclosure in a metal raceway.
   d. Field power interface shall be to wire lugs **OR** fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**.
   e. Provide branch power circuit to each motor and to controls with a disconnect switch or circuit breaker, **as directed**.
   f. Provide each motor with overcurrent protection.

I. Venting Kits
1. Kit: Complete system, ASTM A 959, Type 29-4C stainless steel, pipe, vent terminal, thimble, indoor plate, vent adapter, condensate trap and dilution tank, and sealant.
2. Combustion-Air Intake: Complete system, stainless steel, pipe, vent terminal with screen, inlet air coupling, and sealant.

J. Source Quality Control
1. Burner and Hydrostatic Test: Factory adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency; perform hydrostatic test.
2. Test and inspect factory-assembled boilers, before shipping, according to ASME Boiler and Pressure Vessel Code.
3. Allow the Owner access to source quality-control testing of boilers. Notify the Owner 14 days in advance of testing.

1.3 EXECUTION

A. Boiler Installation

1. Install boilers level on concrete base. Concrete base is specified in Division 23 Section "Common Work Results For Hvac", and concrete materials and installation requirements are specified in Division 31..
2. Vibration Isolation for Equipment Supported on Slabs-On -Grade: Elastomeric isolation pads **OR** mounts, **as directed**, with a minimum static deflection of 0.25 inch (6.35 mm). Vibration isolation devices and installation requirements are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
3. Install gas-fired boilers according to NFPA 54.
4. Assemble and install boiler trim.
5. Install electrical devices furnished with boiler but not specified to be factory mounted.
6. Install control wiring to field-mounted electrical devices.

B. Connections
1. Piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
2. Install piping adjacent to boiler to allow service and maintenance.
3. Install piping from equipment drain connection to nearest floor drain. Piping shall be at least full size of connection. Provide an isolation valve if required.
4. Connect piping to boilers, except safety relief valve connections, with flexible connectors of materials suitable for service. Flexible connectors and their installation are specified in Division 23 Section "Common Work Results For Hvac".
5. Connect gas piping to boiler gas-train inlet with union. Piping shall be at least full size of gas train connection. Provide a reducer if required.
6. Connect hot-water piping to supply- and return-boiler tappings with shutoff valve and union or flange at each connection.
7. Connect steam and condensate piping to supply-, return-, and blowdown-boiler tappings with shutoff valve and union or flange at each connection.
8. Install piping from safety relief valves to nearest floor drain.
9. Install piping from safety valves to drip-pan elbow and to nearest floor drain.
10. Boiler Venting:
    a. Install flue venting kit and combustion-air intake.
    b. Connect full size to boiler connections. Comply with requirements in Division 23 Section "Breechings, Chimneys, And Stacks".
11. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
12. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

C. Field Quality Control
1. Perform tests and inspections and prepare test reports.
    a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
2. Tests and Inspections:
    a. Perform installation and startup checks according to manufacturer's written instructions.
    b. Leak Test: Hydrostatic test. Repair leaks and retest until no leaks exist.
    c. Operational Test: Start units to confirm proper motor rotation and unit operation. Adjust air-fuel ratio and combustion.
    d. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
        1) Check and adjust initial operating set points and high- and low-limit safety set points of fuel supply, water level and water temperature **OR** steam pressure, **as directed**.
        2) Set field-adjustable switches and circuit-breaker trip ranges as indicated.
3. Remove and replace malfunctioning units and retest as specified above.

4. Occupancy Adjustments: When requested within 12 months of date of Final Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other than normal occupancy hours for this purpose.
5. Performance Tests, **as directed**:
    a. Engage a factory-authorized service representative to inspect component assemblies and equipment installations, including connections, and to conduct performance testing.
    b. Boilers shall comply with performance requirements indicated, as determined by field performance tests. Adjust, modify, or replace equipment to comply.
    c. Perform field performance tests to determine capacity and efficiency of boilers.
        1) Test for full capacity.
        2) Test for boiler efficiency at low fire 20, 40, 60, 80, 100, 80, 60, 40, and 20 percent of full capacity. Determine efficiency at each test point.
    d. Repeat tests until results comply with requirements indicated.
    e. Provide analysis equipment required to determine performance.
    f. Provide temporary equipment and system modifications necessary to dissipate the heat produced during tests if building systems are not adequate.
    g. Notify the Owner in advance of test dates.
    h. Document test results in a report and submit to the Owner.

D. Demonstration
1. Train the Owner's maintenance personnel to adjust, operate, and maintain boilers.

END OF SECTION 23 52 16 00

Task	Specification	Specification Description
23 52 16 13	23 52 16 00	Condensing Boilers
23 52 16 16	23 52 16 00	Condensing Boilers
23 52 16 19	23 52 16 00	Condensing Boilers
23 52 16 23	23 52 16 00	Condensing Boilers

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SECTION 23 52 33 13 - WATER-TUBE BOILERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for water-tube boilers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes packaged, factory-fabricated and -assembled, gas-fired, finned water-tube boilers, trim, and accessories for generating hot water.
2. This Section includes packaged, water-tube boilers, trim, and accessories for generating hot water or steam with the following configurations, burners, and outputs:
   a. Factory and Field assembled.
   b. Atmospheric gas, Forced-draft gas, Oil, and Combination gas and oil burner.

C. Submittals
1. Product Data: Include performance data, operating characteristics, furnished specialties, and accessories.
2. Shop Drawings: For boilers, boiler trim, and accessories. Include plans, elevations, sections, details, and attachments to other work.
   a. Design calculations and vibration isolation base details, signed and sealed by a qualified professional engineer.
      1) Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
      2) Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails and equipment mounting frames.
   b. Wiring Diagrams: Power, signal, and control wiring.
3. Manufacturer Seismic Qualification Certification: Submit certification that boiler, accessories, and components will withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment". Include the following:
4. Source quality-control test reports.
5. Field quality-control test reports.
6. Operation and maintenance data.
7. Warranty: Special warranty specified in this Section.
8. Other Informational Submittals:
   a. ASME "A" Stamp Certification and Report: Submit "A" stamp certificate of authorization as required by authorities having jurisdiction, and document hydrostatic testing of piping external to boiler.
   b. Startup service reports.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. ASME Compliance: Fabricate and label boilers to comply with ASME Boiler and Pressure Vessel Code.
3. ASHRAE/IESNA 90.1 Compliance: Boilers shall have minimum efficiency according to "Gas and Oil Fired Boilers - Minimum Efficiency Requirements."
4. DOE Compliance: Minimum efficiency shall comply with 10 CFR 430, Subpart B, Appendix N, "Uniform Test Method for Measuring the Energy Consumption of Furnaces and Boilers."

5. I=B=R Compliance: Boilers shall be tested and rated according to HI's "Rating Procedure for Heating Boilers" and "Testing Standard for Commercial Boilers," with I=B=R emblem on a nameplate affixed to boiler.
6. UL Compliance: Test boilers for compliance with UL 726, "Oil-Fired Boiler Assemblies" **OR** UL 726, "Oil-Fired Boiler Assemblies" and UL 795, "Commercial-Industrial Gas Heating Equipment" **OR** UL 795, "Commercial-Industrial Gas Heating Equipment", **as directed**. Boilers shall be listed and labeled by a testing agency acceptable to authorities having jurisdiction.

E. Warranty
1. Special Warranty for Finned Water-Tube Boilers: Manufacturer's standard form in which manufacturer agrees to repair or replace heat exchangers damaged by thermal shock and vent dampers of boilers that fail in materials or workmanship within specified warranty period.
   a. Warranty Period for Heat Exchangers: 20 years from date of Final Completion.
   b. Warranty Period for Vent Dampers: Five years from date of Final Completion.
2. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace drums, tubes, headers, cabinets, atmospheric gas burners, and pressure vessels of boilers that fail in materials or workmanship within specified warranty period.
   a. Warranty Period for Drums, Tubes, Headers, Cabinets, and Atmospheric Gas Burner: Five years from date of Final Completion, pro rata.
   b. Warranty Period for Pressure Vessel: 20 years from date of Final Completion, for thermal shock.

1.2 PRODUCTS

A. Finned Water-Tube Boilers
1. Description: Factory-fabricated, -assembled, and -tested boiler with tubes sealed into headers pressure tight, and set on a steel base; including insulated jacket, flue-gas vent, combustion-air intake connections, water supply and return connections, and controls.
2. Heat Exchanger:
   a. Finned copper **OR** steel **OR** copper-nickel, **as directed**, tubing with stainless-steel baffles.
   b. Bronze **OR** Cast-iron **OR** Steel, **as directed**, headers.
   c. Single-pass **OR** Two-pass, **as directed**, horizontal **OR** vertical **OR** coil, **as directed**, configuration.
   d. Tubes shall be sealed in header with silicone O-ring gaskets **OR** by welding **OR** by mechanically rolling tubes in header, **as directed**.
3. Combustion Chamber Internal Insulation: Interlocking panels of refractory insulation, high-temperature cements, mineral fiber, and ceramic refractory tile for service temperatures to 2000 deg F (1100 deg C).
4. Casing:
   a. Jacket: Sheet metal **OR** Stainless steel, **as directed**, with snap-in or interlocking closures.
   b. Control Compartment Enclosure: NEMA 250, Type 1A.
   c. Finish: Baked enamel over primer **OR** Baked enamel over galvanizing **OR** Powder coated, **as directed**.
   d. Insulation: Minimum 1-inch- (25-mm-) **OR** 2-inch- (50-mm-), **as directed**, thick, mineral-fiber insulation surrounding the heat exchanger.
   e. Draft Hood: Integral **OR** External, **as directed**.
   f. Combustion-Air Connection: Inlet duct collar and sheet metal closure over burner compartment.
   g. Mounting base to secure boiler with accessory for mounting on combustible surface, **as directed**.
      1) Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler pressure vessel, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration And

Seismic Controls For Hvac Piping And Equipment" when mounting base is anchored to building structure.

5. Burner:
   a. Burner Tubes and Orifices: Stainless steel, for natural **OR** propane, **as directed**, gas. Mount burner tubes in a slide-out burner drawer for ease of inspection, **as directed**.
      1) Sealed Combustion: Factory-mounted centrifugal fan to draw outside air into boiler and discharge into burner compartment.
      2) Direct Vent: Factory-mounted centrifugal fan to draw flue gas out of boiler and discharge into boiler vent.
   b. Vertical Burner:
      1) High-temperature stainless steel **OR** Ceramic, **as directed**, to fire in a 360-degree pattern.
      2) Burner shall have a viewing port for observation of burner operation and a factory-mounted centrifugal fan to supply room **OR** outside, **as directed**, air through a replaceable 99 percent efficient (1-micrometer particles) filter, **as directed**, to boiler burner.
      3) Fan shall be controlled to prepurge and postpurge the combustion chamber before firing.
   c. Gas Train for Commercial Boilers: Control devices and full-modulation **OR** on-off **OR** low-high-low **OR** proportional, **as directed**, control sequence shall comply with requirements in AGA **OR** ASME CSD-1 **OR** FMG **OR** IRI **OR** UL, **as directed**. In addition to these requirements, include shutoff cock, pressure regulator, and control valve.
   d. Gas Train for Residential Boilers: Combination gas valve with manual shutoff, pressure regulator, and pilot adjustment.
   e. Pilot: Standing **OR** Intermittent-electric-spark **OR** Hot-surface, **as directed**, pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.
   f. Flue-Gas Recirculation Fans: Centrifugal fans on burner assembly to recirculate flue gas to decrease oxides of nitrogen emissions to less than 30 ppm.

   g. Motors: Comply with requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
6. Trim:
   a. Aquastat Controllers: Operating, firing rate, **as directed**, and high limit.
   b. Safety Relief Valve: ASME rated.
   c. Pressure and Temperature Gage: Minimum 3-1/2-inch- (89-mm-) diameter, combination water-pressure and -temperature gage. Gages shall have operating-pressure and -temperature ranges so normal operating range is about 50 percent of full range.
   d. Boiler Air Vent: Automatic **OR** Manual, **as directed**.
   e. Drain Valve: Minimum NPS 3/4 (DN 20) hose-end gate valve.
   f. Circulation Pump: Non-overloading, in-line pump with split-capacitor motor having thermal-overload protection and lubricated bearings; designed to operate at specified boiler pressures and temperatures.
7. Controls:
   a. Refer to Division 23 Section "Instrumentation And Control For Hvac".
      OR
      Boiler operating controls shall include the following devices and features:
      1) Control transformer.
      2) Motorized Vent Damper: Interlocked with burner to open before burner starts. If damper fails to open, stop burner operation.
      3) Set-Point Adjust: Set points shall be adjustable.
      4) Sequence of Operation: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain space temperature in response to thermostat with heat anticipator located in heated space.
         OR

Sequence of Operation: Electric, factory-fabricated and field-installed panel to control burner firing rate to reset supply-water temperature inversely with outside-air temperature. At 0 deg F (minus 17 deg C) outside-air temperature, set supply-water temperature at 200 deg F (93 deg C); at 60 deg F (15 deg C) outside-air temperature, set supply-water temperature at 140 deg F (60 deg C).

5) Include automatic, alternating-firing sequence for multiple boilers to ensure maximum system efficiency throughout the load range and to provide equal runtime for boilers.

b. Burner Operating Controls: To maintain safe operating conditions, burner safety controls limit burner operation.

1) High Cutoff: Manual **OR** Automatic, **as directed**, reset stops burner if operating conditions rise above maximum boiler design temperature.

2) Water Flow Switch: Automatic-reset paddle-switch shall prevent burner operation on low water flow.

3) Blocked Vent Safety Switch: Manual-reset switch factory mounted on draft diverter.

4) Rollout Safety Switch: Factory mounted on boiler combustion chamber.

5) Audible Alarm: Factory mounted on control panel with silence switch; shall sound alarm for above conditions.

c. Building Automation System Interface: Factory install hardware and software to enable building automation system to monitor, control, and display boiler status and alarms.

1) Monitoring: On/off status, common trouble alarm **OR** low water level alarm, **as directed**.

2) Control: On/off operation, hot water supply temperature set-point adjustment, **as directed**.

3) A communication interface with building automation system shall enable building automation system operator to remotely control and monitor the boiler from an operator workstation. Control features available, and monitoring points displayed, locally at boiler control panel shall be available through building automation system.

B. Steel **OR** Flexible, **as directed**, Water-Tube Boilers

1. Description: Factory-fabricated and assembled **OR** Field-assembled, **as directed**, water-tube boiler with heat exchanger sealed pressure tight, built on a steel base; including insulated jacket, flue-gas vent, supply and return connections, and controls.

2. Heat-Exchanger Design: Straight steel tubes rolled into steel headers.

a. Accessible head plates at both ends.

b. Handholes or couplings, **as directed**, in headers for water-side inspections.

c. Accessible drain and blowdown tappings, both high and low, for surface and mud removal.

d. Lifting lugs on top of boiler.

e. Built-in air separator.

3. Heat-Exchanger Design: Bent steel tubes swaged **OR** welded, **as directed**, into steel headers with membrane waterwall design, **as directed**.

a. Limit tube configurations to two **OR** four, **as directed**.

b. Accessible drain and blowdown tappings, both high and low, for surface and mud removal.

c. Accessible inspection ports in drum, mud legs, and tube manifolds.

d. Lifting lugs on top of boiler.

e. Built-in air separator.

4. Combustion Chamber: Equipped with minimum 2-1/2-inch (64-mm) **OR** 3-inch (75-mm) **OR** 4-inch (100-mm), **as directed**, 2700 deg F (1482 deg C) poured refractory on floor and minimum 2-inch (50-mm) **OR** 3-1/2-inch (89-mm), **as directed**, lap-jointed cast refractory with fiber-blanket joint seals on side walls. Combustion chamber shall have flame observation ports in front and back **OR** back, **as directed**.

5. Casing:

a. Insulation: Minimum 2-inch (50-mm) thick, lightweight refractory; 1-inch (25-mm) thick insulating board; galvanized-steel membrane, and 2-inch (50-mm) thick, mineral-fiber insulation surrounding the heat exchanger and combustion chamber **OR** 2-inch (50-mm)

thick, mineral-fiber insulation surrounding the heat exchanger and combustion chamber, **as directed**.

b. Top Flue Connection: Constructed of aluminized steel **OR** stainless steel, **as directed**.

c. Jacket: Mirror-finish stainless steel, with screw-fastened closures.

OR

Jacket: Sheet metal **OR** Galvanized sheet metal, **as directed**, with screw-fastened closures and baked-enamel **OR** powder-coated, **as directed**, protective finish.

d. Mounting base to secure boiler to concrete base.

1) Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" when mounting base is anchored to building structure.

e. Control Compartment Enclosure: NEMA 250, Type 1A.

6. Draft Diverter **OR** Barometric Damper, **as directed**: Galvanized-steel assembly with flue-gas thermometer.

7. Burner - Atmospheric Gas Burners:

a. Burner and Orifices: Stainless steel **OR** Cast iron, **as directed**, for natural **OR** propane, **as directed**, gas.

b. Gas Train for Commercial Boilers: Control devices and full-modulation **OR** on-off **OR** low-high-low, **as directed**, control sequence shall comply with requirements in AGA **OR** ASME CSD-1 **OR** FMG **OR** IRI **OR** UL, **as directed**.

c. Gas Train for Residential Boilers: Combination gas valve with manual shutoff, pressure regulator, and pilot adjustment.

d. Pilot: Standing **OR** Intermittent-electric-spark, **as directed**, pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.

8. Burner - Forced-Draft Gas Burners:

a. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for natural **OR** propane, **as directed**, gas. Mount burner on hinged access door to permit access to combustion chamber, **as directed**.

b. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.

1) Motors: Comply with requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".

a) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.

c. Gas Train: Control devices and modulating **OR** on-off **OR** low-high-low, **as directed**, control sequence shall comply with requirements in AGA **OR** ASME CSD-1 **OR** FMG **OR** IRI **OR** UL, **as directed**.

d. Pilot: Intermittent **OR** Interrupted, **as directed**,-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.

e. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.

1) Maximum Oxides of Nitrogen Emissions: 20 **OR** 30, **as directed**, ppm.

9. Burner - Oil Burners:

a. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for fuel oil. Mount burner on hinged access door to permit access to combustion chamber, **as directed**.

b. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.

1) Motors: Comply with requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".

a) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.

c. Oil Supply: Control devices and modulating **OR** on-off **OR** low-high-low, **as directed**, control sequence shall comply with requirements in ASME CSD-1 **OR** FMG **OR** IRI **OR** UL, **as directed**.

1) Oil Pump: Two-stage, gear-type oil pump integral to and directly driven by blower, **as directed**, shall be capable of producing 300-psig (2070-kPa) discharge pressure and 15-inch Hg (50.7-kPa) vacuum.
2) Oil Piping Specialties:
a) Suction-line, manual, gate valve.
b) Removable-mesh oil strainer.
c) 0- to 30-inch Hg (0- to 101.3-kPa) vacuum; 0- to 30-psig (0- to 207-kPa) vacuum-pressure gage.
d) 0- to 300-psig (0- to 2070-kPa) oil-nozzle pressure gage.
e) Nozzle-line, solenoid-safety-shutoff oil valve.

d. Pilot: Intermittent **OR** Interrupted, **as directed**,-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff solenoid using cadmium sulfide **OR** UV scanner, **as directed**, flame-safety control.

e. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.
1) Maximum Oxides of Nitrogen Emissions: 30 ppm.

10. Burner - Combination Gas and Oil Burners:

a. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for fuel oil and natural **OR** propane, **as directed** gas. Mount burner on hinged access door to permit access to combustion chamber, **as directed**.

b. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
1) Motors: Comply with requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
a) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.

c. Oil Supply: Control devices and modulating **OR** on-off **OR** low-high-low, **as directed**, control sequence shall comply with requirements in ASME CSD-1 **OR** FMG **OR** IRI, **as directed**.
1) Oil Pump: Two-stage, gear-type oil pump integral to and directly driven by blower, **as directed**, shall be capable of producing 300-psig (2070-kPa) discharge pressure and 15-inch Hg (50.7-kPa) vacuum.
2) Oil Piping Specialties:
a) Suction-line, manual, gate valve.
b) Removable-mesh oil strainer.
c) 0- to 30-inch Hg (0- to 101.3-kPa) vacuum; 0- to 30-psig (0- to 207-kPa) vacuum-pressure gage.
d) 0- to 300-psig (0- to 2070-kPa) oil-nozzle pressure gage.
e) Nozzle-line, solenoid-safety-shutoff oil valve.

d. Gas Train: Control devices and modulating **OR** on-off **OR** low-high-low, **as directed**, control sequence shall comply with requirements in ASME CSD-1 **OR** FMG **OR** IRI **OR** UL, **as directed**.

e. Gas Pilot: Intermittent **OR** Interrupted, **as directed**,-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.

f. Oil Pilot: Intermittent **OR** Interrupted, **as directed**,-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff solenoid with cadmium sulfide **OR** UV scanner, **as directed**, flame-safety control.

g. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.
1) Maximum Oxides of Nitrogen Emissions: 20 **OR** 30, **as directed**, ppm.

11. Trim for Hot-Water Boilers:

a. Include devices sized to comply with ANSI B31.1, "Power Piping **OR** ANSI B31.9, "Building Services Piping", **as directed**.

b. Aquastat Controllers: Operating, firing rate, **as directed**, and high limit.

c. Safety Relief Valve: ASME rated.

d. Pressure and Temperature Gage: Minimum 3-1/2-inch- (89-mm-) diameter, combination water-pressure and -temperature gage. Gages shall have operating-pressure and -temperature ranges so normal operating range is about 50 percent of full range.
e. Boiler Air Vent: Automatic **OR** Manual, **as directed**.
f. Drain Valve: Minimum NPS 3/4 (DN 20) hose-end gate valve.
g. Tankless Heater: Carbon-steel **OR** Bronze, **as directed**, header with copper-tube heat exchanger, mounted in a port of upper drum and sealed with fiber gasket.
1) Tappings NPS 2 (DN 50) and Smaller: Threaded ends according to ASME B1.20.1 for pipe threads.
2) Tappings NPS 2-1/2 (DN 65) and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges, and according to ASME B16.24 for copper and copper-alloy flanges.

12. Trim for Steam Boilers:
a. Include devices sized to comply with ANSI B31.1, "Power Piping **OR** ANSI B31.9, "Building Services Piping", **as directed**.
b. Pressure Controllers: Operating, firing rate, **as directed**, and high limit.
c. Safety Relief Valve:
1) Size and Capacity: As required for equipment according to ASME Boiler and Pressure Vessel Code.
2) Description: Fully enclosed steel spring with adjustable pressure range and positive shutoff; factory set and sealed.
a) Drip-Pan Elbow: Cast iron and having threaded inlet and outlet with threads complying with ASME B1.20.1.
d. Pressure Gage: Minimum 3-1/2-inch (89-mm) diameter. Gage shall have normal operating pressure about 50 percent of full range.
e. Water Column: Minimum 12-inch (300-mm) glass gage with shutoff cocks.
f. Drain Valves: Minimum NPS 3/4 (DN 20) or nozzle size with hose-end connection.
g. Blowdown Valves: Factory-installed bottom and surface, slow-acting blowdown valves same size as boiler nozzle. Blowdown valves shall be combination of slow and quick acting as required by ANSI B31.1, **as directed**.
h. Stop Valves: Boiler inlets and outlets, except safety relief valves or preheater inlet and outlet, shall be equipped with stop valve in an accessible location as near as practical to boiler nozzle and same size or larger than nozzle. Valves larger than NPS 2 (DN 50) shall have rising stem.
i. Stop-Check Valves: Factory-installed, stop-check valve and stop valve at boiler outlet with free-blow drain valve factory installed between the two valves and visible when operating stop-check valve.
j. Tankless Heater: Carbon-steel header with copper-tube heat exchanger, mounted in a port of upper manifold and sealed with fiber gasket.
1) Tappings NPS 2 (DN 50) and Smaller: Threaded ends according to ASME B1.20.1 for pipe threads.
2) Tappings NPS 2-1/2 (DN 65) and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges, and according to ASME B16.24 for copper and copper-alloy flanges.

13. Controls:
a. Refer to Division 23 Section "Instrumentation And Control For Hvac".
OR
Boiler operating controls shall include the following devices and features:
1) Control transformer.
2) Set-Point Adjust: Set points shall be adjustable.
3) Operating Pressure Control for Steam Boilers: Factory wired and mounted to cycle burner.
4) Low-Water Cutoff and Pump Control for Steam Boilers: Cycle feedwater pump(s) for makeup water control.

5) Sequence of Operation for Hot-Water Boilers: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain space temperature in response to thermostat with heat anticipator located in heated space.
OR
Sequence of Operation for Hot-Water Boilers: Electric, factory-fabricated and field-installed panel to control burner firing rate to reset supply-water temperature inversely with outside-air temperature. At 0 deg F (minus 17 deg C) outside-air temperature, set supply-water temperature at 200 deg F (93 deg C); at 60 deg F (15 deg C) outside-air temperature, set supply-water temperature at 140 deg F (60 deg C).
6) Sequence of Operation for Steam Boilers: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain a constant steam pressure. Maintain pressure set point plus or minus 10 percent.
7) Include automatic, alternating-firing sequence for multiple boilers to ensure maximum system efficiency throughout the load range and to provide equal runtime for boilers.

b. Burner Operating Controls: To maintain safe operating conditions, burner safety controls limit burner operation.
1) High Cutoff: Manual **OR** Automatic, **as directed**, reset stops burner if operating conditions rise above maximum boiler design temperature for hot-water boiler or design pressure for steam boiler.
2) Low-Water Cutoff Switch: Electronic (for hot-water boilers) or Float and electronic (for steam boilers) probe shall prevent burner operation on low water. Cutoff switch shall be manual **OR** automatic, **as directed**,-reset type.
3) Blocked Vent Safety Switch (Atmospheric Boilers): Manual-reset switch factory mounted on draft diverter.
4) Rollout Safety Switch (Atmospheric Boilers): Factory mounted on boiler combustion chamber.
5) Audible Alarm: Factory mounted on control panel with silence switch; shall sound alarm for above conditions.

c. Building Automation System Interface: Factory install hardware and software to enable building automation system to monitor, control, and display boiler status and alarms.
1) Monitoring: On/off status, common trouble alarm **OR** low water level alarm, **as directed**.
2) Control: On/off operation, hot water supply temperature set-point adjustment **OR** steam pressure adjustment, **as directed**.
3) A communication interface with building automation system shall enable building automation system operator to remotely control and monitor the boiler from an operator workstation. Control features available, and monitoring points displayed, locally at boiler control panel shall be available through building automation system.

C. Electrical Power
1. Controllers, Electrical Devices, and Wiring: Electrical devices and connections are specified in Division 22.
OR
Single-Point Field Power Connection: Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to boiler.
a. House in NEMA 250, Type 1 enclosure.
b. Wiring shall be numbered and color-coded to match wiring diagram.
c. Install factory wiring outside of an enclosure in a metal, **as directed**, raceway.
d. Field power interface shall be to wire lugs **OR** fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**.
e. Provide branch power circuit to each motor and to controls with disconnect switch or circuit breaker, **as directed**.

f. Provide each motor with overcurrent protection.

D. Venting Kits
1. Vent Damper (for Finned Water-Tube Boilers): Motorized, UL listed for use on atmospheric burner boiler equipped with draft hood; motor to open and close damper; stainless-steel vent coupling and damper blade; keyed wiring harness connector plug; and dual-position switches to permit burner operation.
2. Kit: Complete system, ASTM A 959, Type 29-4C, **as directed**, stainless steel, pipe, vent terminal, thimble, indoor plate, vent adapter, condensate trap, and sealant.
3. Combustion-Air Intake: Stainless steel, pipe, vent terminal with screen, inlet air coupling, and sealant.

E. Source Quality Control
1. Test and inspect factory-assembled boilers, before shipping, according to ASME Boiler and Pressure Vessel Code.
2. Burner and Hydrostatic Test (for Factory-Assembled Boilers): Factory adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency; perform hydrostatic test.
3. Allow the Owner access to source quality-control testing of boilers. Notify the Owner 14 days in advance of testing.

1.3 EXECUTION

A. Boiler Installation
1. Install boilers level on concrete base. Concrete base is specified in Division 23 Section "Common Work Results For Hvac", and concrete materials and installation requirements are specified in Division 31.
2. Vibration Isolation: Elastomeric isolator pads **OR** mounts, **as directed**, with a minimum static deflection of 0.25 inch (6.35 mm). Vibration isolation devices and installation requirements are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
3. Install gas-fired boilers according to NFPA 54.
4. Install oil-fired boilers according to NFPA 31.
5. Assemble boiler tubes in sequence and seal each tube joint.
6. Assemble and install boiler trim.
7. Install electrical devices furnished with boiler but not specified to be factory mounted.
8. Install control wiring to field-mounted electrical devices.

B. Connections
1. Piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
2. Install piping adjacent to boiler to allow service and maintenance.
3. Connect gas piping to boiler gas-train inlet with union. Piping shall be at least full size of gas train connection. Provide a reducer if required.
4. Connect oil piping full size to burner inlet with shutoff valve and union.
5. Connect hot-water piping to supply- and return-boiler tappings with shutoff valve and union or flange at each connection.
6. Connect steam and condensate piping to supply-, return-, and blowdown-boiler tappings with shutoff valve and union or flange at each connection.
7. Install piping from safety relief valves to nearest floor drain (for hot-water boilers).
8. Install piping from safety valves to drip-pan elbow and to nearest floor drain (for steam boilers).
9. Install piping from equipment drain connection to nearest floor drain. Piping shall be at least full size of connection. Provide an isolation valve if required.
10. Boiler Flue Venting (for Finned Water-Tube Boilers):
    a. Install venting kit and combustion-air intake.

b. Connect full size to boiler connections. Comply with requirements in Division 23 Section "Breechings, Chimneys, And Stacks".

11. Connect breeching to full size of boiler outlet. Comply with requirements in Division 23 Section "Breechings, Chimneys, And Stacks" for venting materials.
12. Install flue-gas recirculation duct from vent to burner. Comply with requirements in Division 23 Section "Breechings, Chimneys, And Stacks" for recirculation duct materials.
13. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
14. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

C. Field Quality Control

1. Perform tests and inspections and prepare test reports.
   a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
2. Tests and Inspections:
   a. Perform installation and startup checks according to manufacturer's written instructions.
   b. Leak Test: Hydrostatic test. Repair leaks and retest until no leaks exist.
   c. Operational Test: Start units to confirm proper motor rotation and unit operation. Adjust air-fuel ratio and combustion.
   d. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
      1) Burner Test (for Field-Assembled Boilers): Adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency.
      2) Check and adjust initial operating set points and high- and low-limit safety set points of fuel supply, water level, and water temperature **OR** steam pressure, **as directed**.
      3) Set field-adjustable switches and circuit-breaker trip ranges as indicated.
3. Remove and replace malfunctioning units and retest as specified above.
4. Occupancy Adjustments: When requested within 12 months of date of Final Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other than normal occupancy hours for this purpose.
5. Performance Tests, as directed:
   a. Engage a factory-authorized service representative to inspect component assemblies and equipment installations, including connections, and to conduct performance testing.
   b. Boilers shall comply with performance requirements indicated, as determined by field performance tests. Adjust, modify, or replace equipment in order to comply.
   c. Perform field performance tests to determine the capacity and efficiency of the boilers.
      1) For dual-fuel boilers, perform tests for each fuel.
      2) Test for full capacity.
      3) Test for boiler efficiency at low fire 20, 40, 60, 80, 100, 80, 60, 40 and 20, **as directed**, percent of full capacity. Determine efficiency at each test point.
   d. Repeat tests until results comply with requirements indicated.
   e. Provide analysis equipment required to determine performance.
   f. Provide temporary equipment and system modifications necessary to dissipate the heat produced during tests if building systems are not adequate.
   g. Notify the Owner in advance of test dates.
   h. Document test results in a report and submit to the Owner.

D. Demonstration

1. Train the Owner's maintenance personnel to adjust, operate, and maintain boilers.

END OF SECTION 23 52 33 13

Task	Specification	Specification Description
23 52 33 16	23 52 33 13	Water-Tube Boilers

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SECTION 23 52 36 00 - FIRE-TUBE BOILERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for fire-tube boilers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes packaged, factory-fabricated and -assembled boilers, trim, and accessories for generating hot water **OR** steam, **as directed**, with the following configurations and burners:
   a. Horizontal, fire-tube, Vertical, fire-tube, and Fire-box boiler.
   b. Gas, Oil, and Combination gas and oil burner.

C. Submittals
1. Product Data: Include performance data, operating characteristics, furnished specialties, and accessories.
2. Shop Drawings: For boilers, boiler trim, and accessories. Include plans, elevations, sections, details, and attachments to other work.
   a. Design calculations and vibration isolation base details, signed and sealed by a qualified professional engineer.
      1) Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
      2) Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails and equipment mounting frames.
   b. Wiring Diagrams: Power, signal, and control wiring.
3. Manufacturer Seismic Qualification Certification: Submit certification that boiler, accessories, and components will withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment". Include the following:
4. Source quality-control test reports.
5. Field quality-control test reports.
6. Operation and maintenance data.
7. Warranty: Special warranty specified in this Section.
8. Other Informational Submittals:
   a. ASME Stamp Certification and Report: Submit "A," "S," or "PP" stamp certificate of authorization, as required by authorities having jurisdiction, and document hydrostatic testing of piping external to boiler.
   b. Startup service reports.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. ASME Compliance: Fabricate and label boilers to comply with ASME Boiler and Pressure Vessel Code.
3. ASHRAE/IESNA 90.1 Compliance: Boilers shall have minimum efficiency according to "Gas and Oil Fired Boilers - Minimum Efficiency Requirements."
4. UL Compliance: Test Boilers for compliance with UL 726, "Oil-Fired Boiler Assemblies" **OR** UL 726, "Oil-Fired Boiler Assemblies" and UL 795, "Commercial-Industrial Gas Heating Equipment" **OR** UL 795, "Commercial-Industrial Gas Heating Equipment", **as directed**. Boilers shall be listed and labeled by a testing agency acceptable to authorities having jurisdiction.

E. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace front- and rear-door refractories and heat exchangers of boilers that fail in materials or workmanship within specified warranty period.
   a. Horizontal, Fire-Tube and Fire-Box Boilers: Refractory in front and rear doors, 10 years from date of startup by factory-authorized personnel.
   b. Vertical, Fire-Tube Boilers and Heat Exchanger: Five years from date of Final Completion, if following water-treatment program recommended by manufacturer.

1.2 PRODUCTS

A. Manufactured Units - Horizontal, Fire-Tube Boilers
1. Description: Factory-fabricated, -assembled, and -tested, horizontal, fire-tube boilers with heat exchanger sealed pressure tight, built on a steel base; including insulated jacket, flue-gas vent, water supply and return connections, and controls.
2. Pressure Vessel Design: Straight, steel tubes rolled **OR** welded, **as directed**, into steel headers. Three **OR** Four, **as directed**, passes with dry-back **OR** wet-back, **as directed**, design. Minimum heat-exchanger surface of 5 sq. ft./bhp (2.1 sq. m/10 kW). Include the following accessories:
   a. Handholes for water-side inspections.
   b. Lifting lugs on top of boiler.
   c. Minimum NPS 1 (DN 25) hose-end drain valves at shell low point.
   d. For hot-water boilers only:
      1) Tappings or flanges for supply- and return-water piping.
      2) Built-in air separator.
   e. For steam boilers only:
      1) Accessible drain and blowdown tappings, both high and low, for surface and mud removal.
      2) Tappings for steam supply, makeup, level controls, and chemical treatment.
3. Front and Rear Doors:
   a. Bolted **OR** Hinged **OR** Davited, **as directed**, sealed with heat-resistant gaskets and fastened with lugs and cap screws.
   b. Designed so tube sheets and flues are fully accessible for inspection or cleaning when doors are open.
   c. Include observation ports in doors at both ends of boiler for inspection of flame conditions.
   d. Door refractory **OR** insulation, **as directed**, shall be accessible for inspection and maintenance.
4. Casing:
   a. Insulation: Minimum 2-inch- (50-mm-) thick, mineral-fiber insulation surrounding the boiler shell.
   b. Flue Connection: Flange at top of boiler.
   c. Jacket: Galvanized sheet **OR** Sheet, **as directed**, metal, with screw-fastened closures and baked-enamel **OR** powder-coated, **as directed**, protective finish.
   d. Mounting base to secure boiler to concrete base.
      1) Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" when mounting base is anchored to building structure.
   e. Control Compartment Enclosure: NEMA 250, Type 1 **OR** 4 **OR** 4X **OR** 12, **as directed**.
5. Barometric Damper: Galvanized-steel assembly with flue-gas thermometer having a minimum 3-1/2-inch- (89-mm-) diameter dial.

B. Manufactured Units - Vertical, Fire-Tube Boilers

1. Description: Factory-fabricated, -assembled, and -tested, vertical, fire-tube boilers with heat exchanger sealed pressure tight, built on a steel base; including insulated jacket, flue-gas vent, water supply and return connections, and controls.
2. Pressure Vessel Design: Straight, steel pipe welded in a concentric pattern to separate flue-gas and heating media to form two **OR** four, **as directed**, passes with welded fins to improve heat transfer in secondary flue-gas passages. Include the following accessories:
   a. Handholes for water-side inspections.
   b. Lifting lugs on top of boiler.
   c. Minimum NPS 1 (DN 25) hose-end drain valves at water passage low point.
   d. For hot-water boilers only:
      1) Tappings or flanges for supply- and return-water piping.
      2) Built-in air separator.
   e. For steam boilers only:
      1) Accessible drain and blowdown tappings, both high and low, for surface and mud removal.
      2) Tappings for steam supply, makeup, level controls, and chemical treatment.
3. Combustion Chamber: Equipped with flame retainer to lengthen flame-residence time.
4. Casing:
   a. Insulation: Minimum 4-inch- (100-mm-) thick, mineral-fiber insulation surrounding the heat exchanger and combustion chamber.
   b. Flue Connection: Top connection, constructed of aluminized **OR** stainless, **as directed**, steel.
   c. Jacket: Mirror-finish stainless steel with screw-fastened closures.
      OR
      Jacket: Galvanized sheet **OR** Sheet, **as directed**, metal, with screw-fastened closures and baked-enamel **OR** powder-coated, **as directed**, protective finish.
   d. Mounting base to secure boiler to concrete base.
      1) Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Division 22 Section "Identification For Plumbing Piping And Equipment" when mounting base is anchored to building structure.
   e. Control Compartment Enclosure: NEMA 250, Type 1 **OR** 4 **OR** 4X **OR** 12, **as directed**.
5. Barometric Damper: Galvanized-steel assembly with flue-gas thermometer having a minimum 3-1/2-inch- (89-mm-) diameter dial.

C. Manufactured Units - Fire-Box Boilers
1. Description: Factory-fabricated, -assembled, and -tested, fire-box boilers with heat exchanger sealed pressure tight, built on a steel base; including insulated jacket, flue-gas vent, water supply and return connections, and controls.
2. Pressure Vessel Design: Straight, steel tubes rolled **OR** welded, **as directed**, into steel headers. Three passes with wet-back design. Minimum heat-exchanger surface of 5 sq. ft./bhp (2.1 sq. m/10 kW). Include the following features and accessories:
   a. Tube Size and Thickness: Minimum NPS 2 (DN 50), minimum 0.105 inch (2.667 mm) thick.
   b. Brass washout plugs.
   c. Steel turbulators.
   d. Lifting lugs on top of boiler.
   e. Minimum NPS 1 (DN 25) hose-end drain valves at shell low point.
   f. For hot-water boilers only:
      1) Tappings or flanges for supply- and return-water piping.
      2) Built-in air separator.
   g. For steam boilers only:
      1) Accessible drain and blowdown tappings, both high and low, for surface and mud removal.
      2) Tappings for steam supply, makeup, level controls, and chemical treatment.

3. Combustion Chamber: Welded steel, waterwall and -floor design **OR** water-leg design with refractory insulation poured in the floor, **as directed**. Flame observation port.
4. Casing:
   a. Insulation: Minimum 2-inch- (50-mm-) thick, foil-backed, **as directed**, mineral-fiber insulation surrounding the boiler shell.
   b. Insulated removable smoke boxes and reversing chamber cover.
   c. Flue Connection: Steel top **OR** rear, **as directed**.
   d. Jacket: Sheet metal, with screw-fastened closures and baked-enamel **OR** powder-coated, **as directed**, protective finish.
   e. Control Compartment Enclosure: NEMA 250, Type 1 **OR** 1A **OR** 4 **OR** 4X **OR** 12, **as directed**.
   f. Mounting base to secure boiler to concrete base.
      1) Seismic Fabrication Requirements: Fabricate mounting base and attachment to boiler, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" when mounting base is anchored to building structure.
5. Barometric Damper: Galvanized-steel assembly with flue-gas thermometer having a minimum 3-1/2-inch- (89-mm-) diameter dial.

D. Burner For Forced-Draft Gas Burners
1. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for natural **OR** propane, **as directed**, gas. Mount burner on hinged access door to permit access to combustion chamber, **as directed**.
2. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
   a. Motors: Comply with requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
      1) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
3. Gas Train: Control devices and modulating **OR** on-off **OR** low-high-low, **as directed**, control sequence shall comply with requirements in ASME CSD-1 **OR** FMG **OR** IRI **OR** UL, **as directed**.
4. Pilot: Intermittent **OR** Interrupted, **as directed**,-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.
5. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.
   a. Maximum Oxides of Nitrogen Emissions: 20 **OR** 30, **as directed**, ppm.

E. Burner For Oil Burners
1. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for fuel oil. Mount burner on hinged access door to permit access to combustion chamber, **as directed**.
2. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
   a. Motors: Comply with requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
      1) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
3. Oil Supply: Control devices and modulating **OR** on-off **OR** low-high-low, **as directed**, control sequence shall comply with requirements in ASME CSD-1 **OR** FMG **OR** IRI **OR** UL, **as directed**.
   a. Oil Pump: Two-stage, gear-type oil pump integral to and directly driven by blower, **as directed**, shall be capable of producing 300-psig (2070-kPa) discharge pressure and 15-inch Hg (50.7-kPa) vacuum.
   b. Oil Piping Specialties:
      1) Suction-line, manual, gate valve.
      2) Removable-mesh oil strainer.
      3) 0- to 30-inch Hg (0- to 101.3-kPa) vacuum; 0- to 30-psig (0- to 207-kPa) vacuum-pressure gage.

4) 0- to 300-psig (0- to 2070-kPa) oil-nozzle pressure gage.
5) Nozzle-line, solenoid-safety-shutoff oil valve.

4. Pilot: Intermittent **OR** Interrupted, **as directed**,-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff solenoid with cadmium sulfide **OR** UV scanner, **as directed**, flame-safety control.
5. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.
   a. Maximum Oxides of Nitrogen Emissions: 30 ppm.

F. Burner For Combination Gas And Oil Burners
1. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser for fuel oil and natural **OR** propane, **as directed**, gas. Mount burner on hinged access door to permit access to combustion chamber, **as directed**.
2. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
   a. Motors: Comply with requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
      1) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
3. Oil Supply: Control devices and modulating **OR** on-off **OR** low-high-low, **as directed**, control sequence shall comply with requirements in ASME CSD-1 **OR** FMG **OR** IRI **OR** UL, **as directed**.
   a. Oil Pump: Two-stage, gear-type oil pump integral to and directly driven by blower, **as directed**, shall be capable of producing 300-psig (2070-kPa) discharge pressure and 15-inch Hg (50.7-kPa) vacuum.
   b. Oil Piping Specialties:
      1) Suction-line, manual, gate valve.
      2) Removable-mesh oil strainer.
      3) 0- to 30-inch Hg (0- to 101.3-kPa) vacuum; 0- to 30-psig (0- to 207-kPa) vacuum-pressure gage.
      4) 0- to 300-psig (0- to 2070-kPa) oil-nozzle pressure gage.
      5) Nozzle-line, solenoid-safety-shutoff oil valve.
4. Gas Train: Control devices and modulating **OR** on-off **OR** low-high-low, **as directed**, control sequence shall comply with requirements in ASME CSD-1 **OR** FMG **OR** IRI **OR** UL, **as directed**.
5. Gas Pilot: Intermittent **OR** Interrupted, **as directed**,-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.
6. Oil Pilot: Intermittent **OR** Interrupted, **as directed**,-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff solenoid with cadmium sulfide **OR** UV scanner, **as directed**, flame-safety control.
7. Flue-Gas Recirculation: Burner connections shall be equipped for recirculating flue gas.
   a. Maximum Oxides of Nitrogen Emissions: 20 **OR** 30, **as directed**, ppm.

G. Trim For Hot-Water Boilers
1. Include devices sized to comply with ANSI B31.1, "Power Piping **OR** ANSI B31.9, "Building Services Piping", **as directed**.
2. Aquastat Controllers: Operating, firing rate, **as directed**, and high limit.
3. Safety Relief Valve: ASME rated.
4. Pressure and Temperature Gage: Minimum 3-1/2-inch- (89-mm-) diameter, combination water-pressure and -temperature gage. Gages shall have operating-pressure and -temperature ranges so normal operating range is about 50 percent of full range.
5. Boiler Air Vent: Automatic **OR** Manual, **as directed**.
6. Drain Valve: Minimum NPS 3/4 (DN 20) hose-end gate valve.
7. Tankless Heater: Carbon-steel **OR** Bronze, **as directed**, header with copper-tube heat exchanger, mounted in a port of upper drum and sealed with fiber gasket.
   a. Tappings NPS 2 (DN 50) and Smaller: Threaded ends according to ASME B1.20.1 for pipe threads.

b. Tappings NPS 2-1/2 (DN 65) and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges, and according to ASME B16.24 for copper and copper-alloy flanges.

H. Trim For Steam Boilers
1. Include devices sized to comply with ANSI B31.1, "Power Piping **OR** ANSI B31.9, "Building Services Piping", **as directed**.
2. Pressure Controllers: Operating, firing rate, **as directed**, and high limit.
3. Safety Relief Valve:
   a. Size and Capacity: As required for equipment according to ASME Boiler and Pressure Vessel Code.
   b. Description: Fully enclosed steel spring with adjustable pressure range and positive shutoff; factory set and sealed.
      1) Drip-Pan Elbow: Cast iron and having threaded inlet and outlet with threads complying with ASME B1.20.1.
4. Pressure Gage: Minimum 3-1/2-inch (89-mm) diameter. Gage shall have normal operating pressure about 50 percent of full range.
5. Water Column: Minimum 12-inch (300-mm) glass gage with shutoff cocks.
6. Drain Valves: Minimum NPS 3/4 (DN 20) or nozzle size with hose-end connection.
7. Blowdown Valves: Factory-installed bottom and surface, slow-acting blowdown valves same size as boiler nozzle. Blowdown valves shall be combination of slow and quick acting as required by ANSI B31.1, **as directed.**
8. Stop Valves: Boiler inlets and outlets, except safety relief valves or preheater inlet and outlet, shall be equipped with stop valve in an accessible location as near as practical to boiler nozzle and same size or larger than nozzle. Valves larger than NPS 2 (DN 50) shall have rising stem.
9. Stop-Check Valves: Factory-installed, stop-check valve and stop valve for field installation at boiler outlet with free-blow drain valve for field installation between the two valves and visible when operating stop-check valve.
10. Tankless Heater: Carbon-steel header with copper-tube heat exchanger, mounted in a port of upper manifold and sealed with fiber gasket.
    a. Tappings NPS 2 (DN 50) and Smaller: Threaded ends according to ASME B1.20.1 for pipe threads.
    b. Tappings NPS 2-1/2 (DN 65) and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges, and according to ASME B16.24 for copper and copper-alloy flanges.

I. Controls
1. Refer to Division 23 Section "Instrumentation And Control For Hvac".
   OR
   Boiler operating controls shall include the following devices and features:
   a. Control transformer.
   b. Set-Point Adjust: Set points shall be adjustable.
   c. Operating Pressure Control for steam boilers: Factory wired and mounted to cycle burner.
   d. Low-Water Cutoff and Pump Control for steam boilers: Cycle feedwater pump(s) **OR** Operate feedwater pump(s) continuously and modulate valve, **as directed**, for makeup water control.
   e. Sequence Of Operation For Hot-Water Boilers: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain space temperature in response to thermostat with heat anticipator located in heated space.
      OR
      Sequence Of Operation For Hot-Water Boilers: Electric, factory-fabricated and field-installed panel to control burner firing rate to reset supply-water temperature inversely with outside-air temperature. At 0 deg F (minus 17 deg C) outside-air temperature, set supply-water temperature at 200 deg F (93 deg C); at 60 deg F (15 deg C) outside-air temperature, set supply-water temperature at 140 deg F (60 deg C).

f. Sequence Of Operation For Steam Boilers: Electric, factory-fabricated and field-installed panel to control burner firing rate to maintain a constant steam pressure. Maintain pressure set point plus or minus 10 percent.
   1) Include automatic, alternating-firing sequence for multiple boilers to ensure maximum system efficiency throughout the load range and to provide equal runtime for boilers.

2. Burner Operating Controls: To maintain safe operating conditions, burner safety controls limit burner operation.
   a. High Cutoff: Manual **OR** Automatic, **as directed**, reset stops burner if operating conditions rise above maximum boiler design temperature for hot-water boiler **OR** design pressure for steam boiler, **as directed**.
   b. Low-Water Cutoff Switch: Electronic for hot-water boilers **OR** Float and electronic for steam boilers, **as directed**, probe shall prevent burner operation on low water. Cutoff switch shall be manual **OR** automatic, **as directed**,-reset type.
   c. Audible Alarm: Factory mounted on control panel with silence switch; shall sound alarm for above conditions.
3. Building Automation System Interface: Factory-install hardware and software to enable building automation system to monitor, control, and display boiler status and alarms.
   a. Hardwired Points:
      1) Monitoring: On/off status, common trouble alarm **OR** low water level alarm, **as directed**.
      2) Control: On/off operation, hot water supply temperature set-point adjustment **OR** steam pressure adjustment, **as directed**.
   b. A communication interface with building automation system shall enable building automation system operator to remotely control and monitor the boiler from an operator workstation. Control features available, and monitoring points displayed, locally at boiler control panel shall be available through building automation system.

J. Electrical Power
1. Controllers, Electrical Devices, and Wiring: Electrical devices and connections are specified in Division 22..
   OR
   Single-Point Field Power Connection: Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to boiler.
   a. House in NEMA 250, Type 1 **OR** 4 **OR** 4X **OR** 12, **as directed**, enclosure.
   b. Wiring shall be numbered and color-coded to match wiring diagram.
   c. Install wiring outside of an enclosure in a metal, **as directed**, raceway.
   d. Field power interface shall be to wire lugs **OR** fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**.
   e. Provide branch power circuit to each motor and to controls with a disconnect switch or circuit breaker, **as directed**.
   f. Provide each motor with overcurrent protection.

K. Source Quality Control
1. Test and inspect factory-assembled boilers, before shipping, according to ASME Boiler and Pressure Vessel Code.
2. Burner and Hydrostatic Test for factory-assembled boilers: Factory adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency; perform hydrostatic test.
3. Allow the Owner access to source quality-control testing of boilers. Notify the Owner 14 days in advance of testing.

1.3 EXECUTION

A. Boiler Installation
1. Install boilers level on concrete base. Concrete base is specified in Division 23 Section "Common Work Results For Hvac", and concrete materials and installation requirements are specified in Division 31.
2. Vibration Isolation: Elastomeric isolator pads **OR** mounts, **as directed**, with a minimum static deflection of 0.25 inch (6.35 mm). Vibration isolation devices and installation requirements are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
3. Install gas-fired boilers according to NFPA 54.
4. Install oil-fired boilers according to NFPA 31.
5. Assemble and install boiler trim.
6. Install electrical devices furnished with boiler but not specified to be factory mounted.
7. Install control wiring to field-mounted electrical devices.

B. Connections
1. Piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
2. Install piping adjacent to boiler to allow service and maintenance.
3. Connect gas piping to boiler gas-train inlet with union. Piping shall be at least full size of gas train connection. Provide a reducer if required.
4. Connect oil piping full size to burner inlet with shutoff valve and union.
5. Connect hot-water piping to supply- and return-boiler tappings with shutoff valve and union or flange at each connection.
6. Connect steam and condensate piping to supply-, return-, and blowdown-boiler tappings with shutoff valve and union or flange at each connection.
7. Install piping from safety relief valves to nearest floor drain, for hot-water boilers.
8. Install piping from safety valves to drip-pan elbow and to nearest floor drain, for steam boilers.
9. Install piping from equipment drain connection to nearest floor drain. Piping shall be at least full size of connection. Provide an isolation valve if required.
10. Connect breeching full size to boiler outlet. Comply with requirements in Division 23 Section "Breechings, Chimneys, And Stacks" for venting materials.
11. Install flue-gas recirculation duct from vent to burner. Comply with requirements in Division 23 Section "Breechings, Chimneys, And Stacks" for recirculation duct materials.
12. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
13. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

C. Field Quality Control
1. Perform tests and inspections and prepare test reports.
   a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
2. Tests and Inspections:
   a. Perform installation and startup checks according to manufacturer's written instructions.
   b. Leak Test: Hydrostatic test. Repair leaks and retest until no leaks exist.
   c. Operational Test: Start units to confirm proper motor rotation and unit operation. Adjust air-fuel ratio and combustion.
   d. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
      1) Burner Test for field-assembled boilers: Adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency.

2) Check and adjust initial operating set points and high- and low-limit safety set points of fuel supply, water level, and water temperature **OR** steam pressure, **as directed**.
3) Set field-adjustable switches and circuit-breaker trip ranges as indicated.

3. Remove and replace malfunctioning units and retest as specified above.
4. Occupancy Adjustments: When requested within 12 months of date of Final Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other than normal occupancy hours for this purpose.
5. Performance Tests, **as directed**:
   a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect component assemblies and equipment installations, including connections, and to conduct performance testing.
   b. Boilers shall comply with performance requirements indicated, as determined by field performance tests. Adjust, modify, or replace equipment in order to comply.
   c. Perform field performance tests to determine the capacity and efficiency of boilers.
      1) For dual-fuel boilers, perform tests for each fuel.
      2) Test for full capacity.
      3) Test for boiler efficiency at low fire, 20, 40, 60, 80, 100, 80, 60, 40 and 20, **as directed**, percent of full capacity. Determine efficiency at each test point.
   d. Repeat tests until results comply with requirements indicated.
   e. Provide analysis equipment required to determine performance.
   f. Provide temporary equipment and system modifications necessary to dissipate the heat produced during tests if building systems are not adequate.
   g. Notify the Owner in advance of test dates.
   h. Document test results in a report and submit to the Owner.

D. Demonstration
   1. Train the Owner's maintenance personnel to adjust, operate, and maintain boilers.

END OF SECTION 23 52 36 00

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SECTION 23 53 16 00 - FEEDWATER EQUIPMENT

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for feedwater equipment. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following:
a. Feedwater pumps and receivers.
b. Vacuum-type feedwater pumps and receivers.

C. Definition
1. NPSH: Net-positive suction head.

D. Submittals
1. Product Data: For each type of product indicated. Include rated capacity, temperature and NPSH required, pump performance curves with selection points clearly indicated, and furnished specialties and accessories.
2. Shop Drawings: Include plans, elevations, sections, details, dimensions, weights, loadings, required clearances, method of field assembly, and attachments to other work.
a. Wiring Diagrams: Power, signal, and control wiring.
3. Manufacturer Seismic Qualification Certification: Submit certification that feedwater equipment, accessories, and components will withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
4. Field quality-control test reports.
5. Operation and Maintenance Data.

E. Quality Assurance
1. Regulatory Requirements: Fabricate and test unit according to ASME PTC 12.1, "Closed Feedwater Heaters."
2. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
3. ASME Compliance: ASME B31.1, "Power Piping," for systems more than 15 psig (104 kPa); ASME B31.9, "Building Services Piping," for systems equal to or less than 15 psig (104 kPa). Safety valves and pressure vessels shall bear the appropriate ASME label.

F. Delivery, Storage, And Handling
1. Preparation for Shipping: Clean flanges and exposed-metal surfaces and treat with anticorrosion compound after assembly and testing. Protect flanges, pipe openings, and nozzles with wooden flange covers or with screwed-in plugs.
2. Store units in dry location.
3. Retain protective flange covers and machined-surface protective coatings during storage.
4. Protect bearings and couplings against damage from sand, grit, and other foreign matter.
5. Comply with manufacturer's written rigging instructions.

1.2 PRODUCTS

A. Feedwater Units

1. Description: Factory-assembled and -tested unit consisting of a receiver, simplex **OR** duplex, **as directed**, feedwater pumps, controls, and the following features and accessories:
   a. Liquid-filled industrial **OR** Bimetal dial-type, **as directed**, thermometer graduated in Fahrenheit **OR** Celsius **OR** both Fahrenheit and Celsius, **as directed**.
   b. Level gage glass, reflex flat type, **as directed**, with stops at top and bottom.
   c. Lifting eyes.
   d. Companion flanges.
   e. Pump, suction and discharge isolation valve, inlet strainer, discharge check valve, and liquid-filled pressure gage.
   f. Makeup Water Assembly: Float operated with integral valve **OR** Electric level controller and valve, **as directed**; with inlet strainer and three-valve bypass.
   g. Feedwater Heater: Sparge tube, thermostat, and control valve.
   h. Factory-Installed Pipe, NPS 2-1/2 (DN 65) and Smaller: ASTM A 53/A 53M, Type S (seamless), Grade B; or ASTM A 106, Type S, Grade B, Schedule 40 **OR** 80, **as directed**; with threaded joints and fittings.
      1) Cast-Iron Threaded Fittings: ASME B16.4; Class 125 **OR** 250, **as directed**.
      2) Malleable-Iron Threaded Fittings: ASME B16.3, Class 150 **OR** 300, **as directed**.
      3) Forged-Steel Fittings: ASME B16.11, Class 3000.
      4) Malleable-Iron Unions: ASME B16.39; Class 150 **OR** 300, **as directed**.
      5) Forged-Steel Unions: MSS SP-83, Class 3000.
   i. Factory-Installed Pipe, NPS 3 (DN 80) and Larger: ASTM A 53/A 53M, Type E (electric-resistance welded), Grade B; or ASTM A 106, Type S, Grade B, Schedule 40 **OR** 80, **as directed**; with welded joints and carbon-steel fittings and flanges.
      1) Wrought-Steel Fittings: ASME B16.9, wall thickness to match adjoining pipe.
      2) Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, Class 150 **OR** 300, **as directed**, including bolts, nuts, and gaskets.
2. Receiver:
   a. Material: Close-grain cast iron **OR** Welded carbon steel **OR** Welded carbon steel galvanized after fabrication **OR** Stainless steel, **as directed**.
   b. Additional corrosion protection:
      1) 0.07-inch (1.8-mm) **OR** 0.13-inch (3.3-mm) **OR** 0.19-inch (4.8-mm), **as directed,** thickness allowance.
      2) Electrolytic corrosion-inhibitor anode.
   c. Finish: Primer **OR** Primer under enamel topcoat **OR** Primer under epoxy topcoat, **as directed**.
   d. Factory-Applied Insulation and Jacket: Minimum thickness of 2 inches (50 mm) for mineral-fiber pipe and tank insulation. Cover insulation with painted steel **OR** stucco-embossed aluminum **OR** stainless-steel, **as directed**, jacket.
   e. Mounting Arrangement: Recessed below floor **OR** Floor mounted, **as directed**.
   f. Mounting Frame: Structural-steel stand to support receiver and pumps. Fabricate stand with bracing adequate for seismic forces according to authorities having jurisdiction and to allow anchoring mounting frame to floor, **as directed**.
3. Vertical Feedwater Pump: Flange-mounted, close-coupled, single-stage, **OR** multistage, **as directed**, radially split-case-design centrifugal pump; rated for 175-psig (1205-kPa) minimum working pressure and a continuous water temperature of at least 225 deg F (107 deg C); with the following features:
   a. Impeller: Bronze **OR** Stainless steel, **as directed**.
   b. Seals: Mechanical.
   c. Motor: Open dripproof **OR** Totally enclosed **OR** Totally enclosed fan-cooled, **as directed**, enclosure. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
4. Horizontal Feedwater Pump: Base-mounted, single-stage, **OR** multistage, **as directed**, radially split-case-design centrifugal pump; rated for 175-psig (1205-kPa) minimum working pressure and a continuous water temperature of at least 225 deg F (107 deg C); with the following features:
   a. Impeller: Bronze **OR** Stainless steel, **as directed**.

b. Coupling: Close **OR** Flexible, **as directed**.
c. Seals: Mechanical.
d. Motor: Open dripproof **OR** Totally enclosed **OR** Totally enclosed fan-cooled, **as directed**, enclosure. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".

5. Control panel shall be unit mounted and factory wired and include the following:
   a. NEMA 250, Type 1 **OR** 4 **OR** 4X **OR** 12, **as directed**, enclosure.
   b. Single-point field power interface to fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**.
      1) Branch power circuit to each motor and to controls with a disconnect switch or circuit breaker, **as directed**.
   c. NEMA-rated motor controller for each motor, and include a hand-off-auto switch and overcurrent protection.
      1) Alternating controls for duplex units with intermittent operation as indicated by control sequence.
   d. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
   e. Wiring outside of an enclosure in a metal, **as directed**, raceway. Make connections to motor with liquidtight conduit.
   f. Removable control mounting plate.
   g. Visual indication of status and alarm with momentary test push button, **as directed**.
   h. Audible alarm and silence switch.
   i. Visual indication of elapsed run time, graduated in hours.
   j. Fused control-circuit transformer.
   k. Microprocessor-based controller.
6. Feedwater Simplex-Pump Control Sequence:
   a. Boiler water-level controller starts and stops pump to maintain boiler water-level set point.
   b. Visual indication of pump on and off, **as directed**, status.
   c. Visual and audible, **as directed**, alarm indication of pump failure.
7. Feedwater Duplex-Pump Control Sequence (for duplex-pump units with operating and standby pump):
   a. Boiler water-level controller starts and stops lead pump to maintain boiler water-level set point.
   b. Lead and lag pumps alternate after each start **OR** to equalize run time, **as directed**.
   c. Lead pump failure, lag pump automatically starts if lead pump cannot maintain set point **OR** is started manually, **as directed**.
   d. Visual indication of pump on and off, **as directed**, status.
   e. Visual indication of pump lead/lag status.
   f. Visual and audible, **as directed**, alarm indication of pump failure.
8. Feedwater Duplex-Pump Control Sequence (for duplex-pump units with continuous pump operation and modulating control valve):
   a. Pump runs continuously while boiler operates. Electric interlock with boiler control starts lead pump when boiler starts.
   b. Boiler water-level controller modulates feedwater control valve to maintain boiler water-level set point. Valve closes when boiler is off.
   c. Lead and lag pumps alternate after each start **OR** to equalize run time, **as directed**.
   d. Lead pump failure automatically starts lag pump.
      OR
      Feedwater pressure controller starts and stops lag pump to maintain feedwater pressure set point.
   e. Visual indication of pump on and off, **as directed**, status.
   f. Visual indication of pump lead/lag status.
   g. Visual and audible, **as directed**, alarm indication of pump failure.
9. Receiver Makeup Water Control Sequence:
   a. Electric level controller operates electric control valve to maintain receiver water-level set point.
      OR

Mechanical float operates integral valve to maintain water-level set point.

b. Visual and audible, **as directed**, alarm indication of low and high, **as directed**, receiver-water level.

10. Building Management System Interface: Factory install hardware to enable building management system to monitor and display points.

a. Hardwired Monitoring Points: On/off status for each pump, failure alarm for each pump, receiver low-water-level alarm, receiver high-water-level alarm, feedwater temperature, **as directed**.

B. Feedwater Unit With Vacuum Producer

1. Description: Receiver mounted, consisting of multijet vacuum producer, centrifugal pump and motor assembly mounted on separation chamber, and automatic pressure and water temperature controls. Include the following accessories:

a. Liquid-filled industrial **OR** Bimetal dial-type, **as directed**, thermometer graduated in Fahrenheit **OR** Celsius **OR** both Fahrenheit and Celsius, **as directed**.

b. Vacuum Gage: Dial-type register in inches of mercury (kPa).

c. Level Gage Glass: Stops top and bottom.

d. Air-suction check valve.

e. Lifting eyes.

f. Companion flanges.

g. Low-water cutoff switch.

h. Cooling-Water Control: Aquastat, inlet strainer, and electric valve.

i. Air vent.

j. Overflow drain from vacuum-producer receiver.

k. Factory-Installed Pipe, NPS 2-1/2 (DN 65) and Smaller: ASTM A 53/A 53M, Type S (seamless), Grade B; or ASTM A 106, Type S, Grade B, Schedule 40 **OR** 80, **as directed**; with threaded joints and fittings.

1) Cast-Iron Threaded Fittings: ASME B16.4; Class 125 **OR** 250, **as directed**.

2) Malleable-Iron Threaded Fittings: ASME B16.3, Class 150 **OR** 300, **as directed**.

3) Forged-Steel Fittings: ASME B16.11, Class 3000.

4) Malleable-Iron Unions: ASME B16.39; Class 150 **OR** 300, **as directed**.

5) Forged-Steel Unions: MSS SP-83, Class 3000.

l. Factory-Installed Pipe, NPS 3 (DN 80) and Larger: ASTM A 53/A 53M, Type E (electric-resistance welded), Grade B; or ASTM A 106, Type S, Grade B, Schedule 40 **OR** 80, **as directed**; with welded joints and carbon-steel fittings and flanges.

1) Wrought-Steel Fittings: ASME B16.9, wall thickness to match adjoining pipe.

2) Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, Class 150 **OR** 300, **as directed**, including bolts, nuts, and gaskets.

2. Vacuum-Producer Reservoir and Vacuum Receiver:

a. Material: Close-grain cast iron **OR** Welded carbon steel **OR** Welded carbon steel galvanized after fabrication **OR** Stainless steel, **as directed**.

b. Additional corrosion protection:

1) 0.07-inch (1.8-mm) **OR** 0.13-inch (3.3-mm) **OR** 0.19-inch (4.8-mm), **as directed,** thickness allowance.

2) Electrolytic corrosion-inhibitor anode.

c. Finish: Primer **OR** Primer under enamel topcoat **OR** Primer under epoxy topcoat, **as directed**.

d. Factory-Applied Insulation and Jacket: Minimum thickness of 2 inches (50 mm) for mineral-fiber pipe and tank insulation. Cover insulation with painted steel **OR** stucco-embossed aluminum **OR** stainless-steel, **as directed**, jacket.

e. Mounting Arrangement: Recessed below floor **OR** Floor mounted, **as directed**.

f. Mounting Frame: Structural-steel stand to support receiver and pumps. Fabricate stand with bracing adequate for seismic forces according to authorities having jurisdiction and to allow anchoring mounting frame to floor, **as directed**.

3. Vertical Vacuum-Producer Pump: Flange-mounted, close-coupled, single-stage, radially split-case-design centrifugal pump; rated for 175-psig (1205-kPa) minimum working pressure and a continuous water temperature of at least 225 deg F (107 deg C); with the following features:
   a. Impeller: Bronze.
   b. Shaft: Stainless steel.
   c. Seals: Mechanical.
   d. Motor: Open dripproof **OR** Totally enclosed **OR** Totally enclosed fan-cooled, **as directed**, enclosure. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
4. Horizontal Vacuum-Producer Pump: Base-mounted, single-stage, radially split-case-design centrifugal pump; rated for 175-psig (1205-kPa) minimum working pressure and a continuous water temperature of at least 225 deg F (107 deg C); with the following features:
   a. Impeller: Bronze.
   b. Shaft: Stainless steel.
   c. Coupling: Close **OR** Flexible, **as directed**.
   d. Seals: Mechanical.
   e. Motor: Open dripproof **OR** Totally enclosed **OR** Totally enclosed fan-cooled, **as directed**, enclosure. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
5. Vertical Feedwater Pump: Flange-mounted, close-coupled, single-stage, **OR** multistage, **as directed**, radially split-case-design centrifugal pump; rated for 175-psig (1205-kPa) minimum working pressure and a continuous water temperature of at least 225 deg F (107 deg C); with the following features:
   a. Impeller: Bronze **OR** Stainless steel, **as directed**.
   b. Seals: Mechanical.
   c. Motor: Open dripproof **OR** Totally enclosed **OR** Totally enclosed fan-cooled, **as directed**, enclosure. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
6. Horizontal Feedwater Pump: Base-mounted, single-stage, **OR** multistage, **as directed**, radially split-case-design centrifugal pump; rated for 175-psig (1205-kPa) minimum working pressure and a continuous water temperature of at least 225 deg F (107 deg C); with the following features:
   a. Impeller: Bronze **OR** Stainless steel, **as directed**.
   b. Coupling: Close **OR** Flexible, **as directed**.
   c. Seals: Mechanical.
   d. Motor: Open dripproof **OR** Totally enclosed **OR** Totally enclosed fan-cooled, **as directed**, enclosure. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
7. Control panel shall be unit mounted and factory wired and include the following:
   a. Vacuum Switches for Simplex Vacuum-Producer Pumps: Include pressure adjustment, and test push button. Factory set to operate pump between 3 and 6 inches of mercury (10.1 and 20.2 kPa).
      OR
      Vacuum Switches for Duplex Vacuum-Producer Pumps: Include pressure adjustment, and test push button. Factory set so one pump operates for 3 to 5 inches of mercury (10.1 to 16.9 kPa) and both pumps operate for 4 to 6 inches of mercury (13.5 to 20.2 kPa).
   b. NEMA 250, Type 1 **OR** 4 **OR** 4X **OR** 12, **as directed**, enclosure.
   c. Single-point field power interface to fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**.
      1) Branch power circuit to each motor and to controls with a disconnect switch or circuit breaker, **as directed**.
   d. NEMA-rated motor controller for each motor and include a hand-off-auto switch and overcurrent protection.
      1) Alternating control for units with intermittent operation as indicated by control sequence.
   e. Terminal blocks with numbered and color-coded wiring to match wiring diagram.

f. Wiring outside of an enclosure in a metal, **as directed**, raceway. Make connections to motor with liquidtight conduit.
g. Removable control mounting plate.
h. Visual indication of status and alarm with momentary test push button, **as directed**.
i. Audible alarm and silence switch.
j. Visual indication of elapsed run time, graduated in hours.
k. Fused control-circuit transformer.

8. Vacuum-Producer Control Sequence:
   a. Cycle pumps to maintain vacuum-pressure set point.
   b. Visual indication of pump on and off, **as directed**, status.
   c. Visual and audible, **as directed**, alarm indication of pump failure.
9. Feedwater Simplex-Pump Control Sequence:
   a. Boiler water-level controller starts and stops pump to maintain boiler water-level set point.
   b. Visual indication of pump on and off, **as directed**, status.
   c. Visual and audible, **as directed**, alarm indication of pump failure.
10. Feedwater Duplex-Pump Control Sequence (for duplex-pump units with operating and standby pump):
    a. Boiler water-level controller starts and stops lead pump to maintain boiler water-level set point.
    b. Lead and lag pumps alternate after each start **OR** to equalize run time, **as directed**.
    c. Lead pump failure, lag pump automatically starts if lead pump cannot maintain set point **OR** is started manually, **as directed**.
    d. Visual indication of pump on and off, **as directed**, status.
    e. Visual indication of pump lead/lag status.
    f. Visual and audible, **as directed**, alarm indication of pump failure.
11. Feedwater Duplex-Pump Control Sequence (for duplex-pump units with continuous pump operation and modulating control valve):
    a. Pump runs continuously while boiler operates. Electric interlock with boiler control starts lead pump when boiler starts.
    b. Boiler water-level controller modulates feedwater control valve to maintain boiler water-level set point. Valve closes when boiler is off.
    c. Lead and lag pumps alternate after each start **OR** to equalize run time, **as directed**.
    d. Lead pump failure automatically starts lag pump.
       OR
       Feedwater pressure controller starts and stops lag pump to maintain feedwater pressure set point.
    e. Visual indication of pump on and off, **as directed**, status.
    f. Visual indication of pump lead/lag status.
    g. Visual and audible, **as directed**, alarm indication of pump failure.
12. Makeup Water Control Sequence:
    a. Electric level controller operates electric control valve to maintain water temperature set point.
    b. Visual and audible, **as directed**, alarm indication of low and high, **as directed**, water level.
13. Building Management System Interface: Factory install hardware to enable building management system to monitor and display points.
    a. Hardwired Monitoring Points: On/off status for each pump, failure alarm for each pump, receiver low-water-level alarm, receiver high-water-level alarm, feedwater temperature, **as directed**.

1.3 EXECUTION

A. Installation

1. Install feedwater unit level on concrete base. Concrete base is specified in Division 23 Section "Common Work Results For Hvac", and concrete materials and installation requirements are specified in Division 31.
2. Vibration Isolation: Elastomeric isolator pads **OR** mounts, **as directed**, with a minimum static deflection of 0.25 inch (6.35 mm). Vibration isolation devices and installation requirements are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
3. Install unit to permit access for maintenance.
4. Support piping independent of pumps.
5. Install base-mounted pumps on concrete bases with grouted base frames.
6. Install parts and accessories shipped loose.
7. Piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
8. Install piping adjacent to machine to allow service and maintenance.
9. Connect makeup water piping and cooling-water piping with reduced-pressure backflow preventers.
10. Install overflow drain piping to nearest floor drain.
11. Install vents and extend to outdoors; terminate with elbow turned down and an insect screen.
12. Adjust boiler water-level controls to properly stage unit.
13. Set field-adjustable, makeup water and cooling-water controls.
14. Clean equipment internally; remove coatings applied for protection during shipping and storage, foreign material, and oily residue according to manufacturer's written instructions.
15. Clean strainers.

B. Field Quality Control
1. Perform tests and inspections and prepare test reports.
   a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
2. Tests and Inspections:
   a. Inspect field-assembled components, equipment installation, and piping and electrical connections for compliance with manufacturer's written instructions.
   b. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
   c. Check bearing lubrication.
   d. Verify proper motor rotation.
   e. Start up service.
   f. Report results in writing.
3. Remove and replace malfunctioning units and retest as specified above.

END OF SECTION 23 53 16 00

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SECTION 23 53 16 00a - DEAERATORS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for deaerators. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes packaged, factory-assembled deaerators.

C. Definitions
1. Feedwater Pump: Pump that moves feedwater from the deaerator to the boiler.
2. Transfer Pump: Pump that moves feedwater from the surge tank to the deaerator.
3. NPSH: Net-positive suction head.

D. Submittals
1. Product Data: For each type of product indicated. Include rated makeup water, feedwater, and steam flow rates; working pressure; tank capacities; storage capacity in minutes; temperature and NPSH required; pump performance curves with selection points clearly indicated; furnished specialties; and accessories.
2. Shop Drawings: For deaerators, signed and sealed by a qualified professional engineer; include plans, elevations, sections, details, dimensions, weights, loadings, required clearances, and attachments to other work.
   a. For installed products indicated to comply with design loads, include structural analysis data.
   b. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing deaerator bases.
   c. Wiring Diagrams: Power, signal, and control wiring.
3. Manufacturer Seismic Qualification Certification: Submit certification that deaerators, accessories, and components will withstand seismic forces as indicated in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
4. Field quality-control test reports.
5. Operation and Maintenance Data: For deaerators to include in emergency, operation, and maintenance manuals.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. ASME Compliance: ASME B31.1, "Power Piping," for systems more than 15 psig (104 kPa); ASME B31.9, "Building Services Piping," for systems equal to or less than 15 psig (104 kPa). Safety valves and pressure vessels shall bear the appropriate ASME label.

F. Delivery, Storage, And Handling
1. Protect flanges, pipe openings, nozzles, bearings, and couplings from damage during shipping and storage.
2. Comply with manufacturer's written rigging instructions.
3. Deliver deaerators as factory-assembled units with protective crating and covering.

1.2 PRODUCTS

A. Manufactured Units

1. Horizontal **OR** Vertical, **as directed**, packed-column **OR** spray **OR** tray, **as directed**, single-compartment deaerator, and a separate packaged surge tank with transfer and feedwater pumps and controls to supply feedwater to deaerator, **as directed**.

   OR

   Horizontal **OR** Vertical, **as directed**, packed-column **OR** spray **OR** tray, **as directed**, two-compartment deaerator. One compartment for deaeration and one for surge volume, each with its own transfer and feedwater pumps and controls.

   OR

   Horizontal **OR** Vertical, **as directed**, packed-column **OR** spray **OR** tray, **as directed**, single-compartment deaerator and separate surge tank, both mounted on same factory-fabricated stand with necessary transfer and feedwater pumps and controls.
2. Material for Wetted Components: Components in contact with water that has not been deaerated shall be made of Type 304 **OR** 316, **as directed**, stainless steel.
3. Adjustable Spray Valves: Type 316 stainless steel. Arrange spray valves for counterflow of steam and condensate and so corrosive gases being vented do not contact deaerator's head or shell.
4. Vent Condenser: Stainless steel, with automatic and manual vent valves.
5. Deaerator and Storage Tank:
   a. Material: Welded carbon steel **OR** Welded carbon steel galvanized after fabrication **OR** Stainless steel, **as directed**.
   b. Additional Corrosion Protection:
      1) 0.07-inch (1.8-mm) **OR** 0.13-inch (3.3-mm) **OR** 0.19-inch (4.8-mm), **as directed**, thickness allowance.
      2) Electrolytic corrosion-inhibitor anode.
   c. Access: Manhole in deaerator and storage tank for access to internal components for inspection and service.
   d. Factory-Applied Insulation and Jacket: Minimum thickness of 2 inches (50 mm), **as directed,** for mineral-fiber pipe and tank insulation. Cover insulation with painted steel **OR** stucco-embossed aluminum **OR** stainless-steel, **as directed**, jacket.
   e. Factory-Installed Pipe, NPS 2-1/2 (DN 65) and Smaller: ASTM A 53/A 53M, Type S (seamless), Grade B; or ASTM A 106, Type S, Grade B, Schedule 40 **OR** 80, **as directed**; with threaded joints and fittings.
      1) Cast-Iron Threaded Fittings: ASME B16.4, Class 125 **OR** 250, **as directed**.
      2) Malleable-Iron Threaded Fittings: ASME B16.3, Class 150 **OR** 300, **as directed**.
      3) Forged-Steel Fittings: ASME B16.11, Class 3000.
      4) Malleable-Iron Unions: ASME B16.39, Class 150 **OR** 300, **as directed**.
      5) Forged-Steel Unions: MSS SP-83, Class 3000.
   f. Factory-Installed Pipe, NPS 3 (DN 80) and Larger: ASTM A 53/A 53M, Type E (electric-resistance welded), Grade B; or ASTM A 106, Type S, Grade B, Schedule 40 **OR** 80, **as directed**; with welded joints and carbon-steel fittings and flanges.
      1) Wrought-Steel Fittings: ASME B16.9, wall thickness to match adjoining pipe.
      2) Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, Class 150 **OR** 300, **as directed**, including bolts, nuts, and gaskets.
6. Accessories:
   a. Lifting eyes.
   b. Companion flanges.
   c. Pump suction piping with vortex breaker, isolation valve, strainer, and flexible connector.
   d. Pump discharge piping with check valve, isolation valve, and liquid-filled pressure gage graduated in pounds force per square inch **OR** kilopascals **OR** both pounds force per square inch and kilopascals, **as directed**.
   e. Pump-discharge bypass relief valve **OR** orifice plate **OR** relief valve with orifice plate, **as directed**.

f. Makeup Water Assembly:
   1) Factory-mounted modulating valve with mechanical level control, external float cage, and stainless-steel float.
      OR
      Factory **OR** Field, **as directed**,-mounted, electric, pilot-operated, solenoid **OR** modulating, **as directed**, valve with factory-mounted, probe-type, **as directed**, water-level controller.
      OR
      Factory **OR** Field, **as directed**,-mounted, pneumatic modulating valve with factory-mounted water-level controller.
   2) Factory **OR** Field, **as directed**,-mounted, three-valve bypass and inlet strainer.

g. Steam Pressure-Reducing Valve(s): Steam **OR** Electric **OR** Pneumatic, **as directed**, operated with three-valve bypass, **as directed**, and sized to reduce boiler outlet pressure to the deaerator design pressure.

h. Tank Overflow Drain: Sized to relieve full capacity at operating pressure.

i. Safety Valve(s): ASME labeled and sized to relieve full capacity of pressure-reducing valve.

j. Vents: Manual and automatic vent valves.

k. Vacuum breaker.

l. Meters and Gages:
   1) Full-height, water-level gage glass, reflex flat type, **as directed**, and stop valve set.
   2) Liquid-filled industrial **OR** Bimetal dial-type, **as directed**, thermometer graduated in Fahrenheit **OR** Celsius **OR** both Fahrenheit and Celsius, **as directed**, mounted to measure temperature in storage and steam, **as directed**, section of tank.
   3) Pressure gage graduated in pounds force per square inch **OR** kilopascals **OR** both pounds force per square inch and kilopascals, **as directed**, mounted to measure pressure in steam section of tank.

m. Provision for chemical injection quill.

n. Chemical injection quill.

o. Sampling connection with valve.

p. Tank drain connection with valve.

q. Oxygen test kit.

7. Support Frame: Structural-steel frame for supporting tank and pumps. Weld or bolt to tank.
   a. Fabricate support frame with bracing adequate for seismic forces according to authorities having jurisdiction and to allow installation by anchoring deaerators to floor only, as directed.

8. Feedwater Pump: Cast-iron, flange **OR** base, **as directed**,-mounted volute; with bronze **OR** stainless-steel, **as directed**, multistage centrifugal **OR** turbine, **as directed**, impeller, renewable bronze case ring, and stainless-steel shaft.
   a. Seals: Mechanical, suitable for 250 deg F (121 deg C).
   b. Pump Motor: Vertical **OR** Horizontal, **as directed**, open dripproof **OR** totally enclosed **OR** totally enclosed fan-cooled, **as directed**, enclosure, close **OR** flexible, **as directed**, coupled to pump. Comply with requirements in Division 15 Section "Motors."

9. Feedwater Pump Control Panel: Factory mounted and wired and including the following:
   a. NEMA 250, Type 1 **OR** 4 **OR** 4X **OR** 12, **as directed**, enclosure.
   b. Single-point, field power connection to fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**.
      1) Branch power circuit to each motor and to controls with a disconnect switch or circuit breaker, **as directed**.
   c. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor.
      1) Alternating control as indicated by control sequence for each pump.
   d. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
   e. Metal raceway **OR** Raceway, **as directed**, for factory-installed wiring outside of enclosures. Make connections to motor with liquidtight conduit.
   f. Removable control mounting plate.

g. Visual indication of status and alarm with momentary test push button, **as directed**.
h. Audible alarm and silence switch.
i. Visual indication of elapsed run time, graduated in hours.
j. Fusible, control-circuit transformer.
k. Microprocessor-based controller.

10. Feedwater Pump Start-Stop Control Sequence (for intermittent pump operation):
    a. Boiler water-level controller starts and stops lead pump to maintain boiler water-level set point.
    b. Lead and lag pumps alternate after each start **OR** to equalize run time, **as directed**.
    c. Lead pump failure, lag pump automatically starts if lead pump cannot maintain set point **OR** is started manually, **as directed**.
    d. Visual indication of pump on **OR** on and off, **as directed**, status.
    e. Visual indication of pump lead/lag status.
    f. Visual **OR** Visual and audible, **as directed**, alarm indication of pump failure.
11. Feedwater Pump Continuous Control Sequence (for continuous pump operation and modulating control valve):
    a. Pump runs continuously while boiler operates. Electric interlock with boiler control starts lead pump when boiler starts.
    b. Boiler water-level controller modulates feedwater control valve to maintain boiler water-level set point. Valve closes when boiler is off.
    c. Lead and lag pumps alternate after each start **OR** to equalize run time, **as directed**.
    d. Lead pump failure automatically starts lag pump.
       OR
       Feedwater pressure controller starts and stops lag pump to maintain feedwater pressure set point.
    e. Visual indication of pump on **OR** on and off, **as directed**, status.
    f. Visual indication of pump lead/lag status.
    g. Visual **OR** Visual and audible, **as directed**, alarm indication of pump failure.
12. Makeup Water Control Sequence:
    a. Electric level controller operates electric control valve to maintain tank water-level set point.
       OR
       Pneumatic level controller operates pneumatic control valve to maintain tank water-level set point.
       OR
       Mechanical float operates valve to maintain water-level set point.
    b. Visual **OR** Visual and audible, **as directed**, alarm indication of low **OR** low and high, **as directed**, tank water level.
13. Building Management System Interface: Factory install hardware to enable building management system to monitor and display points.
    a. Hardwired Monitoring Points: On/off status for each pump, failure alarm for each pump, low-water level alarm, high-water level alarm, feedwater temperature, **as directed**.

B. Surge Tank
1. Description: Factory-assembled and -tested unit consisting of a condensate receiver, transfer pumps, and controls.
2. Accessories:
    a. Liquid-filled industrial **OR** Bimetal dial-type, **as directed**, thermometer graduated in Fahrenheit **OR** Celsius **OR** both Fahrenheit and Celsius, **as directed**.
    b. Level gage glass, reflex flat type, **as directed**, with stops at top and bottom.
    c. Lifting eyes.
    d. Companion flanges.
    e. Pump suction piping with vortex breaker, isolation valve, strainer, and flexible connector.
    f. Pump discharge piping with check valve, isolation valve, and liquid-filled pressure gage graduated in pounds force per square inch **OR** kilopascals **OR** both pounds force per square inch and kilopascals, **as directed**.

g. Pump-discharge bypass relief valve **OR** orifice plate **OR** relief valve with orifice plate, **as directed**.

3. Factory-Installed Pipe, NPS 2-1/2 (DN 65) and Smaller: ASTM A 53/A 53M, Type S (seamless), Grade B; or ASTM A 106, Type S, Grade B, Schedule 40 **OR** 80, **as directed**; with threaded joints and fittings.
   a. Cast-Iron Threaded Fittings: ASME B16.4, Class 125 **OR** 250, **as directed**.
   b. Malleable-Iron Threaded Fittings: ASME B16.3, Class 150 **OR** 300, **as directed**.
   c. Forged-Steel Fittings: ASME B16.11, Class 3000.
   d. Malleable-Iron Unions: ASME B16.39, Class 150 **OR** 300, **as directed**.
   e. Forged-Steel Unions: MSS SP-83, Class 3000.
4. Factory-Installed Pipe, NPS 3 (DN 80) and Larger: ASTM A 53/A 53M, Type E (electric-resistance welded), Grade B; or ASTM A 106, Type S, Grade B, Schedule 40 **OR** 80, **as directed**; with welded joints and carbon-steel fittings and flanges.
   a. Wrought-Steel Fittings: ASME B16.9, wall thickness to match adjoining pipe.
   b. Wrought Cast- and Forged-Steel Flanges and Flanged Fittings: ASME B16.5, Class 150 **OR** 300, **as directed**, including bolts, nuts, and gaskets.
5. Tank:
   a. Material: Welded carbon steel **OR** Welded carbon steel galvanized after fabrication **OR** Stainless steel, **as directed**.
   b. Additional Corrosion Protection:
      1) 0.07-inch (1.8-mm) **OR** 0.13-inch (3.3-mm) **OR** 0.19-inch (4.8-mm), **as directed**, thickness allowance.
      2) Electrolytic corrosion-inhibitor anode.
   c. Access: Manhole in tank for access to internal components for inspection and service.
   d. Factory-Applied Insulation and Jacket: Minimum thickness of 2 inches (50 mm) for mineral-fiber pipe and tank insulation. Cover insulation with painted steel **OR** stucco-embossed aluminum **OR** stainless-steel, **as directed**, jacket.
6. Support Frame: Structural-steel frame for supporting tank. Weld or bolt to tank.
   a. Fabricate support frame with bracing adequate for seismic forces according to authorities having jurisdiction and to allow installation by anchoring deaerators to floor only.
7. Transfer Pump: Vertical, flange-mounted, close-coupled, single-stage **OR** multistage, **as directed**, radially split-case centrifugal pump; rated for 175-psig (1205-kPa) minimum working pressure and a continuous water temperature of 225 deg F (107 deg C); with the following features:
   a. Impeller: Bronze **OR** Stainless steel, **as directed**.
   b. Seals: Mechanical.
   c. Motor: Open dripproof **OR** Totally enclosed **OR** Totally enclosed fan-cooled, **as directed**, enclosure. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
8. Transfer Pump: Horizontal, base-mounted, single-stage **OR** multistage, **as directed**, radially split-case centrifugal pump; rated for 175-psig (1205-kPa) minimum working pressure and a continuous water temperature of 225 deg F (107 deg C); with the following features:
   a. Impeller: Bronze **OR** Stainless steel, **as directed**.
   b. Coupling: Close **OR** Flexible, **as directed**.
   c. Seals: Mechanical.
   d. Motor: Open dripproof **OR** Totally enclosed **OR** Totally enclosed fan-cooled, **as directed**, enclosure. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
9. Transfer Pump Control Panel: Factory mounted and wired and including the following:
   a. NEMA 250, Type 1 **OR** 4 **OR** 4X **OR** 12, **as directed**, enclosure.
   b. Single-point, field power connection to fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**.
      1) Branch power circuit to each motor and to controls with a disconnect switch or circuit breaker, **as directed**.
   c. NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor.

1) Alternating control indicated by control sequence for each pump.
d. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
e. Metal raceway **OR** Raceway, **as directed**, for factory-installed wiring outside of enclosures. Make connections to motor with liquidtight conduit.
f. Removable control mounting plate.
g. Visual indication of on/off status and pump failure alarm with momentary test push button, **as directed**.
h. Audible alarm and silence switch.
i. Visual indication of elapsed run time, graduated in hours.
j. Fusible, control-circuit transformer.
k. Microprocessor-based controller.

10. Transfer Pump Start-Stop Control Sequence: Deaerator water-level controller controls lead pump; alternator switches lead and lag pump(s) after each start **OR** to equalize run time, **as directed**; failure of lead pump switches to lag pump and sounds audible alarm, **as directed**.
11. Transfer Pump Continuous-Run Control Sequence: Lead pump runs continuously while deaerator is operating; deaerator water-level controller modulates water-level-control valve; lead and lag pump(s) switch to equalize run time; lag pump operates if lead pump fails; pump failure sounds audible alarm, **as directed**.
12. Building Management System Interface: Factory install hardware to enable building management system to monitor and display points.
    a. Hardwired Monitoring Points: On/off status for each pump, failure alarm for each pump, low-water level alarm, high-water level alarm, **as directed**.

C. Factory Finishes
1. Manufacturer's standard prime-coat finish ready for field painting.
2. Manufacturer's standard paint in standard colors, applied to factory-assembled and -tested unit before shipping.
3. Do not paint aluminum, galvanized-steel, and stainless-steel surfaces.

D. Source Quality Control
1. Fabricate and label deaerator tanks according to ASME Boiler and Pressure Vessel Code: Section VIII, "Pressure Vessels," Division 1.
2. Factory install and test piping that connects pumps to tanks according to ASME B31.1, "Power Piping" **OR** ASME B31.9, "Building Services Piping," **as directed**.
3. Factory test performance and certify test results on packaged deaerator units, according to ASME PTC 12.3, before shipping to Project.

1.3 EXECUTION

A. Examination
1. Before deaerator installation, examine roughing-in for concrete equipment bases, anchor-bolt sizes and locations, and piping and electrical connections to verify actual locations, sizes, and other conditions affecting performance, maintenance, and operations.
    a. Final deaerator locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
    b. Proceed with installation only after unsatisfactory conditions have been corrected.

B. Installation
1. Install deaerators level on concrete base. Concrete base is specified in Division 23 Section "Common Work Results For Hvac", and concrete materials and installation requirements are specified in Division 31.
2. Vibration Isolation: Elastomeric isolator pads **OR** mounts, **as directed**, with a minimum static deflection of 0.25 inch (6.35 mm). Vibration isolation devices and installation requirements are

specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".

3. Install deaerators to permit access for service and maintenance.
4. Support piping independent of pumps.
5. Install base-mounted pumps on concrete base with grouted base frame.
6. Install all parts and materials not factory installed.
7. Extend overflow drains to floor drains.
8. Extend vent piping to outside and terminate with manufacturer-approved cap furnished with deaerator.
9. Install piping adjacent to machine to allow service and maintenance.

C. Connections
1. Steam and condensate piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
2. Connect steam and condensate piping to tank tappings with shutoff valves and unions or flanges at each connection.
3. Connect condensate drains, pump-discharge piping, vents, overflow drains, makeup water, steam supply, and cooling water piping.

D. Field Quality Control
1. Perform tests and inspections and prepare test reports.
2. Tests and Inspections:
   a. Inspect field-assembled components and equipment installation, including piping and electrical connections, for compliance with requirements.
   b. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
   c. Verify bearing lubrication.
   d. Verify proper motor rotation.
   e. Test Reports: Prepare a written report to record the following:
      1) Test procedures used.
      2) Test results that comply with requirements.
      3) Test results that do not comply with requirements and corrective action taken to achieve compliance with requirements.
3. Remove and replace malfunctioning equipment and retest as specified above.

E. Startup Service
1. Engage a factory-authorized service representative to perform startup service.
2. Complete installation and startup checks according to manufacturer's written instructions and do the following:
   a. Set deaerator makeup water-level controls.
   b. Verify bearing lubrication.
   c. Verify proper motor rotation.
   d. Start pumps according to manufacturer's written instructions.

F. Adjusting And Cleaning
1. Adjust initial temperature and pressure set points.
2. Set field-adjustable switches and circuit-breaker trip ranges.
3. Clean strainers.

G. Demonstration
1. Train Owner's maintenance personnel to adjust, operate, and maintain deaerators.

END OF SECTION 23 53 16 00a

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SECTION 23 54 16 13 - FURNACES

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for furnaces. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following:
a. Gas-fired, noncondensing, Gas-fired, condensing, Oil-fired, and Electric furnaces and accessories complete with controls.
b. Air filters.
c. Air cleaners.
d. Ultraviolet germicidal lights.
e. Humidifiers.
f. Ventilation heat exchangers.
g. Refrigeration components.

C. Submittals
1. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories for each of the following:
a. Furnace.
b. Thermostat.
c. Humidistat.
d. Air filter.
e. Air cleaner.
f. Ultraviolet germicidal light.
g. Humidifier.
h. Ventilation heat exchanger.
i. Refrigeration components.
2. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
a. Wiring Diagrams: Power, signal, and control wiring.
3. Operation and maintenance data.
4. LEED Submittals:
a. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.
b. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
c. Product Data for Credit EQ 4.1: For solvent cements and adhesive primers, including printed statement of VOC content.
5. Warranty: Special warranty specified in this Section.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

3. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
4. Comply with NFPA 70.

E. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace the following components of furnaces that fail in materials or workmanship within specified warranty period:
   a. Warranty Period, Commencing on Date of Final Completion:
      1) Furnace Heat Exchanger: 10 years **OR** 20 years **OR** Lifetime, **as directed**.
      2) Integrated Ignition and Blower Control Circuit Board: Five years.
      3) Draft-Inducer Motor: Five years.
      4) High-Efficiency Oil Furnace Burner: Three years.
      5) Refrigeration Compressors: 10 years **OR** Lifetime, **as directed**.
      6) Evaporator and Condenser Coils: Five years.

1.2 PRODUCTS

A. Gas-Fired Furnaces, Noncondensing
1. General Requirements for Gas-Fired, Noncondensing Furnaces: Factory assembled, piped, wired, and tested; complying with ANSI Z21.47/CSA 2.3, "Gas-Fired Central Furnaces," and with NFPA 54.
2. Cabinet: Steel **OR** Galvanized steel, **as directed**.
   a. Cabinet interior around heat exchanger shall be factory-installed insulation.
   b. Lift-out panels shall expose burners and all other items requiring access for maintenance.
   c. Factory paint external cabinets in manufacturer's standard color.
   d. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
3. Fan: Centrifugal, factory balanced, resilient mounted, direct drive **OR** belt drive **OR** direct or belt drive **OR** drive type indicated on Drawings, **as directed**.
   a. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   b. Special Motor Features: Single speed, Premium (TM) efficiency, as defined in Division 23 Section "Common Motor Requirements For Hvac Equipment", and with internal thermal protection and permanent lubrication.
      OR
      Special Motor Features: Multitapped, multispeed with internal thermal protection and permanent lubrication.
      OR
      Special Motor Features: Electronically controlled motor (ECM) controlled by integrated furnace/blower control.
4. Type of Gas: Natural **OR** Propane, **as directed**.
5. Heat Exchanger: Aluminized **OR** Stainless, **as directed**, steel.
6. Burner:
   a. Gas Valve: 100 percent safety two-stage **OR** modulating, **as directed**, main gas valve, main shutoff valve, pressure regulator, safety pilot with electronic flame sensor, limit control, transformer, and combination ignition/fan timer control board.
   b. Ignition: Electric pilot ignition, with hot-surface igniter or electric spark ignition.
7. Gas-Burner Safety Controls:
   a. Electronic Flame Sensor: Prevents gas valve from opening until pilot flame is proven; stops gas flow on ignition failure.
   b. Flame Rollout Switch: Installed on burner box; prevents burner operation.
   c. Limit Control: Fixed stop at maximum permissible setting; de-energizes burner on excessive bonnet temperature; automatic reset.

8. Combustion-Air Inducer: Centrifugal fan with thermally protected motor and sleeve bearings prepurges heat exchanger and vents combustion products; pressure switch prevents furnace operation if combustion-air inlet or flue outlet is blocked.
9. Furnace Controls: Solid-state board integrates ignition, heat, cooling, and fan speeds; and adjustable fan-on and fan-off timing; terminals for connection to accessories.
10. Vent Materials: Comply with requirements in Division 23 Section "Breechings, Chimneys, And Stacks", for Type B metal vents.

B. Gas-Fired Furnaces, Condensing
1. General Requirements for Gas-Fired, Condensing Furnaces: Factory assembled, piped, wired, and tested; complying with ANSI Z21.47/CSA 2.3, "Gas-Fired Central Furnaces," and with NFPA 54.
2. Cabinet: Steel **OR** Galvanized steel, **as directed**.
   a. Cabinet interior around heat exchanger shall be factory-installed insulation.
   b. Lift-out panels shall expose burners and all other items requiring access for maintenance.
   c. Factory paint external cabinets in manufacturer's standard color.
   d. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
3. Fan: Centrifugal, factory balanced, resilient mounted, direct drive.
   a. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   b. Special Motor Features: Single speed, Premium (TM) efficiency, as defined in Division 23 Section "Common Motor Requirements For Hvac Equipment", and with internal thermal protection and permanent lubrication.
      OR
      Special Motor Features: Multitapped, multispeed with internal thermal protection and permanent lubrication.
      OR
      Special Motor Features: Electronically controlled motor (ECM) controlled by integrated furnace/blower control.
4. Type of Gas: Natural **OR** Propane, **as directed**.
5. Heat Exchanger:
   a. Primary: Aluminized **OR** Stainless, **as directed**, steel.
   b. Secondary: Polyethylene-coated **OR** Stainless, **as directed**, steel.
6. Burner:
   a. Gas Valve: 100 percent safety two-stage **OR** modulating, **as directed**, main gas valve, main shutoff valve, pressure regulator, safety pilot with electronic flame sensor, limit control, transformer, and combination ignition/fan timer control board.
   b. Ignition: Electric pilot ignition, with hot-surface igniter or electric spark ignition.
7. Gas-Burner Safety Controls:
   a. Electronic Flame Sensor: Prevents gas valve from opening until pilot flame is proven; stops gas flow on ignition failure.
   b. Flame Rollout Switch: Installed on burner box; prevents burner operation.
   c. Limit Control: Fixed stop at maximum permissible setting; de-energizes burner on excessive bonnet temperature; automatic reset.
8. Combustion-Air Inducer: Centrifugal fan with thermally protected motor and sleeve bearings prepurges heat exchanger and vents combustion products; pressure switch prevents furnace operation if combustion-air inlet or flue outlet is blocked.
9. Furnace Controls: Solid-state board integrates ignition, heat, cooling, and fan speeds; adjustable fan-on and fan-off timing; terminals for connection to accessories; diagnostic light with viewport, **as directed**.
10. Accessories:
   a. Combination Combustion-Air Intake and Vent: PVC plastic fitting to combine combustion-air inlet and vent through outside wall **OR** roof, **as directed**.
   b. CPVC Plastic Vent Materials.
      1) CPVC Plastic Pipe: Schedule 40, complying with ASTM F 441/F 441M.

2) CPVC Plastic Fittings: Schedule 40, complying with ASTM F 438, socket type.
3) CPVC Solvent Cement: ASTM F 493.
a) Use CPVC solvent cement that has a VOC content of 490 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
b) Use adhesive primer that has a VOC content of 550 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

c. PVC Plastic Vent Materials:
1) PVC Plastic Pipe: Schedule 40, complying with ASTM D 1785.
2) PVC Plastic Fittings: Schedule 40, complying with ASTM D 2466, socket type.
3) PVC Solvent Cement: ASTM D 2564.
a) Use PVC solvent cement that has a VOC content of 510 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
b) Use adhesive primer that has a VOC content of 550 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

C. Oil-Fired Furnaces
1. General Requirements for Oil-Fired Furnaces: Factory assembled, piped, wired, and tested; complying with UL 727 and with NFPA 31.
2. Cabinet: Steel **OR** Galvanized steel, **as directed**.
a. Cabinet interior around heat exchanger shall be factory-installed insulation.
b. Lift-out panels shall expose burners and all other items requiring access for maintenance.
c. Factory paint external cabinets in manufacturer's standard color.
d. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
3. Fan: Centrifugal, factory balanced, resilient mounted, direct drive **OR** belt drive **OR** drive type indicated on Drawings, **as directed**.
a. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
4. Special Motor Features: Single speed, Premium (TM) efficiency, as defined in Division 23 Section "Common Motor Requirements For Hvac Equipment", and with internal thermal protection and permanent lubrication.
OR
Special Motor Features: Multitapped, multispeed with internal thermal protection and permanent lubrication.
5. Heat Exchanger: Welded steel with ceramic-fiber liner **OR** refractory insert, **as directed**, at the burner in the combustion chamber. Minimum 2-inch- (50-mm-) diameter access ports in heat exchanger to permit access for cleaning.
6. Burner: High-pressure atomizing type, with rubber-mounted, adjustable, combustion-air blower; integrated fuel pump; hinged, flame-inspection port; cadmium-sulfide flame sensor; electrodes; ignition transformer; and oil nozzle.
a. Time-Delay Relay: Limits time for establishing main flame.
b. Flame Sensor: Monitors flame and stops burner on flame failure.
c. Limit Control: Fixed stop at maximum permissible setting; de-energizes burner on excessive bonnet temperature; automatic reset.
7. Barometric Draft Regulator: Match furnace; for mounting in flue.
8. Furnace Controls: Solid-state board integrates ignition, heat, cooling, and fan speeds; and adjustable fan-on and fan-off timing; terminals for connection to accessories.
9. Vent Materials: Comply with requirements in Division 23 Section "Breechings, Chimneys, And Stacks" for Type B metal vents.

D. Electric Furnaces
1. General Requirements for Electric Furnaces: Factory assembled, piped, wired, and tested.
2. Cabinet: Steel, with duct liner downstream from cooling coil, **as directed**.
a. Duct Liner: Fiberglass, minimum 1/2 inch (13 mm) **OR** 3/4 inch (19 mm), **as directed**, thick, complying with ASTM C 1071 and having a coated surface exposed to airstream

complying with NFPA 90A or NFPA 90B and with NAIMA's "Fibrous Glass Duct Liner Standard."

1) Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

b. Factory paint external cabinets in manufacturer's standard color.

3. Fan: Centrifugal, factory balanced, resilient mounted, direct drive.

a. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".

b. Special Motor Features: Single speed, Premium (TM) efficiency, as defined in Division 23 Section "Common Motor Requirements For Hvac Equipment", and with internal thermal protection and permanent lubrication.

OR

Special Motor Features: Multitapped, multispeed with internal thermal protection and permanent lubrication.

OR

Special Motor Features: Electronically controlled motor (ECM) controlled by integrated furnace/blower control.

4. Electric-Resistant Heating Elements: Helix-wound, nickel-chromium wire-heating elements in ceramic insulators mounted on steel supports.

5. Heating-Element Control: Sequencer relay with relay for each element; switches elements on and off, with delay between each increment; initiates, stops, or changes fan speed.

6. Summer Fan Switch: Connected to permit independent on-off switch of unit fan.

E. Thermostats And Humidistats

1. Solid-State Thermostat: Wall-mounting **OR** Freestanding **OR** Wireless, **as directed**, programmable, microprocessor-based unit with automatic **OR** manual, **as directed**, switching from heating to cooling, preferential rate control, seven-day programmability with minimum of four temperature presets per day, vacation mode, **as directed**, and battery backup protection against power failure for program settings.

OR

Single-Stage, Heating-Cooling Thermostat: Adjustable, heating-cooling, wall-mounting unit with fan on-automatic selector.

OR

Two-Stage, Heating-Cooling Thermostat: Adjustable, heating-cooling, wall-mounting unit with fan on-automatic selector.

OR

Single-Stage **OR** Two-Stage, **as directed**, Heating-Only Thermostat: Wall-mounting unit with fan on-automatic selector.

OR

Solid-State, Combination Thermostat and Humidistat: Wall-mounting **OR** Freestanding **OR** Wireless, **as directed**, programmable, microprocessor-based unit with automatic switching from heating to cooling and humidifying to dehumidifying, preferential rate control, seven-day programmability with minimum of four temperature presets per day, vacation mode, **as directed**, and battery backup protection against power failure for program settings.

2. Humidistat: Adjustable, wall-mounting **OR** duct-mounting, **as directed**, unit.

3. Control Wiring: Unshielded twisted-pair cabling.

a. No. 24 AWG, 100 ohm, four pair.

b. Cable Jacket Color: Blue.

4. Controls shall comply with requirements in ASHRAE/IESNA 90.1, "Controls."

F. Air Filters

1. Washable Filters: 1-inch- (25-mm-) thick, urethane pad.

2. Disposable Filters: 1-inch- (25-mm-) thick fiberglass media with ASHRAE 52.2 MERV rating of 6 or higher, **as directed**, in sheet metal frame.

3. Charged Media Air Filters: Sheet metal housing arranged to be ducted in return-air duct connection to furnace, generates electrostatic charge; MERV 10 rating.

4. HEPA Air Filter Units: Sheet metal housing with fan arranged to be ducted to return-air duct connection to furnace, with activated carbon prefilter, high-efficiency particulate air (HEPA) disposable filter, and carbon VOC, **as directed**. HEPA shall be as follows:
   a. Standard: UL 586, "High-Efficiency, Particulate, Air Filter Units."
   b. Rating: ASHRAE 52.1, dust-spot efficiency of 65 percent; ASHRAE 52.2, 99.97 percent efficiency to 0.03-micrometer particle size.

G. Air Cleaners
1. Electronic Air Cleaners: Packaged system, including sheet metal housing, prefilter, power supply, and automatic control device, arranged for mounting in return-air duct at furnace; equip with on-off and test switches and pilot light.
   a. Standard: UL 586, "High-Efficiency, Particulate, Air Filter Units."
   b. Rating: ASHRAE 52.2, particle size to 0.01 micrometer.
   c. Static Pressure Drop: Maximum 0.14-inch wg (35 Pa) at 300-fpm (1.52-m/s) air velocity.

H. Ultraviolet Germicidal Lights
1. Description: Lighting unit in metal housing arranged for installation in supply-air duct and controlled to cycle on and off with furnace fan, with one **OR** two, **as directed**, 75-W ultraviolet-light bulb(s).

I. Humidifiers
1. Minimum capacity rating indicated according to ARI 610, "Central System Humidifiers for Residential Applications."
2. Media-wheel bypass type with bypass damper and motor-driven media wheel in reservoir with float-valve level control; arranged for mounting on return duct or plenum with bypass connection to supply duct.
   OR
   Wetted-pad, continuous-drain, bypass type with bypass damper and water-flow control orifice; arranged for mounting on return duct or plenum with bypass connection to supply duct.
   OR
   Fan-powered, wetted-pad, continuous-drain type with water-flow control orifice and motor; arranged for mounting on duct or plenum.
   OR
   Pumped, fan-powered, wetted-pad type with reservoir-level control and pump and fan motors; arranged for mounting on duct or plenum.
   OR
   Steam type with electric heating element in stainless-steel reservoir with float-valve level control; arranged for attachment to duct or plenum and for control by humidistat.
3. Comply with applicable requirements in ASHRAE 62.1.

J. Ventilation Air Heat Exchanger
1. Cabinet: Steel, with factory-installed interior insulation and manufacturer's standard factory finish. Fabricate with space for piping and electrical conduits.
2. Heat-Recovery Device: Fixed-plate, polypropylene copolymer (high-density plastic) heat-exchanger plates evenly spaced and sealed and arranged for counter airflow.
3. Supply and Exhaust Fans: Forward curved centrifugal with direct drive. Motors comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
4. Filters: 1-inch- (25-mm-) thick disposable type with ASHRAE 52.2 MERV rating of 6 or higher, **as directed**, in galvanized-steel frame, mounted upstream of unit in both supply and exhaust airstreams.
5. Wiring: Wire motors and controls so only external connections are required during installation.

K. Refrigeration Components
1. General Refrigeration Component Requirements:

a. Refrigeration compressor, coils, and specialties shall be designed to operate with CFC-free refrigerants.
b. Energy Efficiency: Equal to or greater than prescribed by ASHRAE/IESNA 90.1, "Energy Standard for Buildings except Low-Rise Residential Buildings."

2. Refrigerant Coil: Copper tubes mechanically expanded into aluminum fins. Comply with ARI 210/240, "Unitary Air-Conditioning and Air-Source Heat Pump Equipment." Match size with furnace. Include condensate drain pan with accessible drain outlet complying with ASHRAE 62.1, **as directed**.
   a. Refrigerant Coil Enclosure: Steel, matching furnace and evaporator coil, with access panel and flanges for integral mounting at or on furnace cabinet and galvanized sheet metal drain pan coated with black asphaltic base paint.
3. Refrigerant Line Kits: Annealed-copper suction and liquid lines factory cleaned, dried, pressurized with nitrogen, sealed, and with suction line insulated. Provide in standard lengths for installation without joints, except at equipment connections.
   a. Flexible Elastomeric: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534, Type I, 1/2 inch (13 mm) **OR** 1 inch (25 mm), **as directed**, thick.
4. Refrigerant Piping: Comply with requirements in Division 23 Section "Refrigerant Piping".
5. Air-Cooled, Compressor-Condenser Unit:
   a. Casing: Steel, finished with baked enamel, with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Provide brass service valves, fittings, and gage ports on exterior of casing.
   b. Compressor: Hermetically sealed reciprocating **OR** scroll, **as directed**, type.
      1) Crankcase heater.
      2) Restrained vibration **OR** Vibration, **as directed**, isolation mounts for compressor.
      3) Compressor motor shall have thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
      4) Two-speed compressor motors shall have manual-reset high-pressure switch and automatic-reset low-pressure switch.
      5) Refrigerant Charge: R-407C **OR** R-410A, **as directed**.
   c. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with ARI 210/240, and with liquid subcooler.
   d. Heat-Pump Components: Reversing valve and low-temperature air cut-off thermostat.
   e. Fan: Aluminum-propeller type, directly connected to motor.
   f. Motor: Permanently lubricated, with integral thermal-overload protection.
   g. Low Ambient Kit: Permits operation down to 45 deg F (7 deg C).
   h. Mounting Base: Polyethylene.

1.3 EXECUTION

A. Installation
1. Install gas-fired furnaces and associated fuel and vent features and systems according to NFPA 54.
2. Install oil-fired furnaces and associated fuel and vent piping according to NFPA 31.
3. Suspended Units: Suspend from structure using threaded rods, spring hangers, and building attachments. Secure rods to unit hanger attachments. Adjust hangers so unit is level and plumb.
   a. Install seismic restraints to limit movement of furnace by resisting code-required seismic acceleration.
4. Base-Mounted Units: Secure units to substrate. Provide optional bottom closure base if required by installation conditions.
   a. Anchor furnace to substrate to resist code-required seismic acceleration.
5. Controls: Install thermostats and humidistats at mounting height of 60 inches (1500 mm) above floor.
6. Wiring Method: Install control wiring in accessible ceiling spaces and in gypsum board partitions where unenclosed wiring method may be used. Conceal control wiring except in unfinished spaces.

7. Install ground-mounted, compressor-condenser components on 4-inch- (100-mm-) thick, reinforced concrete base; 4 inches (100 mm) larger on each side than unit. Concrete, reinforcement, and formwork are specified in Division 03 Section "Cast-in-place Concrete". Coordinate anchor installation with concrete base.
   OR
   Install ground-mounted, compressor-condenser components on polyethylene mounting base.
8. Install roof-mounted, compressor-condenser components on equipment supports specified in Division 07 Section "Roof Accessories". Anchor units to supports with removable, cadmium-plated fasteners.

B. Connections
1. Gas piping installation requirements are specified in Division 23 Section(s) "Facility Natural-gas Piping" OR "Facility Liquefied-petroleum Gas Piping", **as directed**. Drawings indicate general arrangement of piping, fittings, and specialties. Connect gas piping with union or flange and appliance connector valve.
2. Oil piping installation requirements are specified in Division 23 Section "Facility Fuel-oil Piping". Drawings indicate general arrangement of piping, fittings, and specialties. Connect oil piping with union or flange and ball **OR** gate, **as directed**, valve.
3. Install piping adjacent to equipment to allow service and maintenance.
4. Water piping installation requirements for furnaces with humidifiers are specified in Division 22 Section "Domestic Water Piping". Drawings indicate general arrangement of piping, fittings, and specialties. Connect water piping with union and ball valve.
5. Vent Connection, Noncondensing, Gas-Fired Furnaces: Connect Type B vents to furnace vent connection and extend outdoors. Type B vents and their installation requirements are specified in Division 23 Section "Breechings, Chimneys, And Stacks".
6. Vent and Outside-Air Connection, Condensing, Gas-Fired Furnaces: Connect plastic piping vent material to furnace connections and extend outdoors. Terminate vent outdoors with a cap and in an arrangement that will protect against entry of birds, insects, and dirt.
   a. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
   b. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
   c. Plastic Piping Solvent-Cement Joints: Clean and dry joining surfaces. Join pipe and fittings according to the following:
      1) Comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements.
      2) CPVC Piping: Join according to ASTM D 2846/D 2846M Appendix.
      3) PVC Pressure Piping: Join schedule number ASTM D 1785, PVC pipe and PVC socket fittings according to ASTM D 2672. Join other-than-schedule-number PVC pipe and socket fittings according to ASTM D 2855.
      4) Requirements for Low-Emitting Materials:
         a) Use CPVC solvent cement that has a VOC content of 490 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
         b) Use PVC solvent cement that has a VOC content of 510 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
         c) Use adhesive primer that has a VOC content of 550 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
   d. Slope pipe vent back to furnace or to outside terminal.
7. Vent Connections, Oil-Fired Furnaces: Connect Type L vents to furnace vent connection and extend outdoors. Type L vents and their installation requirements are specified in Division 23 Section "Breechings, Chimneys, And Stacks".
8. Connect ducts to furnace with flexible connector. Comply with requirements in Division 23 Section "Air Duct Accessories".
9. Connect refrigerant tubing kits to refrigerant coil in furnace and to air-cooled, compressor-condenser unit.

a. Flared Joints: Use ASME B16.26 fitting and flared ends, following procedures in CDA's "Copper Tube Handbook."
OR
Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA's "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.
OR
Brazed Joints: Construct joints according to AWS's "Brazing Handbook," "Pipe and Tube" Chapter, using copper-phosphorus brazing filler metal complying with AWS A5.8.

10. Comply with requirements in Division 23 Section "Refrigerant Piping" for installation and joint construction of refrigerant piping.

C. Field Quality Control
1. Perform the following field tests and inspections and prepare test reports:
   a. Perform electrical test and visual and mechanical inspection.
   b. Leak Test: After installation, charge systems with refrigerant and oil and test for leaks. Repair leaks, replace lost refrigerant and oil, and retest until no leaks exist.
   c. Operational Test: After electrical circuitry has been energized, start units to confirm proper operation, product capability, and compliance with requirements.
   d. Verify that fan wheel is rotating in the correct direction and is not vibrating or binding.
   e. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
2. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.

D. Startup Service
1. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
   a. Inspect for physical damage to unit casings.
   b. Verify that access doors move freely and are weathertight.
   c. Clean units and inspect for construction debris.
   d. Verify that all bolts and screws are tight.
   e. Adjust vibration isolation and flexible connections.
   f. Verify that controls are connected and operational.
2. Adjust fan belts to proper alignment and tension.
3. Start unit according to manufacturer's written instructions and complete manufacturer's operational checklist.
4. Measure and record airflows.
5. Verify proper operation of capacity control device.
6. After startup and performance test, lubricate bearings and adjust belt tension, **as directed**.

E. Adjusting
1. Adjust initial temperature and humidity set points.
2. Set controls, burner, and other adjustments for optimum heating performance and efficiency. Adjust heat-distribution features, including shutters, dampers, and relays, to provide optimum heating performance and system efficiency.

F. Cleaning
1. After completing installation, clean furnaces internally according to manufacturer's written instructions.
2. Install new filters in each furnace within 14 days after Final Completion.

G. Demonstration
1. Train Owner's maintenance personnel to adjust, operate, and maintain condensing units.

END OF SECTION 23 54 16 13

Task	Specification	Specification Description
23 54 19 00	23 54 16 13	Furnaces

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SECTION 23 55 23 13 - RADIANT HEATING AND COOLING UNITS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for radiant heating and cooling units. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following:
   a. Electric radiant heaters.
   b. Prefabricated electric radiant heating panels.
   c. Hydronic heating and cooling panels.

C. Definitions
1. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling and power-limited circuits.

D. Submittals
1. Product Data: Include rated capacities, specialties, and accessories for each product indicated.
2. Manufacturer Seismic Qualification Certification.
3. Field quality-control test reports.
4. Operation and maintenance data.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

1.2 PRODUCTS

A. Electric Radiant Heaters
1. Quartz Lamp Heating Elements: Coiled tungsten-wire heating element enclosed in clear quartz tube.
2. Quartz Tube Heating Elements: Nickel-chromium-wire heating element enclosed in quartz tube.
3. Metal-Sheathed Heating Elements: Nickel-chromium-wire heating element embedded in magnesium oxide powder and enclosed in metal sheath. Comply with UL 1030.
4. Comply with UL 499 and UL 2021, **as directed**.
5. Enclosures: Aluminized **OR** Stainless **OR** Painted, **as directed,**-steel housing with anodized-aluminum reflector.
   a. Finish: Baked-enamel finish in manufacturer's standard **OR** custom, **as directed,** paint color as selected.
6. Unit Controls:
   a. Line-voltage thermostat.
   b. Enclosed contactor for remote thermostat.
   c. Snow and ice detector with moisture sensor and integral temperature sensor.

B. Prefabricated Electric Radiant Heating Panels
1. Description: Sheet-metal-enclosed panel with heating element suitable for lay-in installation flush with T-bar ceiling grid **OR** surface mounting **OR** recessed mounting, **as directed**. Comply with UL 2021.

a. Panel: Minimum 0.0276-inch- (0.7-mm-) thick, galvanized-steel sheet back panel riveted to minimum 0.0396-inch- (1.0-mm-) thick, galvanized-steel sheet front panel with fused-on crystalline surface.
b. Heating Element: Powdered graphite sandwiched between sheets of electric insulation **OR** Insulated resistive wires, **as directed**.
c. Electrical Connections: Nonheating, high-temperature, insulated-copper leads, factory connected to heating element.
d. Exposed-Side Panel Finish:
1) Apply silk-screened finish to match appearance of Architect-selected acoustical ceiling tiles.
OR
Factory prime coated, ready for field painting.
OR
Baked-enamel finish in manufacturer's standard **OR** custom, **as directed,** paint color as selected.
e. Surface-Mounting Trim: Sheet metal with baked-enamel finish in manufacturer's standard **OR** custom, **as directed,** paint color as selected.

2. Wall Thermostat: Bimetal, sensing elements calibrated from 55 to 90 deg F (13 to 32 deg C); with contacts suitable for low **OR** line, **as directed,**-voltage circuit, and manually operated on-off switch with contactors, relays, and control transformers.
3. Capacities and Characteristics:
a. Nominal Panel Size: 24 by 24 inches (600 by 600 mm) **OR** 24 by 36 inches (600 by 900 mm) **OR** 24 by 48 inches (600 by 1200 mm) **OR** 24 by 60 inches (600 by 1500 mm), **as directed**.
b. Heating Capacity: 250 **OR** 375 **OR** 500 **OR** 570 **OR** 625 **OR** 750 **OR** 950, **as directed**, kW.

C. Hydronic Heating And Cooling, **as directed**, Panels
1. Description: Modular **OR** Linear, **as directed,** sheet metal panel with serpentine water piping, suitable for lay-in installation flush with T-bar ceiling grid **OR** surface mounting **OR** recessed mounting, **as directed**.
a. Panels: Minimum 0.0336-inch- (0.86-mm-) thick, galvanized-steel **OR** 0.0396-inch- (1.0-mm-) thick, aluminum, **as directed,** sheet.
b. Backing Insulation: Minimum 1-inch- (25-mm-) **OR** 2-inch- (50-mm-), **as directed,** thick, mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 612, Type IA or Type IB with factory-applied jacket.
c. Exposed-Side Panel Finish:
1) Apply silk-screened finish to match appearance of selected acoustical ceiling tiles.
OR
Factory prime coated, ready for field painting.
OR
Baked-enamel finish in manufacturer's standard **OR** custom, **as directed,** paint color as selected.
d. Factory Piping: ASTM B 88, Type L (ASTM B 88M, Type B) **OR** ASTM B 88, Type M (ASTM B 88M, Type C), **as directed,** copper tube with ASME B16.22 wrought-copper fittings and brazed joints. Piping shall be mechanically bonded to panel.
e. Surface-Mounting Trim: Sheet metal with baked-enamel finish in manufacturer's standard **OR** custom, **as directed,** paint color as selected.
f. Accessories:
1) 5-inch (127-mm) **OR** 6-inch (152-mm) **OR** 8-inch (203-mm), **as directed,** panel with drape track recess.
2) 5-inch (127-mm) male bullnose panel.
3) 5-inch (127-mm) female bullnose panel.
4) 4-inch (102-mm) male corner panel.
5) 4-inch (102-mm) female corner panel.

6) Inside corner panel.
7) 1/2-inch (13-mm) filler panel.

2. Capacities and Characteristics:
   a. Nominal Panel Size: 24 by 24 inches (600 by 600 mm) **OR** 24 by 36 inches (600 by 900 mm) **OR** 24 by 48 inches (600 by 1200 mm) **OR** 24 by 60 inches (600 by 1500 mm), **as directed**.
   b. Piping Inlet and Outlet: NPS 1/2 (DN 15).

1.3 EXECUTION

A. Installation
1. Install radiant heating and cooling units level and plumb.
2. Suspend radiant heaters from structure.
3. Support for Radiant Heating and Cooling Panels in or on Grid-Type Suspended Ceilings: Use grid as a support element.
   a. Install a minimum of four ceiling support system rods or wires for each panel. Locate not more than 6 inches (150 mm) from panel corners.
   b. Support Clips: Fasten to panel and to ceiling grid members at or near each panel corner with clips designed for the application.
   c. Panels of Sizes Less Than Ceiling Grid: Install as indicated on reflected ceiling plans or center in acoustical panel, and support panels independently with at least two 3/4-inch (19-mm) metal channels spanning and secured to ceiling tees.
   d. Install at least one independent support rod or wire from structure to a tab on panel. Wire or rod shall have breaking strength of the weight of panel at a safety factor of 3.
4. Verify locations of thermostats with Drawings and room details before installation. Install devices 48 inches (1220 mm) **OR** 60 inches (1525 mm), **as directed,** above finished floor.
5. Piping installation requirements are specified in Division 23 Section "Hydronic Piping". Drawings indicate general arrangement of piping, fittings, and specialties.
6. Unless otherwise indicated, install shutoff valve and union or flange at each connection.
7. Install piping adjacent to unit to allow service and maintenance.
8. Ground electric units according to Division 26 Section "Grounding And Bonding For Electrical Systems".
9. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

B. Field Quality Control
1. Testing: Perform the following field tests and inspections and prepare test reports:
   a. Operate electric heating elements through each stage to verify proper operation and electrical connections.
   b. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and units.
2. Remove and replace malfunctioning units and retest as specified above.
3. After installing panels, inspect unit cabinet for damage to finish. Remove paint splatters and other spots, dirt, and debris. Repair damaged finish to match original finish.

END OF SECTION 23 55 23 13

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SECTION 23 55 23 13a - RADIANT-HEATING ELECTRIC PANELS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for radiant-heating electric panels. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes prefabricated radiant-heating electric panels.

C. Submittals
1. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories for each type of product indicated.
2. Shop Drawings: For electric heating panels. Include plans, sections, details, and attachments to other work.
   a. Wiring Diagrams: Power, signal, and control wiring.
3. Field quality-control test reports.
4. Operation and Maintenance Data: For electric heating panels to include in operation and maintenance manuals.
5. Warranty: Special warranty specified in this Section.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

1.2 PRODUCTS

A. Prefabricated Radiant-Heating Electric Panels
1. Description: Sheet-metal-enclosed panel with heating element suitable for lay-in installation flush with T-bar ceiling grid **OR** surface mounting **OR** recessed mounting, **as directed**. Comply with UL 2021.
   a. Panel: Minimum 0.0276-inch- (0.7-mm-) thick, galvanized-steel sheet back panel riveted to minimum 0.0396-inch- (1.0-mm-) thick, galvanized-steel sheet front panel with fused-on crystalline surface.
   b. Heating Element:
      1) Powdered graphite sandwiched between sheets of electric insulation.
         OR
         Insulated resistive wires.
   c. Electrical Connections: Nonheating, high-temperature, insulated-copper leads, factory connected to heating element.
   d. Exposed-Side Panel Finish:
      1) Apply silk-screened finish to match appearance of selected acoustical ceiling tiles.
      2) Factory prime coated, ready for field painting.
      3) Baked-enamel finish in manufacturer's standard **OR** custom, **as directed**, paint color as selected.
   e. Surface-Mounting Trim: Sheet metal with baked-enamel finish in manufacturer's standard **OR** custom, **as directed**, paint color as selected.

2. Wall Thermostat: Bimetal, sensing elements calibrated from 55 to 90 deg F (13 to 32 deg C); with contacts suitable for low **OR** line, **as directed**,-voltage circuit, and manually operated on-off switch with contactors, relays, and control transformers.

1.3 EXECUTION

A. Installation
1. Install radiant-heating panels level and plumb.
2. Support for Radiant-Heating Panels in or on Grid-Type Suspended Ceilings: Use grid as a support element.
   a. Install a minimum of four ceiling support system rods or wires for each panel. Locate not more than 6 inches (150 mm) from panel corners.
   b. Support Clips: Fasten to panel and to ceiling grid members at or near each panel corner with clips designed for the application.
   c. Panels of Sizes Less Than Ceiling Grid: Install as indicated on reflected ceiling plans or center in acoustical panel, and support panels independently with at least two 3/4-inch (19-mm) metal channels spanning and secured to ceiling tees.
   d. Install at least one independent support rod or wire from structure to a tab on panel. Wire or rod shall have breaking strength of the weight of panel at a safety factor of 3.
3. Verify locations of thermostats with Drawings and room details before installation. Install devices 48 inches (1220 mm) **OR** 60 inches (1525 mm), **as directed**, above finished floor.

B. Connections
1. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
2. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

C. Field Quality Control
1. Testing: Perform the following field tests and inspections and prepare test reports:
   a. Operate electric heating elements through each stage to verify proper operation and electrical connections.
   b. Test and adjust controls and safeties.
2. Remove and replace malfunctioning units and retest as specified above.

END OF SECTION 23 55 23 13a

SECTION 23 55 33 00 - FUEL-FIRED UNIT HEATERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for fuel-fired unit heaters. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes gas and oil-fired unit heaters.

C. Submittals
1. Product Data: For each type of fuel-fired unit heater indicated. Include rated capacities, operating characteristics, and accessories.
2. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   a. Wiring Diagrams: Power, signal, and control wiring.
3. Manufacturer Seismic Qualification Certification: Submit certification that fuel-fired unit heaters, accessories, and components will withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
4. Field quality-control test reports.
5. Operation and maintenance data.
6. Warranty: Special warranty specified in this Section.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

E. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace heat exchanger of fuel-fired unit heater that fails in materials or workmanship within Two **OR** Five, **as directed**, years from date of Final Completion.

1.2 PRODUCTS

A. Gas-Fired Unit Heaters
1. Description: Factory assembled, piped, and wired, and complying with ANSI Z83.8/CSA 2.6.
2. Fuel Type: Design burner for natural **OR** propane, **as directed**, gas having characteristics same as those of gas available at Project site.
3. Type of Venting: Gravity **OR** Powered **OR** Indoor, separated combustion, power, **as directed**, vented.
4. Housing: Steel, with integral draft hood and inserts for suspension mounting rods.
   a. External Casings and Cabinets: Baked enamel **OR** Powder coating, **as directed**, over corrosion-resistant-treated surface.
   b. Suspension Attachments: Reinforce suspension attachments at connection to fuel-fired unit heaters.

1) Seismic Fabrication Requirements: Fabricate suspension attachments of fuel-fired unit heaters, accessories mountings, and components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" when fuel-fired unit heater is anchored to building structure.

5. Heat Exchanger: Aluminized **OR** Stainless, **as directed**, steel.
6. Burner Material: Aluminized steel with stainless-steel inserts **OR** Stainless steel, **as directed**.
7. Unit Fan: Formed-steel **OR** Aluminum, **as directed**, propeller blades riveted to heavy-gage steel spider bolted to cast-iron hub, dynamically balanced, and resiliently mounted.
   a. Fan-Blade Guard: Galvanized steel, complying with OSHA specifications, removable for maintenance.
   b. General requirements for motors are specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
      1) Motors: Totally enclosed with internal thermal-overload protection and complying with Division 23 Section "Common Motor Requirements For Hvac Equipment".
      2) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
      3) Controllers, Electrical Devices, and Wiring: Electrical devices and connections are specified in Division 22.
8. Unit Fan: Steel, centrifugal fan dynamically balanced and resiliently mounted.
   a. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features:
      1) Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
      2) Shaft Bearings: Permanently lubricated, permanently sealed, self-aligning ball bearings.
      3) Pulleys: Cast-iron, adjustable-pitch motor pulley.
   b. General requirements for motors are specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
      1) Motors: Totally enclosed with internal thermal-overload protection and complying with Division 23 Section "Common Motor Requirements For Hvac Equipment".
      2) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
      3) Controllers, Electrical Devices, and Wiring: Electrical devices and connections are specified in Division 22.
9. Controls: Regulated redundant gas valve containing pilot solenoid valve, electric gas valve, pilot filter, pressure regulator, pilot shutoff, and manual shutoff all in one body.
   a. Gas Control Valve: Single stage **OR** Two stage **OR** Modulating, **as directed**.
   b. Ignition: Standing pilot **OR** Electronically controlled electric spark with flame sensor, **as directed**.
   c. Fan Thermal Switch: Operates fan on heat-exchanger temperature.
   d. Vent Flow Verification: Flame rollout switch **OR** Differential pressure switch to verify open vent, **as directed**.
   e. Control transformer.
   f. High Limit: Thermal switch or fuse to stop burner.
   g. Thermostats: Devices and wiring are specified in Division 23 Section "Instrumentation And Control For Hvac".

      OR

      Thermostat: Single-stage, wall-mounting type with 50 to 90 deg F (10 to 32 deg C) operating range and fan on switch.

      OR

      Thermostat: 2-stage, wall-mounting type with 50 to 90 deg F (10 to 32 deg C) operating range and fan on switch.

      OR

      Thermostat: Single-stage type with duct-mounting sensor and 50 to 90 deg F (10 to 32 deg C) operating range.

      OR

Thermostat: 2-stage type with duct-mounting sensor and 50 to 90 deg F (10 to 32 deg C) operating range.

10. Discharge Louvers: Independently adjustable horizontal blades.
11. Accessories:
    a. Vertical discharge louvers.
    b. Discharge Nozzle: Discharge at 25 to 65 degrees (0.44 to 1.13 radians) **OR** 50 to 90 degrees (0.87 to 1.57 radians), **as directed**, from horizontal.
    c. Four-point suspension kit.
    d. Summer fan switch.
    e. Unit-mounted thermostat bracket.
    f. Power Venter: Centrifugal aluminized-steel fan, with stainless-steel shaft; 120-V ac motor.
    g. Concentric, Terminal Vent Assembly: Combined combustion-air inlet and power-vent outlet with wall or roof caps. Include adapter assembly for connection to inlet and outlet pipes, and flashing for wall or roof penetration.

B. Oil-Fired Unit Heaters
1. Description: Factory assembled, piped, and wired, and complying with UL 731.
2. Housing: Steel, with inserts for suspension mounting rods.
    a. External Casings and Cabinets: Baked enamel **OR** Powder coating, **as directed**, over corrosion-resistant-treated surface.
    b. Suspension Attachments: Reinforce suspension attachments at connection to fuel-fired unit heaters.
        1) Seismic Fabrication Requirements: Fabricate suspension attachments of fuel-fired unit heaters, accessories mountings, and components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" when fuel-fired unit heater is anchored to building structure.
3. Heat Exchanger: Minimum 0.09-inch (2.2-mm) steel.
4. Burners: Flame-retention, pressure-atomizing, forced-draft, gun type; with integral fuel pump and electronic spark ignition and flame safety.
    a. Safety Device: Oil-pressure switch.
5. Unit Fan: Propeller fan with aluminum blades dynamically balanced and resiliently mounted.
    a. Steel fan-blade guard.
    b. General requirements for motors are specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
        1) Motors: Totally enclosed with internal thermal-overload protection and complying with Division 23 Section "Common Motor Requirements For Hvac Equipment".
        2) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
        3) Controllers, Electrical Devices, and Wiring: Electrical devices and connections are specified in Division 22.
6. Unit Fan: Steel, centrifugal fan dynamically balanced and resiliently mounted.
    a. Belt driven with adjustable-pitch motor sheave.
    b. General requirements for motors are specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
        1) Motors: Totally enclosed with internal thermal-overload protection and complying with Division 23 Section "Common Motor Requirements For Hvac Equipment".
        2) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
        3) Controllers, Electrical Devices, and Wiring: Electrical devices and connections are specified in Division 22.
7. Controls: Factory piped and prewired to electrical junction box mounted on unit, including the following:
    a. Control Transformer: Integrally mounted, 120 to 24 V ac.
    b. Cad-cell safety system.
    c. Manual reset safety.

d. Thermostat: Devices and wiring are specified in Division 23 Section "Instrumentation And Control For Hvac".
OR
Thermostat: Single-stage, 24-V ac, wall-mounting type with 50 to 90 deg F (10 to 32 deg C) operating range and fan on switch.
OR
Thermostat: 2-stage, 24-V ac, wall-mounting type with 50 to 90 deg F (10 to 32 deg C) operating range and fan on switch.
OR
Thermostat: Single-stage, 24-V ac type with duct-mounting sensor and 50 to 90 deg F (10 to 32 deg C) operating range.
OR
Thermostat: 2-stage, 24-V ac type with duct-mounting sensor and 50 to 90 deg F (10 to 32 deg C) operating range.

8. Automatic Fan Thermal Switch: Fan operates with heat-exchanger temperature more than 135 deg F (58 deg C).
9. Discharge Louvers: Independently adjustable horizontal blades.
10. Accessories:
    a. Vertical discharge louvers.
    b. Discharge Nozzle: Discharge at 25 to 65 degrees (0.44 to 1.13 radians) **OR** 50 to 90 degrees (0.87 to 1.57 radians), **as directed**, from horizontal.
    c. Summer fan switch.
    d. Unit-mounted thermostat bracket.
    e. Oil Booster Pump: 30-gph (108-L/h) **OR** 70-gph (252-L/h), **as directed**, capacity; motor and 2-stage fuel unit with pressure-regulating valve and strainer.
    f. Oil safety valve.
    g. Outdoor Combustion-Air Adapter: Sealed to housing and fitted with quick access cover or door and fitting for terminating outdoor-air duct.

1.3 EXECUTION

A. Installation
1. Install and connect gas-fired unit heaters and associated fuel and vent features and systems according to NFPA 54 **OR** CAN/CSA B149.1, **as directed**, applicable local codes and regulations, and manufacturer's written installation instructions.
2. Install and connect oil-fired unit heaters and associated fuel and vent piping according to NFPA 31 **OR** CAN/CSA B139, **as directed**, applicable local codes and regulations, and manufacturer's written installation instructions.
3. Suspended Units: Suspend from substrate using threaded rods, spring hangers, and building attachments. Secure rods to unit hanger attachments. Adjust hangers so unit is level and plumb.
    a. Restrain the unit to resist code-required horizontal acceleration.
4. Substrate-Mounted Units: Provide supports connected to substrate. Secure units to supports.
    a. Spring hangers and seismic restraints are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
    b. Anchor the unit to resist code-required horizontal acceleration.

B. Connections
1. Piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
2. Install piping adjacent to fuel-fired unit heater to allow service and maintenance.
3. Gas Piping: Comply with Division 23 Section(s) "Facility Natural-gas Piping" OR "Facility Liquefied-petroleum Gas Piping", **as directed**. Connect gas piping to gas train inlet; provide union with enough clearance for burner removal and service.

4. Fuel Oil Piping: Comply Division 23 Section "Facility Fuel-oil Piping". Connect to fuel oil supply and return piping with shutoff valve and union at each connection.
5. Vent Connections: Comply with Division 23 Section "Breechings, Chimneys, And Stacks".
6. Electrical Connections: Comply with applicable requirements in Division 22.
   a. Install electrical devices furnished with heaters but not specified to be factory mounted.

C. Field Quality Control
1. Perform tests and inspections and prepare test reports.
2. Tests and Inspections:
   a. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
   b. Verify bearing lubrication.
   c. Verify proper motor rotation.
   d. Test Reports: Prepare a written report to record the following:
      1) Test procedures used.
      2) Test results that comply with requirements.
      3) Test results that do not comply with requirements and corrective action taken to achieve compliance with requirements.
3. Remove and replace malfunctioning units and retest as specified above.

D. Adjusting
1. Adjust initial temperature set points.
2. Adjust burner and other unit components for optimum heating performance and efficiency.

E. Demonstration
1. Train Owner's maintenance personnel to adjust, operate, and maintain fuel-fired unit heaters.

END OF SECTION 23 55 33 00

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SECTION 23 55 33 00a - UNIT HEATERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for unit heaters. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Cabinet unit heaters with centrifugal fans and hot-water, steam, and electric-resistance heating coils.
b. Propeller unit heaters with hot-water, steam, and electric-resistance heating coils.
c. Wall and ceiling heaters with propeller fans and electric-resistance heating coils.

C. Definitions
1. BAS: Building automation system.
2. CWP: Cold working pressure.
3. PTFE: Polytetrafluoroethylene plastic.
4. TFE: Tetrafluoroethylene plastic.

D. Submittals
1. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories for each product indicated.
2. LEED Submittal:
a. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1-2004, Section 5 - "Systems and Equipment."
3. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
a. Plans, elevations, sections, and details.
b. Location and size of each field connection.
c. Details of anchorages and attachments to structure and to supported equipment.
d. Equipment schedules to include rated capacities, operating characteristics, furnished specialties, and accessories.
e. Location and arrangement of piping valves and specialties.
f. Location and arrangement of integral controls.
g. Wiring Diagrams: Power, signal, and control wiring.
4. Manufacturer Seismic Qualification Certification: Submit certification that cabinet unit heaters, accessories, and components will withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
5. Field quality-control test reports.
6. Operation and maintenance data.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1-2004, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
3. ASHRAE/IESNA 90.1-2004 Compliance: Applicable requirements in ASHRAE/IESNA 90.1-2004, Section 6 - "Heating, Ventilating, and Air-Conditioning."

1.2 PRODUCTS

A. Cabinet Unit Heaters
1. Description: A factory-assembled and -tested unit complying with ARI 440.
   a. Comply with UL 2021.
2. Coil Section Insulation (for duct-liner-type, glass-fiber insulation): ASTM C 1071; surfaces exposed to airstream shall be aluminum-foil facing **OR** erosion-resistant coating, **as directed**, to prevent erosion of glass fibers.
   a. Thickness: 1/2 inch (13 mm) **OR** 1 inch (25 mm) **OR** 1-1/2 inches (38 mm), **as directed**.
   b. Thermal Conductivity (k-Value): 0.26 Btu x in./h x sq. ft. at 75 deg F (0.037 W/m x K at 24 deg C) mean temperature.
   c. Fire-Hazard Classification: Maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.
   d. Adhesive: Comply with ASTM C 916 and with NFPA 90A or NFPA 90B.
   e. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.
3. Coil Section Insulation (for flexible elastomeric insulation): Comply with NFPA 90A or NFPA 90B. Unicellular polyethylene thermal plastic, preformed sheet insulation complying with ASTM C 534, Type II, except for density.
   a. Thickness: 3/8 inch (9 mm) **OR** 1/2 inch (13 mm) **OR** 3/4 inch (19 mm) **OR** 1 inch (25 mm), **as directed**.
   b. Thermal Conductivity (k-Value): 0.24 Btu x in./h x sq. ft. at 75 deg F (0.034 W/m x K at 24 deg C) mean temperature.
   c. Fire-Hazard Classification: Maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM C 411.
   d. Adhesive: As recommended by insulation manufacturer and complying with NFPA 90A or NFPA 90B.
   e. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.
4. Cabinet (for surface, semi-recessed, and fully recessed units): Steel with factory prime coating, ready for field painting **OR** baked-enamel finish with manufacturer's standard paint, in color selected by the Owner **OR** baked-enamel finish with manufacturer's custom paint, in color selected by the Owner, **as directed**.
   a. Vertical Unit, Exposed Front Panels: Minimum 0.0528-inch- (1.35-mm-) **OR** 0.0677-inch- (1.7-mm-), **as directed**, thick, galvanized, **as directed**, sheet steel, removable panels with channel-formed edges secured with tamperproof cam fasteners.
   b. Horizontal Unit, Exposed Bottom Panels: Minimum 0.0528-inch- (1.35-mm-) **OR** 0.0677-inch- (1.7-mm-), **as directed**, thick, galvanized, **as directed**, sheet steel, removable panels secured with tamperproof cam fasteners and safety chain.
   c. Recessing Flanges (for units that are semirecessed or fully recessed in walls or ceilings): Steel, finished to match cabinet.
   d. Control Access Door: Key operated.
   e. Base (for surface, vertical, wall-mounting units): Minimum 0.0528-inch- (1.35-mm-) thick steel, finished to match cabinet, 4 inches (100 mm) **OR** 6 inches (150 mm), **as directed**, high with leveling bolts.
   f. Extended Piping Compartment: 8-inch- (200-mm-), **as directed**, wide piping end pocket.
   g. False Back (for vertical, wall-mounting units only): Minimum 0.0428-inch- (1.1-mm-) thick steel, finished to match cabinet.
   h. Outdoor-Air Wall Box (for vertical, wall-mounting units only): Minimum 0.1265-inch- (3.2-mm-) thick, aluminum, rain-resistant louver and box with integral eliminators and bird screen. Aluminum louver with anodized **OR** baked-enamel, **as directed**, finish in color selected by the Owner from manufacturer's standard **OR** custom, **as directed**, colors.
      1) Outdoor-Air Damper: Galvanized-steel blades with edge and end seals and nylon bearings; with manual **OR** electronic **OR** pneumatic, **as directed**, two-position actuators.

5. Filters: Minimum arrestance according to ASHRAE 52.1 and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.
   a. Washable Foam: 70 percent arrestance and 3 MERV.
   b. Glass Fiber Treated with Adhesive: 80 percent arrestance and 5 MERV.
   c. Pleated: 90 percent arrestance and 7 MERV.
6. Hot-Water Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm) and rated for a minimum working pressure of 200 psig (1378 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain.
   OR
   Steam Coil: Copper distributing, **as directed**, tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm) and rated for a minimum working pressure of 75 psig (517 kPa).
   OR
   Electric-Resistance Heating Coil: Nickel-chromium heating wire, free from expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with fuses in terminal box for overcurrent protection and limit controls for high-temperature protection. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.
7. Fan and Motor Board: Removable.
   a. Fan: Forward curved, high static, **as directed**, double width, centrifugal; directly connected to motor. Thermoplastic or painted-steel wheels, and aluminum, painted-steel, or galvanized-steel fan scrolls.
   b. Motor: Permanently lubricated, multispeed; resiliently mounted on motor board. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   c. Wiring Terminations: Connect motor to chassis wiring with plug connection.
8. Factory, Hot-Water Piping Package: ASTM B 88, Type L (ASTM B 88M, Type B) **OR** ASTM B 88, Type M (ASTM B 88M Type C), **as directed**, copper tube with wrought-copper fittings and brazed joints. Label piping to indicate service, inlet and outlet.
   a. Two **OR** Three, **as directed**,-way, two-position **OR** modulating, **as directed**, control valve. Three-way valve packages shall include bypass line with manually adjustable balance device, **as directed**.
   b. Hose Kits: Minimum 400-psig (2758-kPa) working pressure, and operating temperatures from 33 to 211 deg F (0.5 to 99 deg C). Tag hose kits to equipment designations.
      1) Length: 24 inches (600 mm) **OR** 36 inches (900 mm), **as directed**,.
      2) Minimum Diameter: Equal to cabinet unit heater connection size.
   c. Two-Piece, Ball Valves: Bronze body with full-port, chrome-plated bronze ball; PTFE or TFE seats; and 600-psig (4140-kPa) minimum CWP rating and blowout-proof stem.
   d. Calibrated-Orifice Balancing Valves: Bronze body, ball type, 125-psig (860-kPa) working pressure, 250 deg F (121 deg C) maximum operating temperature; with calibrated orifice or venture, connection for portable differential pressure meter with integral seals, threaded ends, and equipped with a memory stop to retain set position.
   e. Automatic Flow-Control Valve: Brass or ferrous-metal body, 300-psig (2068-kPa) working pressure at 250 deg F (121 deg C), with removable, corrosion-resistant, tamperproof, self-cleaning, piston-spring; factory set to maintain constant indicated flow with plus or minus 10 percent over differential pressure range of 2 to 80 psig (13.8 to 552 kPa).
   f. Y-Pattern, Hot-Water Strainers: Cast-iron body (ASTM A 126, Class B); 125-psig (860-kPa) minimum working pressure; with threaded connections, bolted cover, perforated stainless-steel basket, and bottom drain connection. Include minimum NPS 1/2 (DN 15) threaded pipe and full-port ball valve in strainer drain connection.
   g. Wrought-Copper Unions: ASME B16.22.
9. Control devices and operational sequences are specified in Division 23 Section(s) "Instrumentation And Control For Hvac" AND "Sequence Of Operations For Hvac Controls".
10. Basic Unit Controls:
   a. Control voltage transformer.
   b. Wall-mounting **OR** Unit-mounted, **as directed**, thermostat with the following features.
      1) Heat-off switch.

2) Fan on-auto switch.
3) Manual fan speed switch (for use with multispeed motors).
4) Adjustable deadband.
5) Concealed **OR** Exposed, **as directed**, set point.
6) Concealed **OR** Exposed, **as directed**, indication.
7) Deg F (Deg C) indication.

c. Wall-mounting **OR** Unit-mounted, **as directed**, temperature sensor.
d. Unoccupied period override push button.
e. Data entry and access port.
1) Input data includes room temperature, and occupied and unoccupied periods.
2) Output data includes room temperature, supply-air temperature, entering-water temperature, operating mode, and status.

11. DDC, **as directed**, Terminal Controller:
a. Scheduled Operation: Occupied and unoccupied periods on seven-day clock with a minimum of four programmable periods per day.
b. Unoccupied Period Override: Two, **as directed**, hours.
c. Unit Supply-Air Fan Operations:
1) Occupied Periods: Fan runs continuously.
2) Unoccupied Periods: Fan cycles to maintain setback room temperature.
d. Heating Coil Operations:
1) Occupied Periods: Open control valve **OR** Modulate control valve **OR** Energize electric-resistance coil, **as directed**, to provide heating if room temperature falls below thermostat set point.
2) Unoccupied Periods: Start fan and open control valve **OR** modulate control valve **OR** energize electric-resistance coil, **as directed**, if room temperature falls below setback temperature.
e. Outdoor-Air Damper Operation:
1) Occupied Periods: Open dampers. Delay damper opening if room temperature is more than three degrees below set point.
2) Unoccupied Periods: Close damper.
f. Controller shall have volatile-memory backup.

12. BAS Interface Requirements:
a. Interface relay for scheduled operation.
b. Interface relay to provide indication of fault at central workstation.
c. Interface shall be BAC-net **OR** LonWorks, **as directed**, compatible for central BAS workstation and include the following functions:
1) Adjust set points.
2) Cabinet unit heater start, stop, and operating status.
3) Data inquiry, including outdoor-air damper position, **as directed**, supply-air and room-air temperature.
4) Occupied and unoccupied schedules.

13. Electrical Connection: Factory wire motors and controls for a single field connection.

B. Propeller Unit Heaters
1. Description: An assembly including casing, coil, fan, and motor in vertical **OR** horizontal **OR** vertical and horizontal, **as directed**, discharge configuration with adjustable discharge louvers.
2. Comply with UL 2021, for electric unit heaters.
3. Comply with UL 823, for explosion-proof electric unit heaters.
4. Cabinet: Removable panels for maintenance access to controls.
5. Cabinet Finish: Manufacturer's standard **OR** custom, **as directed**, baked enamel applied to factory-assembled and -tested propeller unit heater before shipping.
6. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.
7. Discharge Louver: Adjustable fin diffuser for horizontal units and conical diffuser for vertical units.

8. General Coil Requirements: Test and rate hot-water **OR** steam, **as directed**, propeller unit heater coils according to ASHRAE 33.
9. Hot-Water Coil: Copper tube, minimum 0.025-inch (0.635-mm) wall thickness, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm) and rated for a minimum working pressure of 200 psig (1380 kPa) and a maximum entering-water temperature of 325 deg F (163 deg C), with manual air vent. Test for leaks to 350 psig (2413 kPa) underwater.
   OR
   Hot-Water Coil: Cupronickel tube, minimum 0.031-inch (0.78-mm) wall thickness, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm) and rated for a minimum working pressure of 400 psig (2760 kPa) and a maximum entering-water temperature of 450 deg F (232 deg C), with manual air vent. Test for leaks to 600 psig (4137 kPa) underwater.
   OR
   Hot-Water Coil: Red brass tube, minimum 0.049-inch (1.24-mm) wall thickness, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm) and rated for a minimum working pressure of 260 psig (1793 kPa) and a maximum entering-water temperature of 390 deg F (199 deg C), with manual air vent. Test for leaks to 390 psig (2689 kPa) underwater.
   OR
   Hot-Water Coil: Steel tube, minimum 0.049-inch (1.24-mm) wall thickness, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm) and rated for a minimum working pressure of 400 psig (2760 kPa) and a maximum entering-water temperature of 450 deg F (232 deg C), with manual air vent. Test for leaks to 600 psig (4137 kPa) underwater.
   OR
   Hot-Water Coil: Vertical steel tube, minimum 0.065-inch (1.65-mm) wall thickness, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm) and rated for a minimum working pressure of 400 psig (2760 kPa) and a maximum entering-water temperature of 450 deg F (232 deg C), with steel headers at top and bottom. Test for leaks to 600 psig (4137 kPa) underwater.
   OR
   Steam Coil: Copper tube, minimum 0.025-inch (0.635-mm) wall thickness, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm) and rated for a minimum working pressure of 75 psig (520 kPa).
   OR
   Steam Coil: Red brass tube, minimum 0.049-inch (1.24-mm) wall thickness, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm) and rated for a minimum working pressure of 75 psig (520 kPa).
   OR
   Steam Coil: Vertical steel tube, minimum 0.065-inch (1.65-mm) wall thickness, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm) and rated for a minimum working pressure of 100 psig (690 kPa) **OR** 200 psig (1380 kPa), **as directed**, with steel headers at top and bottom.
10. Electric-Resistance Heating Elements: Nickel-chromium heating wire, free from expansion noise and 60-Hz hum, embedded in magnesium oxide refractory and sealed in steel or corrosion-resistant metallic sheath with fins no closer than 0.16 inch (4 mm). Element ends shall be enclosed in terminal box. Fin surface temperature shall not exceed 550 deg F (288 deg C) at any point during normal operation.
    a. Circuit Protection: One-time fuses in terminal box for overcurrent protection and limit controls for high-temperature protection of heaters.
    b. Wiring Terminations: Stainless-steel or corrosion-resistant material.
11. Fan: Propeller type with aluminum wheel directly mounted on motor shaft in the fan venturi.
12. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
    a. Motor Type: Permanently lubricated, explosion proof **OR** multispeed **OR** variable speed, **as directed**.
13. Control Devices:
    a. Unit-mounted **OR** Wall-mounting, **as directed**, variable, **as directed**, fan-speed switch.
    b. Unit-mounted **OR** Wall-mounting, **as directed**, thermostat.

C. Wall And Ceiling Heaters
1. Description: An assembly including chassis, electric heating coil, fan, motor, and controls. Comply with UL 2021.
2. Cabinet:
   a. Front Panel: Stamped-steel louver **OR** Extruded-aluminum bar grille, **as directed**, with removable panels fastened with tamperproof fasteners.
   b. Finish: Baked enamel over baked-on primer with manufacturer's standard **OR** custom, **as directed**, color selected by the Owner, applied to factory-assembled and -tested wall and ceiling heaters before shipping.
   c. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1-2004.
3. Surface-Mounting Cabinet Enclosure: Steel with finish to match cabinet.
4. Electric-Resistance Heating Coil: Nickel-chromium heating wire, free from expansion noise and hum, embedded in magnesium oxide refractory and sealed in corrosion-resistant metallic sheath. Terminate elements in stainless-steel, machine-staked terminals secured with stainless-steel hardware, and limit controls for high temperature protection. Provide integral circuit breaker for overcurrent protection, **as directed**.
5. Fan: Aluminum propeller directly connected to motor.
   a. Motor: Permanently lubricated, multispeed, **as directed**. Comply with requirements inDivision 23 Section "Common Motor Requirements For Hvac Equipment".
6. Controls: Unit-mounted thermostat. Low-voltage relay with transformer kit, **as directed**.
7. Electrical Connection: Factory wire motors and controls for a single field connection with disconnect switch, **as directed**.

1.3 EXECUTION

A. Installation
1. Install wall boxes in finished wall assembly; seal and weatherproof. Joint-sealant materials and applications are specified in Division 07 Section "Joint Sealants".
2. Install cabinet unit heaters to comply with NFPA 90A.
3. Install propeller unit heaters level and plumb.
4. Suspend cabinet unit heaters from structure with elastomeric hangers and seismic restraints, **as directed**. Vibration isolators and seismic restraints, **as directed**, are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
5. Suspend propeller unit heaters from structure with all-thread hanger rods and elastomeric hangers **OR** spring hangers **OR** spring hangers with vertical-limit stop, **as directed**. Hanger rods and attachments to structure are specified in Division 23 Section "Hangers And Supports For Hvac Piping And Equipment". Vibration hangers are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
6. Install wall-mounting thermostats and switch controls in electrical outlet boxes at heights to match lighting controls. Verify location of thermostats and other exposed control sensors with Drawings and room details before installation.
7. Install new filters in each fan-coil unit within two weeks of Final Completion.

B. Connections
1. Piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
2. Install piping adjacent to machine to allow service and maintenance.
3. Connect piping to cabinet unit heater's factory, hot-water piping package. Install the piping package if shipped loose.
4. Connect supply and return ducts to cabinet unit heaters with flexible duct connectors specified in Division 23 Section "Air Duct Accessories".
5. Comply with safety requirements in UL 1995.

6. Unless otherwise indicated, install union and gate or ball valve on supply-water connection and union and calibrated balancing valve on return-water connection of unit heater. Hydronic specialties are specified in Division 23 Section "Hydronic Piping".
7. Unless otherwise indicated, install union and gate or ball valve on steam-supply connection and union, strainer, steam trap, and gate or ball valve on condensate-return connection of unit heater. Steam specialties are specified in Division 23 Section "Steam And Condensate Heating Piping".
8. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
9. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

C. Field Quality Control
1. Perform the following field tests and inspections and prepare test reports:
   a. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   b. Operate electric heating elements through each stage to verify proper operation and electrical connections.
   c. Test and adjust controls and safety devices. Replace damaged and malfunctioning controls and equipment.
2. Remove and replace malfunctioning units and retest as specified above.

D. Adjusting
1. Adjust initial temperature set points.
2. Occupancy Adjustments: When requested within 12 months of date of Final Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.

E. Demonstration
1. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain cabinet unit heaters.

END OF SECTION 23 55 33 00a

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Task	Specification	Specification Description
23 55 33 00	01 22 16 00	No Specification Required

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SECTION 23 57 13 00 - HEAT EXCHANGERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for hydronic and steam heat exchangers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes shell-and-tube and plate heat exchangers.

C. Submittals
1. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories.
2. Coordination Drawings: Equipment room, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:
   a. Tube-removal space.
   b. Structural members to which heat exchangers will be attached.
3. Manufacturer Seismic Qualification Certification: Submit certification that heat exchanger, accessories, and components will withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".

D. Quality Assurance
1. ASME Compliance: Fabricate and label heat exchangers to comply with ASME Boiler and Pressure Vessel Code: Section VIII, "Pressure Vessels," Division 1.

1.2 PRODUCTS

A. Shell-And-Tube Heat Exchangers
1. Configuration: U-tube with removable bundle.
2. Shell Materials: Steel.
3. Head:
   a. Materials: Cast iron **OR** Cast stainless steel **OR** Fabricated steel **OR** Fabricated steel with removable cover **OR** Fabricated stainless steel **OR** Fabricated stainless steel with removable cover, **as directed**.
   b. Flanged and bolted to shell.
4. Tube:
   a. Seamless copper **OR** Steel **OR** Stainless-steel **OR** Cupronickel **OR** Admiralty-metal, **as directed,** tubes.
   b. Tube diameter is determined by manufacturer based on service.
5. Tubesheet Materials: Steel **OR** Stainless-steel, **as directed,** tubesheets.
6. Baffles: Steel **OR** Stainless steel, **as directed**.
7. Piping Connections:
   a. Shell: Flanged inlet and threaded **OR** Threaded inlet and **OR** Flanged inlet and, **as directed,** outlet fluid connections, threaded drain, and vent connections.
   b. Head: Threaded **OR** Flanged, **as directed,** inlet and outlet fluid connections.
8. Support Saddles:
   a. Fabricated of material similar to shell.
   b. Foot mount with provision for anchoring to support.

c. Fabricate attachment of saddle supports to pressure vessel with reinforcement strong enough to resist heat-exchanger movement during a seismic event when heat-exchanger saddles are anchored to building structure.

B. Gasketed Plate Heat Exchangers
1. Configuration: Freestanding assembly consisting of frame support, top and bottom carrying and guide bars, fixed and movable end plates, tie rods, individually removable plates, and one-piece gaskets.
2. Frame:
   a. Capacity to accommodate 20 percent additional plates.
   b. Painted carbon steel with provisions for anchoring to support.
3. Top and Bottom Carrying and Guide Bars: Painted carbon steel, aluminum, or stainless steel.
   a. Fabricate attachment of heat-exchanger carrying and guide bars with reinforcement strong enough to resist heat-exchanger movement during a seismic event when heat-exchanger carrying and guide bars are anchored to building structure.
4. End-Plate Material: Painted carbon steel.
5. Tie Rods and Nuts: Steel or stainless steel.
6. Plate Material: 0.024 inch (0.6 mm) **OR** 0.031 inch (0.8 mm) **OR** 0.039 inch (1 mm), **as directed,** thick before stamping; Type 304 **OR** 304L **OR** 316 **OR** 316L, **as directed,** stainless steel.
7. Gasket Material: Nitrile rubber **OR** EPDM, **as directed**.
8. Piping Connections:
   a. Threaded port for NPS 2 (DN 50) and smaller. For larger sizes, furnish end-plate port with threaded studs suitable for flanged connection.
   b. End plate with welded carbon-steel nozzles. Threaded pipe connection for NPS 2 (DN 50) and smaller; carbon-steel flanged pipe connection for larger sizes.
   c. Line wetted surfaces with same material as plates.
9. Enclose plates in a solid aluminum **OR** stainless-steel, **as directed,** removable shroud.

C. Brazed Plate Heat Exchangers
1. Configuration: Brazed assembly consisting of two end plates, one with threaded nozzles and pattern-embossed plates.
2. End-Plate Material: Type 316 stainless steel.
3. Threaded Nozzles: Type 316 stainless steel.
4. Plate Material: Type 316 stainless steel.
5. Brazing Material: Copper or nickel.

1.3 EXECUTION

A. Heat-Exchanger Installation
1. Install shell-and-tube heat exchangers on saddle supports.
2. Install shell-and-tube heat exchangers on, and anchor to, concrete base.

B. Connections
1. Install shutoff valves at heat-exchanger inlet and outlet connections.
2. Install relief valves on heat-exchanger heated-fluid connection and install pipe relief valves, full size of valve connection, to floor drain.
3. Install vacuum breaker at heat-exchanger steam inlet connection.
4. Install hose end valve to drain shell.

END OF SECTION 23 57 13 00

Task	Specification	Specification Description
23 57 16 00	23 57 13 00	Heat Exchangers
23 57 19 19	23 57 13 00	Heat Exchangers
23 57 19 23	23 57 13 00	Heat Exchangers

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SECTION 23 61 16 00 - CENTRIFUGAL WATER CHILLERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for centrifugal water chillers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Packaged, water-cooled, electric-motor-driven centrifugal chillers.
b. Packaged, portable refrigerant recovery units.
c. Heat-exchanger, brush-cleaning system.

C. Definitions
1. BAS: Building automation system.
2. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input using consistent units for any given set of rating conditions.
3. EER: Energy-efficiency ratio. The ratio of the cooling capacity given in terms of Btu/h to the total power input given in terms of watts at any given set of rating conditions.
4. IPLV: Integrated part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 550/590 and referenced to ARI standard rating conditions.
5. kW/Ton (kW/kW): The ratio of total power input of the chiller in kilowatts to the net refrigerating capacity in tons (kW) at any given set of rating conditions.
6. NPLV: Nonstandard part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 550/590 and intended for operating conditions other than the ARI standard rating conditions.

D. Performance Requirements
1. Seismic Performance: Centrifugal chillers shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
2. Condenser-Fluid Temperature Performance:
a. Startup Condenser-Fluid Temperature: Chiller shall be capable of starting with an entering condenser-fluid temperature of 60 deg F (16 deg C) **OR** 55 deg F (13 deg C) **OR** 40 deg F (4 deg C), **as directed**, and providing stable operation until the system temperature is elevated to the minimum operating entering condenser-fluid temperature.
b. Minimum Operating Condenser-Fluid Temperature: Chiller shall be capable of continuous operation over the entire capacity range indicated with an entering condenser-fluid temperature of 65 deg F (18 deg C) **OR** 60 deg F (16 deg C) **OR** 55 deg F (13 deg C), **as directed**.
c. Make factory modifications to standard chiller design if necessary to comply with performance indicated.
3. Site Altitude: Chiller shall be suitable for altitude at which installed without affecting performance indicated. Make adjustments to affected chiller components to account for site altitude.
4. Performance Tolerance: Comply with the following in lieu of ARI 550/590, **as directed**:
a. Allowable Capacity Tolerance: Zero percent.
b. Allowable IPLV/NPLV Performance Tolerance: Zero percent.

E. Submittals

1. Product Data: For each type of product indicated. Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.
2. LEED Submittal:
   a. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.
3. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
   a. Detail equipment assemblies and indicate dimensions, weights, load distribution, required clearances, method of field assembly, components, and location and size of each field connection.
   b. Wiring Diagrams: For power, signal, and control wiring.
4. Certificates: For certification required in "Quality Assurance" Article.
5. Seismic Qualification Certificates: For chillers, accessories, and components, from manufacturer.
   a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
   c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
6. Startup service reports.
7. Operation and maintenance data.
8. Warranty: Sample of special warranty.

F. Quality Assurance
1. ARI Certification: Certify chiller according to ARI 550 certification program.
2. ARI Rating: Rate chiller performance according to requirements in ARI 550/590.
3. ASHRAE Compliance:
   a. ASHRAE 15 for safety code for mechanical refrigeration.
   b. ASHRAE 147 for refrigerant leaks, recovery, and handling and storage requirements.
4. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1.
5. ASME Compliance: Fabricate and label chillers to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, as applicable to chiller design. For chillers charged with R-134a refrigerant, include an ASME U-stamp and nameplate certifying compliance.
6. Comply with NFPA 70.
7. Comply with requirements of UL and UL Canada, and include label by a qualified testing agency showing compliance.
8. Green Seal Compliance: Signed by manufacturer **OR** Green Seal, **as directed**, certifying compliance with GS-31.

G. Delivery, Storage, And Handling
1. Ship chillers from the factory fully charged with refrigerant.
   OR
   Ship each chiller with a full charge of refrigerant. Charge each chiller with nitrogen if refrigerant is shipped in containers separate from chiller.
2. Ship each oil-lubricated chiller with a full charge of oil.
   a. Ship oil factory installed in chiller **OR** in containers separate from chiller, **as directed**.
3. Package chiller for export shipping in totally enclosed bagging **OR** crate **OR** crate with bagging, **as directed**.

H. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of chillers that fail in materials or workmanship within specified warranty period.
   a. Extended warranties include, but are not limited to, the following:
      1) Complete chiller including refrigerant and oil charge.
      OR

Complete compressor and drive assembly including refrigerant and oil charge.
OR
Refrigerant **OR** Refrigerant and oil, **as directed**, charge.

2) Parts only **OR** Parts and labor, **as directed**.
3) Loss of refrigerant charge for any reason.

b. Warranty Period: Two **OR** Three **OR** Four **OR** Five, **as directed**, years from date of Final Completion.

1.2 PRODUCTS

A. Manufactured Unit

1. Description: Factory-assembled and -tested chiller complete with compressor, compressor motor, compressor motor controller, evaporator **OR** lubrication system evaporator, **as directed**, condenser, heat-reclaim condenser as indicated, controls, interconnecting unit piping and wiring, and indicated accessories.
   a. Disassemble chiller into major assemblies as required by the installation after factory testing and before packaging for shipment.
   b. For chillers with dual compressors, provide each compressor with a dedicated motor and motor controller, and provide for continued operation when either compressor-drive assembly fails or is being serviced.
2. Fabricate chiller mounting base with reinforcement strong enough to resist chiller movement during a seismic event when chiller is anchored to field support structure.

B. Compressor-Drive Assembly

1. Description: Single-stage or multistage, variable-displacement, centrifugal-type compressor driven by an electric motor.
   a. Where indicated, provide oil-free compressor technology using a permanent magnet synchronous motor, magnetic bearings, integral variable frequency controller, and digital electronic controls.
2. Compressor:
   a. Casing: Cast iron, precision ground.
   b. Impeller: High-strength cast aluminum or cast-aluminum alloy on carbon- or alloy-steel shaft.
3. Drive: Direct-drive, hermetic **OR** Gear-drive, hermetic **OR** Gear-drive, open **OR** Direct- or gear-drive, hermetic **OR** Direct- or gear-drive, open or hermetic, **as directed**, design using an electric motor as the driver.
   a. Gear Drives: For chillers with gear drives, provide single- or double-helical gear design continuously coated with oil while chiller is operating. Gears shall comply with American Gear Manufacturer Association standards.
   b. Drive Coupling: For chillers with open drives, provide flexible disc with all-metal construction and no wearing parts to ensure long life without the need for lubrication.
   c. Seals: Seal drive assembly to prevent refrigerant leakage.
4. Compressor Motor:
   a. Continuous-duty, squirrel-cage, induction-type, two-pole motor with energy efficiency required to suit chiller energy efficiency indicated.
   b. Factory mounted, aligned, and balanced as part of compressor assembly before shipping.
   c. Motor shall be of sufficient capacity to drive compressor throughout entire operating range without overload and with sufficient capacity to start and accelerate compressor without damage.
   d. For chillers with open drives, provide motor with open-dripproof **OR** weather-protected, Type I **OR** weather-protected, Type II **OR** totally enclosed, **as directed**, enclosure.
   e. Provide motor with thermistor or RTD in single motor winding **OR** each of three-phase motor windings, **as directed**, to monitor temperature and report information to chiller control panel.

f. Provide motor with thermistor or RTD to monitor bearing temperature and report information to chiller control panel.
g. Provide open-drive motor with internal electric heater, internally powered from chiller power supply.

5. Vibration Balance: Balance chiller compressor and drive assembly to provide a precision balance that is free of noticeable vibration over the entire operating range.
   a. Overspeed Test: 25 percent above design operating speed.
6. Service: Easily accessible for inspection and service.
   a. Compressor's internal components shall be accessible without having to remove compressor-drive assembly from chiller.
   b. Provide lifting lugs or eyebolts attached to casing.
7. Economizers: For multistage chillers, provide interstage economizers.
8. Capacity Control: Modulating, variable-inlet, guide-vane assembly combined with hot-gas bypass, if necessary, to achieve performance indicated.
   a. Maintain stable operation that is free of surge, cavitation, and vibration throughout range of operation. Configure to achieve most energy-efficient operation possible.
   b. Operating Range: From 100 to 15 **OR** 10 **OR** 5 **OR** zero, **as directed**, percent of design capacity.
   c. Condenser-Fluid Unloading Requirements over Operating Range: Constant-design entering condenser-fluid temperature **OR** Drop-in entering condenser-fluid temperature of 2.5 deg F (1.4 deg C) for each 10 percent in capacity reduction, **as directed**.
   d. Chillers with variable frequency controllers shall modulate compressor speed with variable-inlet, guide-vane control to achieve optimum energy efficiency.
9. Oil Lubrication System: Consisting of pump, filtration, heater, **as directed**, cooler, factory-wired power connection, and controls.
   a. Provide lubrication to bearings, gears, and other rotating surfaces at all operating, startup, coastdown, and standby conditions including power failure.
   b. Manufacturer's standard method **OR** Thermostatically controlled oil heater properly sized, **as directed**, to remove refrigerant from oil.
   c. Oil filter **OR** Dual oil filers, one redundant, **as directed**, shall be the easily replaceable cartridge type, minimum 0.5-micron efficiency, with means of positive isolation while servicing.
   d. Refrigerant **OR** Water, **as directed**,-cooled oil cooler.
   e. Factory-installed and pressure-tested piping with isolation valves and accessories.
   f. Oil compatible with refrigerant and chiller components.
   g. Positive visual indication of oil level.

C. Refrigeration
1. Refrigerant:
   a. Type: R-123; ASHRAE 34, Class B1 **OR** R-134a; ASHRAE 34, Class A1**,** as directed.
   b. Compatibility: Chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
2. Refrigerant Flow Control: Manufacturer's standard refrigerant flow-control device satisfying performance requirements indicated.
3. Pressure Relief Device:
   a. Comply with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
   b. For Chillers Using R-123: Rupture disc constructed of frangible carbon **OR** Spring-loaded, pressure relief valve; single- or multiple-reseating type, **as directed**.
   c. For Chillers Using R-134a: ASME-rated, spring-loaded, pressure relief valve; single- or multiple-reseating type. Pressure relief valve(s) shall be provided for each heat exchanger. Condenser shall have dual valves with one being redundant and configured to allow either valve to be replaced without loss of refrigerant.

4. Refrigeration Transfer: Provide service valves and other factory-installed accessories required to facilitate transfer of refrigerant from chiller to a remote refrigerant storage and recycling system. Comply with requirements in ASHRAE 15 and ASHRAE 147.
5. Refrigerant Isolation for Chillers Using R-134a: Factory install positive shutoff, manual, **as directed**, isolation valves in the compressor discharge line to the condenser and the refrigerant liquid line leaving the condenser to allow for isolation and storage of full refrigerant charge in the chiller condenser shell. In addition, provide isolation valve on suction side of compressor from evaporator to allow for isolation and storage of full refrigerant charge in the chiller evaporator shell, **as directed**.
6. Purge System:
   a. For chillers operating at subatmospheric pressures (using R-123 refrigerant), factory install an automatic purge system for collection and return of refrigerant and lubricating oil and for removal of noncondensables including, but not limited to, water, water vapor, and noncondensable gases.
   b. System shall be a thermal purge design, refrigerant or air cooled, equipped with a carbon filter that includes an automatic regeneration cycle.
   c. Factory wire to chiller's main power supply and system complete with controls, piping, and refrigerant valves to isolate the purge system from the chiller.
   d. Construct components of noncorrodible materials.
   e. Controls shall interface with chiller control panel to indicate modes of operation, set points, data reports, diagnostics, and alarms.
   f. Efficiency of not more than 0.02 lb of refrigerant per pound of air (9 g of refrigerant per gram of air) when rated according to ARI 580.
   g. Operation independent of chiller per ASHRAE 147.
7. Positive-Pressure System:
   a. For chillers operating at subatmospheric pressures (using R-123 refrigerant), factory install an automatic positive-pressure system.
   b. During nonoperational periods, positive-pressure system shall automatically maintain a positive pressure for atmosphere in the refrigerant pressure vessel of not less than 0.5 psig (3 kPa) (adjustable) up to a pressure that remains within the vessel design pressure limits.
   c. System shall be factory wired and include controller, electric heat, pressure transmitter, or switch.

D. Evaporator
1. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from condenser.
2. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
3. Designed to prevent liquid refrigerant carryover from entering compressor.
4. Provide evaporator with sight glass or other form of positive visual verification of liquid-refrigerant level.
5. Tubes:
   a. Individually replaceable from either end and without damage to tube sheets and other tubes.
   b. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
   c. Material: Copper **OR** Copper-nickel alloy **OR** Stainless steel **OR** Titanium, **as directed**.
   d. Nominal OD: Manufacturer's choice **OR** 3/4 inch (19 mm) **OR** 1 inch (25 mm), **as directed**.
   e. Minimum Wall Thickness: Manufacturer's choice **OR** 0.025 inch (0.6 mm) **OR** 0.028 inch (0.7 mm) **OR** 0.035 inch (0.9 mm), **as directed**.
   f. External Finish: Manufacturer's standard.
   g. Internal Finish: Enhanced **OR** Smooth, **as directed**.
6. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.
7. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.

8. Water Box:
   a. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
   b. Standard **OR** Marine, **as directed**, type for water box with piping connections. Standard type for water box without piping connections.
   c. Provide water boxes and marine water-box covers, **as directed**, with lifting lugs or eyebolts.
   d. Hinged **OR** Davited, **as directed**, water boxes.
      OR
      Hinged **OR** Davited, **as directed**, marine water-box covers.
   e. Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.
   f. Thermistor or RTD temperature sensor factory installed in each nozzle.
   g. Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.
9. Additional Corrosion Protection:
   a. Electrolytic corrosion-inhibitor anode.
   b. Coat wetted surfaces with a corrosion-resistant finish.
      OR
      Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

E. Condenser
1. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from evaporator.
2. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
3. Designed to prevent direct impingement of high-velocity hot gas from compressor discharge on tubes.
4. Provide condenser with sight glass or other form of positive visual verification of refrigerant charge and condition.
5. Tubes:
   a. Individually replaceable from either end and without damage to tube sheets and other tubes.
   b. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
   c. Material: Copper **OR** Copper-nickel alloy **OR** Stainless steel **OR** Titanium, **as directed**.
   d. Nominal OD: Manufacturer's choice **OR** 3/4 inch (19 mm) **OR** 1 inch (25 mm), **as directed**
   e. Minimum Wall Thickness: Manufacturer's choice **OR** 0.025 inch (0.6 mm) **OR** 0.028 inch (0.7 mm) **OR** 0.035 inch (0.9 mm), **as directed**.
   f. External Finish: Manufacturer's standard.
   g. Internal Finish: Enhanced **OR** Smooth, **as directed**.
6. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.
7. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.
8. Water Box:
   a. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
   b. Standard **OR** Marine, **as directed**, type for water box with piping connections. Standard type for water box without piping connections.
   c. Provide water boxes and marine water-box covers, **as directed**, with lifting lugs or eyebolts.
   d. Hinged **OR** Davited, **as directed**, water boxes.
      OR

Hinged **OR** Davited, **as directed**, marine water-box covers.

e. Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.

f. Thermistor or RTD temperature sensor factory installed in each nozzle.

g. Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.

9. Additional Corrosion Protection:

a. Electrolytic corrosion-inhibitor anode.

b. Coat wetted surfaces with a corrosion-resistant finish.

OR

Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

F. Heat-Reclaim Condenser

1. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from evaporator and condenser.

2. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.

3. Designed to prevent direct impingement of high-velocity hot gas from compressor discharge on tubes.

4. Tubes:

a. Individually replaceable from either end and without damage to tube sheets and other tubes.

b. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.

c. Material: Copper **OR** Copper-nickel alloy **OR** Stainless steel **OR** Titanium, **as directed**.

d. Nominal OD: Manufacturer's choice **OR** 3/4 inch (19 mm) **OR** 1 inch (25 mm), **as directed**.

e. Minimum Wall Thickness: Manufacturer's choice **OR** 0.025 inch (0.6 mm) **OR** 0.028 inch (0.7 mm) **OR** 0.035 inch (0.9 mm), **as directed**.

f. External Finish: Manufacturer's standard.

g. Internal Finish: Enhanced **OR** Smooth, **as directed**.

5. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.

6. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.

7. Water Box:

a. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.

b. Standard **OR** Marine, **as directed**, type for water box with piping connections. Standard type for water box without piping connections.

c. Provide water boxes and marine water-box covers, **as directed**, with lifting lugs or eyebolts.

d. Hinged **OR** Davited, **as directed**, water boxes.

OR

Hinged **OR** Davited, **as directed**, marine water-box covers.

e. Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.

f. Thermistor or RTD temperature sensor factory installed in each nozzle.

g. Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.

8. Additional Corrosion Protection:

a. Electrolytic corrosion-inhibitor anode.

b. Coat wetted surfaces with a corrosion-resistant finish.

OR

Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

G. Insulation
1. Closed-cell, flexible elastomeric thermal insulation complying with ASTM C 534, Type I for tubular materials and Type II for sheet materials.
   a. Thickness: 3/4 inch (19 mm) **OR** 1-1/2 inches (38 mm), **as directed**.
2. Adhesive: As recommended by insulation manufacturer.
3. Factory-applied insulation over all cold surfaces of chiller capable of forming condensation. Components shall include, but not be limited to, evaporator shell and end tube sheets, evaporator water boxes including nozzles, refrigerant suction pipe from evaporator to compressor, cold surfaces of compressor, refrigerant-cooled motor, and auxiliary piping.
   a. Apply adhesive to 100 percent of insulation contact surface.
   b. Before insulating steel surfaces, prepare surfaces for paint, and prime and paint as indicated for other painted components. Do not insulate unpainted steel surfaces.
   c. Seal seams and joints to provide a vapor barrier.
   d. After adhesive has fully cured, paint exposed surfaces of insulation to match other painted parts.

H. Electrical
1. Factory installed and wired, and functionally tested at factory before shipment.
2. Single-point, field-power connection to fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**. Minimum withstand rating shall be as required by electrical power distribution system, but not less than 42,000 **OR** 65,000, **as directed**, A.
   a. Branch power circuit to each motor, electric heater, dedicated electrical load, and controls with disconnect switch or circuit breaker, **as directed**.
      1) NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
      2) NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit-trip set point.
   b. NEMA ICS 2-rated motor controller for auxiliary motors, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller for each variable-speed motor furnished.
   c. Control-circuit transformer with primary and secondary side fuses.
3. Terminal blocks with numbered and color-coded, **as directed**, wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
4. Factory-installed wiring outside of enclosures shall be in metal raceway except make terminal connections with not more than a 24-inch (610-mm) length of liquidtight **OR** flexible metallic, **as directed**, conduit.
5. Factory install and wire capacitor bank for the purpose of power factor correction to 0.95 at all operating conditions.
   a. If capacitors are mounted in a dedicated enclosure, use same NEMA enclosure type as motor controller. Provide enclosure with service entrance knockouts and bushings for conduit.
   b. Capacitors shall be non-PCB dielectric fluid, metallized electrode design, low loss with low-temperature rise. The kVAr ratings shall be indicated and shall not exceed the maximum limitations set by NFPA 70. Provide individual cells as required.
   c. Provide each cell with current-limiting replaceable fuses and carbon-film discharge resistors to reduce residual voltage to less than 50 V within one minute after de-energizing.
   d. Provide a ground terminal and a terminal block or individual connectors for phase connection.

I. Motor Controller

1. Enclosure: Factory installed, unit mounted **OR** Factory furnished, field mounted, **as directed**, NEMA 250 **OR** NEMA ICS 6, **as directed**, Type 1 **OR** Type 4 **OR** Type 4X **OR** Type 12, **as directed**, with hinged full-front access door with lock and key or padlock and key, **as directed**.
2. Control Circuit: Obtained from integral control power transformer, **as directed**, with a control power transformer **OR** source, **as directed**, of enough capacity to operate connected control devices.
3. Overload Relay: Shall be sized according to UL 1995 or shall be an integral component of chiller control microprocessor.
4. Across-the-Line Controller: NEMA ICS 2, Class A, full voltage, nonreversing; include isolation switch and current-limiting fuses.
5. Star-Delta, Reduced-Voltage Controller: NEMA ICS 2, closed transition.
6. Autotransformer Reduced-Voltage Controller: NEMA ICS 2, closed transition; include isolation switch and current-limiting fuses.
7. Solid-State, Reduced-Voltage Controller: NEMA ICS 2.
   a. Surge suppressor in solid-state power circuits providing three-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.
   b. Visual indication of motor and control status, including the following conditions:
      1) Controller on.
      2) Overload trip.
      3) Loss of phase.
      4) Starter fault.
8. Accessories: Devices shall be factory installed in controller enclosure unless otherwise indicated.
   a. Externally Operated, Door-Interlocked, **as directed**, Disconnect: Fused disconnect switch **OR** Nonfused disconnect switch **OR** Circuit breaker, **as directed**. Minimum withstand rating shall be as required by electrical power distribution system, but not less than 42,000 **OR** 65,000, **as directed**, A.
   b. Push-Button Stations, Pilot Lights, and Selector Switches: NEMA ICS 2, heavy-duty type.
   c. Stop and Lockout Push-Button Station: Momentary-break, push-button station with a factory-applied hasp arranged so padlock can be used to lock push button in depressed position with control circuit open.
   d. Control Relays: Time-delay relays.
   e. Elapsed-Time Meters: Numerical readout in hours on face of enclosure.
   f. Number-of-Starts Counter: Numerical readout on face of enclosure.
   g. Meters: Panel type, 2-1/2 inches (64 mm) **OR** 4-1/4 inches (108 mm), **as directed**, with 90 **OR** 120 **OR** 270, **as directed**,-degree scale and 1 **OR** 2, **as directed**, percent accuracy. Where indicated, provide transfer device with an off position. Meters shall indicate the following:
      1) Ammeter: Output current for each phase, with current sensors rated to suit application.
      2) Voltmeter: Output voltage for each phase.
      3) Frequency Meter, **as directed**: Output frequency.
      4) Real-time clock with current time and date.
      5) Total run time.

      OR

      Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three- or four-wire systems and with the following features:
      1) Selectable, digital display of the following:
         a) Phase Currents, Each Phase: Plus or minus 1 percent.
         b) Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent.
         c) Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 percent.
         d) Three-Phase Real Power: Plus or minus 2 percent.
         e) Three-Phase Reactive Power: Plus or minus 2 percent.
         f) Power Factor: Plus or minus 2 percent.
         g) Frequency: Plus or minus 0.5 percent.
         h) Integrated Demand with Demand Interval Selectable from Five to 60 Minutes: Plus or minus 2 percent.

i) Accumulated energy, in megawatt hours (joules), plus or minus 2 percent; stored values unaffected by power outages for up to 72 hours.

2) Mounting: Display and control unit flush or semirecessed in instrument compartment door.

h. Phase-Failure, Phase-Reversal, Undervoltage Relays: Solid-state sensing circuit with adjustable undervoltage setting and isolated output contacts for hardwired connection.

i. Power Protection: Chiller shall shut down within six cycles of power interruption.

J. Variable Frequency Controller

1. Motor controller shall be factory mounted and wired on the chiller to provide a single-point, field-power termination to the chiller and its auxiliaries.
2. Description: NEMA ICS 2; listed and labeled as a complete unit and arranged to provide variable speed by adjusting output voltage and frequency.
3. Enclosure: Unit mounted, NEMA 250, Type 1 **OR** Type 4 **OR** Type 4x **OR** Type 12, **as directed**, with hinged full-front access door with lock and key.
4. Integral Disconnecting Means: Door-interlocked, **as directed**, NEMA AB 1, instantaneous-trip circuit breaker with lockable handle. Minimum withstand rating shall be as required by electrical power distribution system, but not less than 42,000 **OR** 65,000, **as directed**, A.
5. Technology: Pulse width modulated (PWM) output with insulated gate bipolar transistors (IGBT); suitable for variable torque loads.
6. Controller shall consist of a rectifier converter section, a digital/analog driver regulator section, and an inverter output section.
   a. Rectifier section shall be a full-wave diode bridge that changes fixed-voltage, fixed-frequency, ac line power to a fixed dc voltage. Silicon controller rectifiers, current source inverters, and paralleling of devices are unacceptable. Rectifier shall be insensitive to phase rotation of the ac line.
   b. Regulator shall provide full digital control of frequency and voltage.
   c. Inverter section shall change fixed dc voltage to variable-frequency, variable ac voltage, for application to a squirrel-cage motor. Inverter shall produce a sine-coded, pulse width modulated (PWM) output wave form and shall conduct no radio-frequency interference back to the input power supply.
7. Output Rating: Three phase; with voltage proportional to frequency throughout voltage range.
8. Operating Requirements:
   a. Input AC Voltage Tolerance: 460-V ac, plus 10 percent or 506 V maximum, **as directed**.
   b. Input frequency tolerance of 60 Hz, plus or minus 2 Hz.
   c. Capable of driving full load, without derating, under the following conditions:
      1) Ambient Temperature: 0 to 50 deg C.
      2) Relative Humidity: Up to 90 **OR** 95, **as directed**, percent (noncondensing).
      3) Altitude: 3300 feet (1005 m) **OR** 6600 feet (2010 m), **as directed**.
   d. Minimum Efficiency: 96 percent at 60 Hz, full load.
   e. Minimum Displacement Primary-Side Power Factor: 95 percent without harmonic filter, 98 percent with harmonic filter.
   f. Overload Capability: 1.05 times the full-load current for 7 seconds.
   g. Starting Torque: As required by compressor-drive assembly.
   h. Speed Regulation: Plus or minus 1 percent.
   i. Isolated control interface to allow controller to follow control signal over a 10:1 speed range.
   j. To avoid equipment resonant vibrations, provide critical speed lockout circuitry to allow bands of operating frequency at which controller shall not operate continuously.
   k. Capable of being restarted into a motor coasting in either the forward or reverse direction without tripping.
9. Internal Adjustability Capabilities:
   a. Minimum Output Frequency: 6 Hz.
   b. Maximum Output Frequency: 60 Hz.
   c. Acceleration: 2 seconds to a minimum of 60 seconds.

d. Deceleration: 2 seconds to a minimum of 60 seconds.
e. Current Limit: 30 percent to a minimum of 100 percent of maximum rating.

10. Self-Protection and Reliability Features: Subjecting the controller to any of the following conditions shall not result in component failure or the need for replacement:
    a. Overtemperature.
    b. Short circuit at controller output.
    c. Ground fault at controller output. Variable frequency controller shall be able to start a grounded motor.
    d. Open circuit at controller output.
    e. Input undervoltage.
    f. Input overvoltage.
    g. Loss of input phase.
    h. Reverse phase.
    i. AC line switching transients.
    j. Instantaneous overload, line to line or line to ground.
    k. Sustained overload exceeding 100 percent of controller rated current.
    l. Starting a rotating motor.
11. Motor Protection: Controller shall protect motor against overvoltage and undervoltage, phase loss, reverse phase, overcurrent, overtemperature, and ground fault.
12. Automatic Reset and Restart: Capable of three restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Controller shall be capable of automatic restart on phase-loss and overvoltage and undervoltage trips.
13. Visual Indication: On face of controller enclosure or chiller control enclosure; indicating the following conditions:
    a. Power on.
    b. Run.
    c. Overvoltage.
    d. Line fault.
    e. Overcurrent.
    f. External fault.
    g. Motor speed (percent).
    h. Fault or alarm status (code).
    i. DC-link voltage.
    j. Motor output voltage.
    k. Input kilovolt amperes.
    l. Total power factor.
    m. Input kilowatts.
    n. Input kilowatt-hours.
    o. Three-phase input voltage.
    p. Three-phase output voltage.
    q. Three-phase input current.
    r. Three-phase output current.
    s. Three-phase input voltage total harmonic distortion.
    t. Three-phase input current total harmonic distortion.
    u. Output frequency (Hertz).
    v. Elapsed operating time (hours).
    w. Diagnostic and service parameters.
14. Operator Interface: At controller or chiller control panel; with start-stop and auto-manual selector with manual-speed-control potentiometer.
15. Control Signal Interface:
    a. Electric Input Signal Interface: A minimum of two analog inputs (0 to 10 V or 0/4-20 mA) and six programmable digital inputs.
16. Active Harmonic Distortion Filter: Factory mounted and wired to limit total voltage and current distortion to 5 percent.
    OR
    Input Line Conditioning: <**Insert requirements**>.

17. Cooling: Air **OR** Refrigerant **OR** Water, **as directed**, cooled.
18. Accessories: Devices shall be factory installed in controller enclosure unless otherwise indicated.
    a. Control Relays: Auxiliary and adjustable time-delay relays.
19. Chiller Capacity Control Interface: Equip chiller with adaptive control logic to automatically adjust the compressor motor speed and the compressor pre-rotation inlet vane position independently to achieve maximum part-load efficiency in response to sensor inputs that are integral to the chiller controls.

K. Controls
1. Control: Standalone and microprocessor based, with all memory stored in nonvolatile memory so that reprogramming is not required on loss of electrical power.
2. Enclosure: Unit mounted, NEMA 250, Type 1 **OR** Type 4 **OR** Type 4x **OR** Type 12, **as directed**, hinged or lockable; factory wired with a single-point, field-power connection and a separate control circuit.
3. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. In either imperial or metric units selectable through the interface, display the following information:
    a. Date and time.
    b. Operating or alarm status.
    c. Fault history with not less than last 10 faults displayed.
    d. Set points of controllable parameters.
    e. Trend data.
    f. Operating hours.
    g. Number of chiller starts.
    h. Outdoor-air temperature or space temperature if required for chilled-water reset.
    i. Entering- and leaving-fluid temperatures of evaporator and condenser.
    j. Difference in fluid temperatures of evaporator and condenser.
    k. Fluid flow of evaporator and condenser.
    l. Fluid pressure drop of evaporator and condenser.
    m. Refrigerant pressures in evaporator and condenser.
    n. Refrigerant saturation temperature in evaporator and condenser shell.
    o. Compressor refrigerant suction and discharge temperature.
    p. Compressor bearing temperature.
    q. Motor bearing temperature.
    r. Motor winding temperature.
    s. Oil temperature.
    t. Oil discharge pressure.
    u. Phase current.
    v. Percent of motor rated load amperage.
    w. Phase voltage.
    x. Demand power (kilowatts).
    y. Energy use (kilowatt-hours).
    z. Power factor.
    aa. For chillers equipped with variable frequency controllers and harmonic filters, include the following:
        1) Output voltage and frequency.
        2) Voltage total harmonic distortion for each phase.
        3) Supply current total demand distortion for each phase.
        4) Inlet vane position.
        5) Controller internal ambient temperature.
        6) Heatsink temperature.
    bb. Purge suction temperature if purge system is provided.
    cc. Purge elapsed time if purge system is provided.
4. Control Functions:
    a. Manual or automatic startup and shutdown time schedule.

b. Entering and leaving chilled-water temperatures, control set points, and motor load limits. Evaporator fluid temperature shall be reset based on return-water **OR** outdoor-air **OR** space, **as directed**, temperature.
c. Current limit and demand limit.
d. Condenser-fluid temperature.
e. External chiller emergency stop.
f. Variable evaporator flow.
g. Thermal storage.
h. Heat reclaim.

5. Manually Reset Safety Controls: The following conditions shall shut down chiller and require manual reset:
   a. Low evaporator pressure **OR** temperature, **as directed**; high condenser pressure.
   b. Low evaporator fluid temperature.
   c. Low oil differential pressure.
   d. High or low oil pressure.
   e. High oil temperature.
   f. High compressor-discharge temperature.
   g. Loss of condenser-fluid flow.
   h. Loss of evaporator fluid flow.
   i. Motor overcurrent.
   j. Motor overvoltage.
   k. Motor undervoltage.
   l. Motor phase reversal.
   m. Motor phase failure.
   n. Sensor- or detection-circuit fault.
   o. Processor communication loss.
   p. Motor controller fault.
   q. Extended compressor surge.
   r. Excessive air-leakage detection for chillers using R-123 refrigerant.
6. Trending: Capability to trend analog data of up to five parameters simultaneously over an adjustable period and frequency of polling.
7. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: view only; view and operate; and view, operate, and service.
8. Control Authority: At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.
9. Communication Port: RS-232 port, USB 2.0 port, or equivalent connection capable of connecting a printer and a notebook computer, **as directed**.
10. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display chiller status and alarms.
    a. Hardwired Points:
       1) Monitoring: On-off status, common trouble alarm **OR** electrical power demand (kilowatts) **OR** electrical power consumption (kilowatt-hours) **OR** power factor, **as directed**.
       2) Control: On-off operation, chilled-water, discharge temperature set-point adjustment **OR** electrical power demand limit, **as directed**.
    b. ASHRAE 135 (BACnet) **OR** LonTalk **OR** Modbus **OR** Industry-accepted, open-protocol, **as directed**, communication interface with the BAS shall enable the BAS operator to remotely control and monitor the chiller from an operator workstation. Control features and monitoring points displayed locally at chiller control panel shall be available through the BAS.

L. Finish
1. Paint chiller, using manufacturer's standard procedures, except comply with the following minimum requirements:

a. Provide at least one coat of primer with a total dry film thickness of at least 2 mils (0.05 mm).
b. Provide at least two coats of alkyd-modified, vinyl enamel **OR** epoxy **OR** polyurethane, **as directed**, finish with a total dry film thickness of at least 4 mils (0.10 mm).
c. Paint surfaces that are to be insulated before applying the insulation.
d. Paint installed insulation to match adjacent uninsulated surfaces.
e. Color of finish coat to be manufacturer's standard **OR** custom color selected by the Owner, **as directed**.

2. Provide the Owner with quart container of paint used in application of topcoat to use in touchup applications after Project Closeout.

M. Accessories

1. Flow Switches:
   a. Chiller manufacturer shall furnish a switch for each condenser **OR** evaporator and condenser, **as directed**, and verify field-mounting location before installation.
   b. Paddle Flow Switches:
      1) Vane operated to actuate a double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the BAS.
      2) Contacts: Platinum alloy, silver alloy, or gold-plated switch contacts with a rating of 10 A at 120-V ac.
      3) Pressure rating equal to pressure rating of heat exchanger.
      4) Construct body and wetted parts of Type 316 stainless steel.
      5) House switch in a NEMA 250, Type 4, **as directed**, enclosure constructed of die-cast aluminum.
      6) Vane length to suit installation.

      OR

      Pressure Differential Switches:
      1) Construction: Wetted parts of body and trim constructed of Type 316 stainless steel.
      2) Performance: Switch shall withstand, without damage, the full-pressure rating of the heat exchanger applied to either port and exhibit zero set-point shift due to variation in working pressure.
      3) Set Point: Screw type, field adjustable.
      4) Electrical Connections: Internally mounted screw-type terminal blocks.
      5) Switch Enclosure: NEMA 250, Type 4, **as directed**.
      6) Switch Action: Double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the BAS.
2. Vibration Isolation:
   a. Chiller manufacturer shall furnish vibration isolation for each chiller.
   b. Neoprene Pad:
      1) Two layers of 0.375-inch- (10-mm-) thick, ribbed- or waffle-pattern neoprene pads separated by a 16-gage, stainless-steel plate.
      2) Fabricate pads from 40- to 50-durometer neoprene.
      3) Provide stainless-steel square bearing plate to load the pad uniformly between 20 and 40 psig (138 and 276 kPa) with a 0.12- to 0.16-inch (3- to 4-mm) deflection.

      OR

      Spring Isolator:
      1) Stable in operation and designed for not less than 30 percent reserve deflection beyond actual operating conditions. Isolators shall be designed so that the Kx/Ky ratio shall be 1.0 or more for stability.
      2) Provide PVC or neoprene-coated springs and hot-dip, galvanized-steel components. Aluminum components shall be etched and painted. Nuts, bolts, and washers shall be zinc electroplated.
      3) Isolators shall be adjustable and with an open spring, having one or more coil springs attached to a top compression plate and a baseplate. An elastomeric pad with a minimum thickness of 0.25 inch (6 mm) shall be bonded to the baseplate.

4) Spring assembly shall be removable and shall fit within a welded steel enclosure consisting of a top plate and rigid lower housing, which serves as a blocking device during installation. Isolated restraining bolts shall not be engaged during normal operation and shall connect the top plate and lower housing to prevent the isolated equipment from rising when drained of fluid.
5) Isolators shall be selected for a nominal 1-inch (25-mm) **OR** 2-inch (50-mm), **as directed**, deflection.

3. Sound Barrier:
   a. Furnish removable and reusable sound-barrier covers over the compressor housing, hermetic motor, compressor suction and discharge piping, and condenser shell.
   b. Provide for repeated installation and removal without use of tape or calk.
   c. Inner and outer cover shall consist of a PTFE-impregnated fiberglass cloth enclosing heavy-density, needled fiberglass insulation material with a mass-loaded vinyl acoustic barrier.
   d. Covers shall be double sewn and lock stitched with edges folded and sewn so no raw cut edges are exposed.
   e. Form covers around control devices, gages, conduit, piping, and supports without degrading sound-barrier performance.
   f. Continuously lap all exposed seams at least 2 inches (50 mm) for better sound containment.
   g. Permanently label each section of cover to indicate its location, description, size, and number sequence.
   h. Randomly place stainless-steel quilting pins to prevent covers from shifting and sagging.

N. Packaged Refrigerant Recovery Units
1. Packaged portable unit consisting of compressor, air-cooled condenser, recovery system, tank pressure gages, filter-dryer, and valving that allows for switching between liquid and vapor recovery mode. Refrigerant recovery unit shall be factory mounted on an ASME-constructed and -stamped refrigerant storage vessel that is sized to hold the full refrigerant charge of the largest chiller furnished.

O. Heat-Exchanger, Brush-Cleaning System
1. Furnish for field installation a brush-cleaning system on each chiller condenser, **as directed**, for tube cleaning and improved heat transfer.
2. System shall maintain tube fouling at or below design conditions without interrupting normal equipment operation.
3. System shall consist of a brush inserted in each tube and a catch basket attached to each end of the tube. A four-way valve shall operate to reverse the direction of water flow to push the brush through the tube while removing tube deposits. Four-way reversing valve's actuator shall be controlled by a preset time cycle that provides regular tube brushing during equipment operation. Frequency of the brushing cycle shall be set up to match Project requirements.
4. Components:
   a. Brush: Each brush shall have nylon bristles, titanium wires, and polypropylene tips. Brush interference fit with the ID of the tube shall not exceed 0.025 inch (0.6 mm).
   b. Basket: Single-piece polypropylene basket with neck OD to press fit inner diameter of tube. Design shall provide for insertion of eddy current probe or removal of brushes without removing baskets from the valve.
   c. Four-Way Valve:
      1) Construct valve body of carbon steel with internal sealing parts of hard rubber and Type 304 stainless steel.
      2) Configure valve with parallel flow connections to minimize field installation piping.
      3) Construct to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, at a system working pressure equal to condenser.
      4) Pipe connections shall be flanged.

5) Valve manufacturer to test and certify a maximum leakage rate of less than 0.05 percent of the design flow rate at operation conditions of maximum differential pressure.
6) Hydrostatically test to 1.5 times the design working pressure.
7) Design the valve to cause no more than 0.5-psig (3-kPa) pressure drop at design flow conditions.
8) Provide valve with valve-mounted indicating/warning light, which shall light before the valve begins rotation.
9) Valve Actuator: Mount electric actuator to operate valve.
OR
Valve Actuator: Mount pneumatic piston-type actuator to operate valve. Actuator shall be suitable for operation using field-supplied air pressure.
10) Position Switches: Factory mount microswitches on the valve to indicate the complete turn of valve in both normal and reverse flow.

d. Control Panel: Factory or field mount a control panel on chiller. Control panel shall include the following features:
1) NEMA 250, Type 1 **OR** Type 4 **OR** Type 4x **OR** Type 12, **as directed**, enclosure.
2) Timer to automatically initiate the cleaning cycle over a 24-hour period.
3) Manual override of preset cleaning cycle.
4) Visual indication of "Power On," "Diverter Position," "Normal Flow," "Reverse Flow," and "Valve Malfunction" indicating a slow turn or incomplete valve turn.
5) For pneumatic actuators, mount four-way solenoid valve for actuator operation in the control panel.
6) Flow switch bypass.
7) Unloading signal to chiller.

P. Source Quality Control
1. Perform functional **OR** functional run, **as directed**, tests of chillers before shipping.
2. Factory performance test chillers, before shipping, according to ARI 550/590.
a. Test the following conditions:
1) Design conditions indicated.
2) Reduction in capacity from design to minimum load in steps of 10 **OR** 25 **OR** 33, **as directed**, with condenser fluid at design conditions.
OR
Reduction in capacity from design to minimum load in steps of 10 **OR** 25 **OR** 33, **as directed**, with varying entering condenser-fluid temperature from design to minimum conditions in 5 deg F (3 deg C) increments.
OR
At one **OR** two **OR** three **OR** four **OR** five **OR** 10, **as directed**, point(s) of varying part-load performance to be selected by the Owner at time of test.
b. Allow the Owner access to place where chillers are being tested. Notify the Owner 14 days in advance of testing.
c. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.
3. Factory sound test chillers, before shipping, according to ARI 575, **s directed**.
a. Test the following conditions:
1) Design conditions indicated.
2) Chiller operating at calculated worst-case sound condition.
3) At one **OR** two **OR** three **OR** four **OR** five, **as directed**, point(s) of varying part-load performance to be selected by the Owner at time of test.
b. Allow the Owner access to place where chillers are being tested. Notify the Owner 14 days in advance of testing.
c. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

4. For chillers using R-134a refrigerant, factory test and inspect evaporator and condenser **OR** condenser, and heat-reclaim condenser, **as directed**, according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
5. For chillers using R-123 refrigerant, factory test and inspect evaporator and condenser **OR** condenser and heat-reclaim condenser, **as directed**, according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1. Pressure test fluid side of heat exchangers, including water boxes, to 1.5 times the rated pressure. Pressure proof test refrigerant side of heat exchangers to a minimum of 45 psig (310 kPa). Vacuum and pressure test for leaks.
6. For chillers located indoors, rate sound power level according to ARI 575.

1.3 EXECUTION

A. Chiller Installation
1. Install chillers on support structure indicated.
2. Equipment Mounting: Install chiller on concrete bases using elastomeric pads **OR** restrained spring isolators, **as directed**. Comply with requirements for concrete bases specified in Division 03 Section "Cast-in-place Concrete". Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   a. Minimum Deflection: 1/4 inch (6 mm) **OR** 1/2 inch (13 mm) **OR** 1 inch (25 mm) **OR** 2 inches (50 mm), **as directed**.
   b. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   c. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   d. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   e. Install anchor bolts to elevations required for proper attachment to supported equipment.
3. Equipment Mounting: Install chiller using elastomeric pads **OR** restrained spring isolators, **as directed**. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   a. Minimum Deflection: 1/4 inch (6 mm) **OR** 1/2 inch (13 mm) **OR** 1 inch (25 mm) **OR** 2 inches (50 mm), **as directed**.
4. Equipment Mounting: Install chiller on concrete bases. Comply with requirements for concrete bases specified in Division 03 Section "Cast-in-place Concrete".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   d. Install anchor bolts to elevations required for proper attachment to supported equipment.
5. Maintain manufacturer's recommended clearances for service and maintenance.
6. Charge chiller with refrigerant and fill with oil if not factory installed.
7. Install separate devices furnished by manufacturer and not factory installed.

B. Heat-Exchanger, Brush-Cleaning System Installation
1. Install brush-cleaning system control panel adjacent to chiller control panel.
2. Arrange piping to provide service access to four-way valve assembly without affecting access to chiller. Secure valve to prevent lateral movement and vibration during operation.
3. Provide field electric power, as required, to each system control panel and electric actuated valve.
4. Provide pneumatic piping with pressure regulator and isolation valve to each pneumatic supply connection. Coordinate field source of air with manufacturer to ensure that requirements are satisfied for proper valve operation.

5. Interconnect brush-cleaning system controls with chiller controls. Coordinate requirements to ensure safe, trouble-free operation.
6. Functionally test the entire brush-cleaning system, including the valve, actuator, position indicator, and control panel, with chiller in operation.

C. Connections
1. Comply with requirements for piping specified in Division 23 Section(s) "Hydronic Piping" AND "Refrigerant Piping". Drawings indicate general arrangement of piping, fittings, and specialties.
2. Install piping adjacent to chiller to allow service and maintenance.
3. Evaporator Fluid Connections: Connect to evaporator inlet with shutoff valve, strainer, **as directed**, flexible connector, **as directed**, thermometer, and plugged tee with pressure gage. Connect to evaporator outlet with shutoff valve, balancing valve, flexible connector, **as directed**, flow switch, thermometer, plugged tee with shutoff valve and pressure gage, flow meter, **as directed**, and drain connection with valve. Make connections to chiller with a flange **OR** mechanical coupling, **as directed**.
4. Condenser-Fluid Connections: Connect to condenser inlet with shutoff valve, strainer, **as directed**, flexible connector, **as directed**, thermometer, and plugged tee with pressure gage. Connect to condenser outlet with shutoff valve, balancing valve, flexible connector, **as directed**, flow switch, thermometer, plugged tee with shutoff valve and pressure gage, flow meter, **as directed**, and drain connection with valve. Make connections to chiller with a flange **OR** mechanical coupling, **as directed**.
5. Heat-Reclaim Condenser-Fluid Connections: Connect to condenser inlet with shutoff valve, strainer, **as directed**, flexible connector, **as directed**, thermometer, and plugged tee with pressure gage. Connect to condenser outlet with shutoff valve, balancing valve, flexible connector, **as directed**, flow switch, thermometer, plugged tee with shutoff valve and pressure gage, flow meter, **as directed**, and drain connection with valve. Make connections to chiller with a flange **OR** mechanical coupling, **as directed**.
6. Refrigerant Pressure Relief Device Connections: For chillers installed indoors, extend vent piping **OR** separate vent piping for each chiller, **as directed** to the outdoors without valves or restrictions. Comply with ASHRAE 15. Connect to chiller pressure relief device with flexible connector and dirt leg with drain valve.
7. For chillers equipped with a purge system, extend purge vent piping **OR** separate purge vent piping for each chiller, **as directed**, to the outdoors. Comply with ASHRAE 15 and ASHRAE 147.
8. Connect each chiller drain connection with a union and drain pipe, and extend pipe, full size of connection, to floor drain. Provide a shutoff valve at each connection.

D. Startup Service
1. Engage a factory-authorized service representative to perform startup service.
   a. Complete installation and startup checks according to manufacturer's written instructions.
   b. Verify that refrigerant charge is sufficient and chiller has been leak tested.
   c. Verify that pumps are installed and functional.
   d. Verify that thermometers and gages are installed.
   e. Operate chiller for run-in period.
   f. Check bearing lubrication and oil levels.
   g. Verify that refrigerant pressure relief device is vented outside.
   h. Verify proper motor rotation.
   i. Verify static deflection of vibration isolators, including deflection during chiller startup and shutdown.
   j. Verify and record performance of fluid flow and low-temperature interlocks for evaporator and condenser **OR** condenser, and heat-reclaim condenser, **as directed**.
   k. Verify and record performance of chiller protection devices.
   l. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.
2. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assembly, installation, and connection.

3. Prepare test and inspection startup reports.

END OF SECTION 23 61 16 00

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SECTION 23 61 16 00a - ROTARY-SCREW WATER CHILLERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for rotary screw water chillers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Packaged, water-cooled, single-compressor chillers.
b. Packaged, water-cooled, multiple-compressor chillers.
c. Packaged, air-cooled chillers.
d. Packaged, portable refrigerant recovery units.
e. Heat-exchanger, brush-cleaning system.

C. Definitions
1. BAS: Building automation system.
2. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input using consistent units for any given set of rating conditions.
3. EER: Energy-efficiency ratio. The ratio of the cooling capacity given in terms of Btu/h to the total power input given in terms of watts at any given set of rating conditions.
4. IPLV: Integrated part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 550/590 and referenced to ARI standard rating conditions.
5. kW/Ton (kW/kW): The ratio of total power input of the chiller in kilowatts to the net refrigerating capacity in tons (kW)at any given set of rating conditions.
6. NPLV: Nonstandard part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 550/590 and intended for operating conditions other than ARI standard rating conditions.

D. Performance Requirements
1. Seismic Performance: Chillers shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
2. Condenser-Fluid Temperature Performance:
a. Startup Condenser-Fluid Temperature: Chiller shall be capable of starting with an entering condenser-fluid temperature of 60 deg F (16 deg C) **OR** 55 deg F (13 deg C) **OR** 40 deg F (4 deg C), **as directed**, and providing stable operation until the system temperature is elevated to the minimum operating entering condenser-fluid temperature.
b. Minimum Operating Condenser-Fluid Temperature: Chiller shall be capable of continuous operation over the entire capacity range indicated with an entering condenser-fluid temperature of 65 deg F (18 deg C) **OR** 60 deg F (16 deg C) **OR** 55 deg F (13 deg C), **as directed**.
c. Make factory modifications to standard chiller design if necessary to comply with performance indicated.
3. Site Altitude: Chiller shall be suitable for altitude in which installed without affecting performance indicated. Make adjustments to affected chiller components to account for site altitude.
4. Performance Tolerance: Comply with the following in lieu of ARI 550/590, **as directed**:
a. Allowable Capacity Tolerance: Zero percent.
b. Allowable IPLV/NPLV Performance Tolerance: Zero percent.

E. Submittals
1. Product Data: For each type of product indicated. Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.
2. LEED Submittal:
   a. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.
3. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
   a. Detail equipment assemblies and indicate dimensions, weights, load distribution, required clearances, method of field assembly, components, and location and size of each field connection.
   b. Wiring Diagrams: For power, signal, and control wiring.
4. Certificates: For certification required in "Quality Assurance" Article.
5. Seismic Qualification Certificates: For chillers, accessories, and components, from manufacturer.
6. Startup service reports.
7. Operation and maintenance data.
8. Warranty: Sample of special warranty.

F. Quality Assurance
1. ARI Certification: Certify chiller according to ARI 550 and ARI 590, **as directed**, certification program(s).
2. ARI Rating: Rate chiller performance according to requirements in ARI 550/590.
3. ASHRAE Compliance:
   a. ASHRAE 15 for safety code for mechanical refrigeration.
   b. ASHRAE 147 for refrigerant leaks, recovery, and handling and storage requirements.
4. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1.
5. ASME Compliance: Fabricate and label chiller to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, and include an ASME U-stamp and nameplate certifying compliance.
6. Comply with NFPA 70.
7. Comply with requirements of UL and UL Canada and include label by a qualified testing agency showing compliance.

G. Delivery, Storage, And Handling
1. Ship chillers from the factory fully charged with refrigerant.
   OR
   Ship each chiller with a full charge of refrigerant. Charge each chiller with nitrogen if refrigerant is shipped in containers separate from chiller.
2. Ship each oil-lubricated chiller with a full charge of oil.
   a. Ship oil factory installed in chiller **OR** in containers separate from chiller, **as directed**.
3. Package chiller for export shipping in totally enclosed crate and bagging, **as directed**.

H. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of chillers that fail in materials or workmanship within specified warranty period.
   a. Extended warranties include, but are not limited to, the following:
      1) Complete chiller including refrigerant and oil charge.
         OR
         Complete compressor and drive assembly including refrigerant and oil charge.
         OR
         Refrigerant **OR** Refrigerant and oil charge, **as directed**.
      2) Parts only **OR** Parts and labor, **as directed**.
      3) Loss of refrigerant charge for any reason.
   b. Warranty Period: Two **OR** Three **OR** Four **OR** Five, **as directed**, years from date of Final Completion.

1.2 PRODUCTS

A. Packaged, Water-Cooled, Single-Compressor Chillers
1. Description: Factory-assembled and factory-tested **OR** run-tested, **as directed**, chiller with compressor, compressor motor, compressor motor controller, lubrication system, evaporator, condenser, heat-reclaim condenser as indicated, controls, interconnecting unit piping and wiring, and indicated accessories.
   a. Disassemble chiller into major assemblies as required by the installation after factory testing and before packaging for shipment.
2. Fabricate chiller mounting base with reinforcement strong enough to resist chiller movement during a seismic event when chiller is anchored to field support structure.
3. Compressor:
   a. Description: Hermetic **OR** Open, **as directed**, positive displacement, and oil lubricated.
   b. Casing: Cast iron, precision machined for minimum clearance about periphery of rotors.
   c. Rotors: Manufacturer's standard one-, two-, or three-rotor design.
   d. Drive Coupling: For chillers with open drives, provide flexible disc with all-metal construction and no wearing parts to ensure long life without the need for lubrication.
   e. Seals: Seal drive assembly to prevent refrigerant leakage.
4. Compressor Motor:
   a. Continuous-duty, squirrel-cage, induction-type motor with energy efficiency required to suit chiller energy efficiency indicated.
   b. Factory mounted, aligned, and balanced as part of compressor assembly before shipping.
   c. Motor shall be of sufficient capacity to drive compressor throughout entire operating range without overload and with sufficient capacity to start and accelerate compressor without damage.
   d. For chillers with open drives, provide motor with open-dripproof **OR** weather-protected, Type I **OR** weather-protected, Type II **OR** totally enclosed, **as directed**, enclosure.
   e. Provide motor with thermistor or RTD in single motor winding **OR** each of three-phase motor windings, **as directed**, to monitor temperature and report information to chiller control panel.
   f. Provide motor with thermistor or RTD to monitor bearing temperature and report information to chiller control panel.
   g. Provide open-drive motor with internal electric heater, internally powered from chiller power supply.
5. Vibration Balance: Balance chiller compressor and drive assembly to provide a precision balance that is free of noticeable vibration over the entire operating range.
   a. Overspeed Test: 25 percent above design operating speed.
6. Service: Easily accessible for inspection and service.
   a. Compressor's internal components shall be accessible without having to remove compressor-drive assembly from chiller.
   b. Provide lifting lugs or eyebolts attached to casing.
7. Capacity Control: Modulating slide-valve assembly or port unloaders combined with a variable frequency controller, if applicable, and hot-gas bypass, if necessary, to achieve performance indicated.
   a. Maintain stable operation throughout range of operation. Configure to achieve most energy-efficient operation possible.
   b. Operating Range: From 100 to 20 **OR** 15 **OR** 10 **OR** 5 **OR** zero, **as directed**, percent of design capacity.
   c. Condenser-Fluid Unloading Requirements over Operating Range: Constant-design entering condenser-fluid temperature **OR** Drop-in entering condenser-fluid temperature of 2.5 deg F1.4 deg C drop for each 10 percent in capacity reduction, **as directed**.
8. Oil Lubrication System: Consisting of pump if required, filtration, heater, cooler, factory-wired power connection, and controls.
   a. Provide lubrication to bearings, gears, and other rotating surfaces at all operating, startup, shutdown, and standby conditions including power failure.
   b. Thermostatically controlled oil heater properly sized to remove refrigerant from oil.

c. Oil filter **OR** Dual oil filers, one redundant, **as directed**, shall be the easily replaceable cartridge type, minimum 0.5-micron efficiency, with means of positive isolation while servicing.
d. Refrigerant **OR** Water, **as directed**,-cooled oil cooler.
e. Factory-installed and pressure-tested piping with isolation valves and accessories.
f. Oil compatible with refrigerant and chiller components.
g. Positive visual indication of oil level.

9. Refrigerant Circuit:
   a. Refrigerant: Type as indicated on Drawings.
      OR
      Refrigerant Type: R-134a **OR** HFC, **as directed**. Classified as Safety Group A1 according to ASHRAE 34.
   b. Refrigerant Compatibility: Chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
   c. Refrigerant Flow Control: Manufacturer's standard refrigerant flow-control device satisfying performance requirements indicated.
   d. Pressure Relief Device:
      1) Comply with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
      2) ASME-rated, spring-loaded pressure relief valve; single- or multiple-reseating type. Pressure relief valve(s) shall be provided for each heat exchanger. Condenser shall have dual valves with one being redundant and configured to allow either valve to be replaced without loss of refrigerant.
   e. Refrigeration Transfer: Provide service valves and other factory-installed accessories required to facilitate transfer of refrigerant from chiller to a remote refrigerant storage and recycling system. Comply with requirements in ASHRAE 15 and ASHRAE 147.
   f. Refrigerant Isolation: Factory install positive shutoff isolation valves in the compressor discharge line to the condenser and the refrigerant liquid line leaving the condenser to allow for isolation and storage of full refrigerant charge in the chiller condenser shell. In addition, provide isolation valve on suction side of compressor from evaporator to allow for isolation and storage of full refrigerant charge in the chiller evaporator shell, **as directed**.
10. Evaporator:
   a. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from condenser.
   b. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
   c. Designed to prevent liquid refrigerant carryover from entering compressor.
   d. Provide evaporator with sight glass or other form of positive visual verification of liquid-refrigerant level.
   e. Tubes:
      1) Individually replaceable from either end and without damage to tube sheets and other tubes.
      2) Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
      3) Material: Copper **OR** Copper-nickel alloy, **as directed**.
      4) Nominal OD: Manufacturer's choice **OR** 3/4 inch (19 mm) **OR** 1 inch (25 mm), **as directed**.
      5) Minimum Wall Thickness: Manufacturer's choice **OR** 0.025 inch (0.6 mm) **OR** 0.028 inch (0.7 mm) **OR** 0.035 inch (0.9 mm), **as directed**.
      6) External Finish: Manufacturer's standard.
      7) Internal Finish: Enhanced **OR** Smooth, **as directed**.
   f. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.
   g. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.

h. Water Box:
   1) Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
   2) Standard **OR** Marine, **as directed**, type for water box with piping connections. Standard type for water box without piping connections.
   3) Provide water boxes and marine water-box covers, **as directed**, with lifting lugs or eyebolts.
   4) Hinged **OR** Davited, **as directed**, water boxes.
      OR
      Hinged **OR** Davited, **as directed**, marine water-box covers.
   5) Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.
   6) Thermistor or RTD temperature sensor factory installed in each nozzle.
   7) Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.

i. Additional Corrosion Protection:
   1) Electrolytic corrosion-inhibitor anode.
   2) Coat wetted surfaces with a corrosion-resistant finish.

11. Condenser:
   a. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from evaporator.
   b. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
   c. Designed to prevent direct impingement of high-velocity hot gas from compressor discharge on tubes.
   d. Provide condenser with sight glass or other form of positive visual verification of refrigerant charge and condition.
   e. Tubes:
      1) Individually replaceable from either end and without damage to tube sheets and other tubes.
      2) Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
      3) Material: Copper **OR** Copper-nickel alloy, **as directed**.
      4) Nominal OD: Manufacturer's choice **OR** 3/4 inch (19 mm) **OR** 1 inch (25 mm), **as directed**.
      5) Minimum Wall Thickness: Manufacturer's choice **OR** 0.025 inch (0.6 mm) **OR** 0.028 inch (0.7 mm) **OR** 0.035 inch (0.9 mm), **as directed**.
      6) External Finish: Manufacturer's standard.
      7) Internal Finish: Enhanced **OR** Smooth, **as directed**.
   f. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.
   g. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.
   h. Water Box:
      1) Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
      2) Standard **OR** Marine, **as directed**, type for water box with piping connections. Standard type for water box without piping connections.
      3) Provide water boxes and marine water-box covers, **as directed**, with lifting lugs or eyebolts.
      4) Hinged **OR** Davited, **as directed**, water boxes.
         OR
         Hinged **OR** Davited, **as directed**, marine water-box covers.

5) Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.
6) Thermistor or RTD temperature sensor factory installed in each nozzle.
7) Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.

i. Additional Corrosion Protection:
1) Electrolytic corrosion-inhibitor anode.
2) Coat wetted surfaces with a corrosion-resistant finish.

12. Heat-Reclaim Condenser:
a. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from evaporator and condenser.
b. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
c. Designed to prevent direct impingement of high-velocity hot gas from compressor discharge on tubes.
d. Tubes:
1) Individually replaceable from either end and without damage to tube sheets and other tubes.
2) Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
3) Material: Copper **OR** Copper-nickel alloy, **as directed**.
4) Nominal OD: Manufacturer's choice **OR** 3/4 inch (19 mm) **OR** 1 inch (25 mm), **as directed**.
5) Minimum Wall Thickness: Manufacturer's choice **OR** 0.025 inch (0.6 mm) **OR** 0.028 inch (0.7 mm) **OR** 0.035 inch (0.9 mm), **as directed**.
6) External Finish: Manufacturer's standard.
7) Internal Finish: Enhanced **OR** Smooth, **as directed**.
e. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.
f. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.
g. Water Box:
1) Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
2) Standard **OR** Marine, **as directed**, type for water box with piping connections. Standard type for water box without piping connections.
3) Provide water boxes and marine water-box covers, **as directed**, with lifting lugs or eyebolts.
4) Hinged **OR** Davited, **as directed**, water boxes.
OR
Hinged **OR** Davited, **as directed**, marine water-box covers.
5) Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.
6) Thermistor or RTD temperature sensor factory installed in each nozzle.
7) Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.
h. Additional Corrosion Protection:
1) Electrolytic corrosion-inhibitor anode.
2) Coat wetted surfaces with a corrosion-resistant finish.

13. Electrical Power:
a. Factory installed and wired, and functionally tested at factory before shipment.

b. Single-point, field-power connection to fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**. Minimum withstand rating shall be as required by electrical power distribution system, but not less than 42,000 **OR** 65,000, **as directed**, A.
   1) Provide branch power circuit to each motor, electric heater, dedicated electrical load, and controls with disconnect switch or circuit breaker, **as directed**.
   2) NEMA- and ICS 2-rated motor controller for auxiliary motors, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller for each variable-speed motor furnished.
   3) Control-circuit transformer with primary and secondary side fuses.

c. Terminal blocks with numbered and color-coded, **as directed**, wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.

d. Factory-installed wiring outside of enclosures shall be in metal raceway except make connections to each motor and heater with not more than a 24-inch (610-mm) length of liquidtight conduit.

e. Factory install and wire capacitor bank for the purpose of power factor correction to 0.95 at all operating conditions.
   1) If capacitors are mounted in a dedicated enclosure, use same NEMA enclosure type as motor controller. Provide enclosure with service entrance knockouts and bushings for conduit.
   2) Capacitors shall be non-PCB dielectric fluid, metallized electrode design, low loss with low-temperature rise. The kVAr ratings shall be indicated and shall not exceed the maximum limitations set by NFPA 70. Provide individual cells as required.
   3) Provide each cell with current-limiting replaceable fuses and carbon-film discharge resistors to reduce residual voltage to less than 50 V within 1 minute after de-energizing.
   4) Provide a ground terminal and a terminal block or individual connectors for phase connection.

14. Motor Controller:

a. Enclosure: Factory installed, unit mounted **OR** Factory furnished, field mounted, **as directed**, NEMA 250 **OR** NEMA ICS 6, **as directed**, Type 1 **OR** Type 4 **OR** Type 4X **OR** Type 12, **as directed**, with hinged full-front access door with lock and key or padlock and key, **as directed**.

b. Control Circuit: Obtained from integral control power transformer, **as directed**, with a control power transformer **OR** source, **as directed**, of enough capacity to operate connected control devices.

c. Overload Relay: Shall be sized according to UL 1995 or shall be an integral component of chiller control microprocessor.

d. Across-the-Line Controller: NEMA ICS 2, Class A, full voltage, nonreversing; include isolation switch and current-limiting fuses.

e. Star-Delta, Reduced-Voltage Controller: NEMA ICS 2, closed transition.

f. Autotransformer Reduced-Voltage Controller: NEMA ICS 2, closed transition; include isolation switch and current-limiting fuses.

g. Solid-State, Reduced-Voltage Controller: NEMA ICS 2.
   1) Surge suppressor in solid-state power circuits providing three-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.
   2) Visual indication of motor and control status, including the following conditions:
      a) Controller on.
      b) Overload trip.
      c) Loss of phase.
      d) Starter fault.

h. Accessories: Devices shall be factory installed in controller enclosure unless otherwise indicated.
   1) Externally Operated, Door-Interlocked, **as directed**, Disconnect: Fused disconnect switch **OR** Nonfused disconnect switch **OR** Circuit breaker, **as directed**. Minimum

withstand rating shall be as required by electrical power distribution system, but not less than 42,000 **OR** 65,000, **as directed**, A.

2) Push-Button Stations, Pilot Lights, and Selector Switches: NEMA ICS 2, heavy-duty type.
3) Stop and Lockout Push-Button Station: Momentary-break, push-button station with a factory-applied hasp arranged so padlock can be used to lock push button in depressed position with control circuit open.
4) Control Relays: Time-delay relays.
5) Elapsed-Time Meters: Numerical readout in hours on face of enclosure.
6) Number-of-Starts Counter: Numerical readout on face of enclosure.
7) Meters: Panel type, 2-1/2 inches (64 mm) **OR** 4-1/4 inches (108 mm), **as directed**, with 90 **OR** 120 **OR** 270, **as directed**,-degree scale and 1 **OR** 2, **as directed**, percent accuracy. Where indicated, provide transfer device with an off position. Meters shall indicate the following:
   a) Ammeter: Output current for each phase, with current sensors rated to suit application.
   b) Voltmeter: Output voltage for each phase.
   c) Frequency Meter: Output frequency.
   d) Real-time clock with current time and date.
   e) Total run time.

   OR

   Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three- or four-wire systems and with the following features:
   a) Selectable, digital display of the following:
      i. Phase Currents, Each Phase: Plus or minus 1 percent.
      ii. Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent.
      iii. Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 percent.
      iv. Three-Phase Real Power: Plus or minus 2 percent.
      v. Three-Phase Reactive Power: Plus or minus 2 percent.
      vi. Power Factor: Plus or minus 2 percent.
      vii. Frequency: Plus or minus 0.5 percent.
      viii. Integrated Demand with Demand Interval Selectable from 5 to 60 Minutes: Plus or minus 2 percent.
      ix. Accumulated energy, in megawatt hours (joules), plus or minus 2 percent; stored values unaffected by power outages for up to 72 hours.
   b) Mounting: Display and control unit flush or semirecessed in instrument compartment door.
8) Phase-Failure, Phase-Reversal, Undervoltage Relays: Solid-state sensing circuit with adjustable undervoltage setting and isolated output contacts for hardwired connection.
9) Power Protection: Chiller shall shut down within six cycles of power interruption.

15. Variable Frequency Controller:
   a. Motor controller shall be factory mounted and wired on the chiller to provide a single-point, field-power termination to the chiller and its auxiliaries.
   b. Description: NEMA ICS 2; listed and labeled as a complete unit and arranged to provide variable speed by adjusting output voltage and frequency.
   c. Enclosure: Unit mounted, NEMA 250, Type 1, **as directed**, with hinged full-front access door with lock and key.
   d. Integral Disconnecting Means: Door-interlocked, **as directed**, NEMA AB 1, instantaneous-trip circuit breaker with lockable handle. Minimum withstand rating shall be as required by electrical power distribution system, but not less than 42,000 **OR** 65,000 **OR** 100,000, **as directed**, A.
   e. Technology: Pulse width modulated (PWM) output suitable for constant or variable torque loads.

f. Output Rating: Three phase; with voltage proportional to frequency throughout voltage range.

g. Operating Requirements:
   1) Input AC Voltage Tolerance: 460-V ac, plus 10 percent or 506 V maximum, **as directed**.
   2) Input frequency tolerance of 60 Hz, plus or minus 2 Hz.
   3) Capable of driving full load, without derating, under the following conditions:
      a) Ambient Temperature: 0 to 40 deg C.
      b) Relative Humidity: Up to 90 **OR** 95, **as directed**, percent (noncondensing).
      c) Altitude: 3300 feet (1005 m) **OR** 6600 feet (2010 m), **as directed**.
   4) Minimum Efficiency: 96 percent at 60 Hz, full load.
   5) Minimum Displacement Primary-Side Power Factor: 98 percent.
   6) Overload Capability: 1.05 times the full-load current for 7 seconds.
   7) Starting Torque: As required by compressor-drive assembly.
   8) Speed Regulation: Plus or minus 1 percent.
   9) Isolated control interface to allow controller to follow control signal over a 10:1 speed range.
   10) To avoid equipment resonant vibrations, provide critical speed lockout circuitry to allow bands of operating frequency at which controller shall not operate continuously.
   11) Capable of being restarted into a motor coasting in either the forward or reverse direction without tripping.

h. Internal Adjustability Capabilities:
   1) Minimum Output Frequency: 6 Hz.
   2) Maximum Output Frequency: 60 Hz.
   3) Acceleration: 2 seconds to 60 seconds.
   4) Deceleration: Zero seconds to 60 seconds.
   5) Current Limit: 30 to a minimum of 100 percent of maximum rating.

i. Self-Protection and Reliability Features: Subjecting the controller to any of the following conditions shall not result in component failure or the need for replacement:
   1) Overtemperature.
   2) Short circuit at controller output.
   3) Ground fault at controller output. Variable frequency controller shall be able to start a grounded motor.
   4) Open circuit at controller output.
   5) Input undervoltage.
   6) Input overvoltage.
   7) Loss of input-phase.
   8) Reverse phase.
   9) AC line switching transients.
   10) Instantaneous overload, line to line or line to ground.
   11) Sustained overload exceeding 100 percent of controller rated current.
   12) Starting a rotating motor.

j. Motor Protection: Controller shall protect motor against overvoltage and undervoltage, phase loss, reverse phase, overcurrent, overtemperature, and ground fault.

k. Automatic Reset and Restart: Capable of three restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Controller shall be capable of automatic restart on phase-loss, and overvoltage and undervoltage trips.

l. Visual Indication: On face of controller enclosure or chiller control enclosure; indicating the following conditions:
   1) Power on.
   2) Run.
   3) Overvoltage.
   4) Line fault.
   5) Overcurrent.

6) External fault.
7) Motor speed (percent).
8) Fault or alarm status (code).
9) Motor output voltage.
10) Input kilovolt amperes.
11) Total power factor.
12) Input kilowatts.
13) Input kilowatt-hours.
14) Three-phase input voltage.
15) Three-phase output voltage.
16) Three-phase input current.
17) Three-phase output current.
18) Output frequency (Hertz).
19) Elapsed operating time (hours).
20) Diagnostic and service parameters.

m. Operator Interface: At controller or chiller control panel; with start-stop and auto-manual selector with manual-speed-control potentiometer.

n. Harmonic Distortion Filter: Factory mounted and wired to limit total voltage and current distortion to 5 percent.

16. Controls:

a. Standalone and microprocessor based with all memory stored in nonvolatile memory so that reprogramming is not required on loss of electrical power.

b. Enclosure: Unit mounted, NEMA 250, Type 1 **OR** Type 4 **OR** Type 4x **OR** Type 12, **as directed**, hinged or lockable; factory wired with a single-point, field-power connection and a separate control circuit.

c. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. In either imperial or metric units, display the following information:

1) Date and time.
2) Operating or alarm status.
3) Fault history with not less than last 10 faults displayed.
4) Set points of controllable parameters.
5) Trend data.
6) Operating hours.
7) Number of chiller starts.
8) Outdoor-air temperature or space temperature if required for chilled-water reset.
9) Temperature and pressure of operating set points.
10) Entering- and leaving-fluid temperatures of evaporator and condenser.
11) Difference in fluid temperatures of evaporator and condenser.
12) Fluid flow of evaporator and condenser.
13) Fluid pressure drop of evaporator and condenser.
14) Refrigerant pressures in evaporator and condenser.
15) Refrigerant saturation temperature in evaporator and condenser.
16) Pump status.
17) Antirecycling timer status.
18) Percent of maximum motor amperage.
19) Current-limit set point.
20) Compressor bearing temperature.
21) Motor bearing temperature.
22) Motor winding temperature.
23) Oil temperature.
24) Oil discharge pressure.
25) Phase current.
26) Percent of motor rated load amperes.
27) Phase voltage.

28) Demand power (kilowatts).
29) Energy use (kilowatt-hours).
30) Power factor.

d. Control Functions:
1) Manual or automatic startup and shutdown time schedule.
2) Entering and leaving chilled-water temperatures, control set points, and motor load limits. Evaporator fluid temperature shall be reset based on return-water **OR** outdoor-air **OR** space, **as directed**, temperature.
3) Current limit and demand limit.
4) Condenser-fluid temperature.
5) External chiller emergency stop.
6) Antirecycling timer.
7) Variable evaporator flow.
8) Thermal storage.
9) Heat reclaim.

e. Manually Reset Safety Controls: The following conditions shall shut down chiller and require manual reset:
1) Low evaporator pressure or temperature; high condenser pressure.
2) Low evaporator fluid temperature.
3) Low oil differential pressure.
4) High or low oil pressure.
5) High oil temperature.
6) High compressor-discharge temperature.
7) Loss of condenser-fluid flow.
8) Loss of evaporator-fluid flow.
9) Motor overcurrent.
10) Motor overvoltage.
11) Motor undervoltage.
12) Motor phase reversal.
13) Motor phase failure.
14) Sensor- or detection-circuit fault.
15) Processor communication loss.
16) Motor controller fault.
17) Extended compressor surge.

f. Trending: Capability to trend analog data of up to five parameters simultaneously over an adjustable period and frequency of polling.

g. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: view only; view and operate; and view, operate, and service.

h. Control Authority: At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.

i. Communication Port: RS-232 port or equivalent connection capable of connecting a printer and a notebook computer, **as directed**.

j. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display chiller status and alarms.
1) Hardwired Points:
a) Monitoring: On-off status, common trouble alarm **OR** electrical power demand (kilowatts) **OR** electrical power consumption (kilowatt-hours) **OR** power factor, **as directed**.
b) Control: On-off operation, chilled-water, discharge temperature set-point adjustment **OR** electrical power demand limit, **as directed**.
2) ASHRAE 135 (BACnet) **OR** LonTalk **OR** Modbus **OR** Industry-accepted, open-protocol, **as directed**, communication interface with the BAS shall enable the BAS operator to remotely control and monitor the chiller from an operator workstation. Control features and monitoring points displayed locally at chiller control panel shall be available through the BAS.

17. Insulation:
    a. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type I for tubular materials and Type II for sheet materials.
    b. Thickness: 3/4 inch (19 mm) **OR** 1-1/2 inches (38 mm), **as directed**.
    c. Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.
    d. Factory-applied insulation over cold surfaces of chiller capable of forming condensation. Components shall include, but not be limited to, evaporator shell and end tube sheets, evaporator water boxes including nozzles, refrigerant suction pipe from evaporator to compressor, cold surfaces of compressor, refrigerant-cooled motor, and auxiliary piping.
        1) Before insulating steel surfaces, prepare surfaces for paint, and prime and paint as indicated for other painted components. Do not insulate unpainted steel surfaces.
        2) Seal seams and joints to provide a vapor barrier.
        3) After adhesive has fully cured, paint exposed surfaces of insulation to match other painted parts.
18. Finish:
    a. Paint chiller, using manufacturer's standard procedures, except comply with the following minimum requirements:
        1) Provide at least one coat of primer with a total dry film thickness of at least 2 mils (0.05 mm).
        2) Provide at least two coats of alkyd-modified, vinyl enamel **OR** epoxy **OR** polyurethane, **as directed**, finish with a total dry film thickness of at least 4 mils (0.10 mm).
        3) Paint surfaces that are to be insulated before applying the insulation.
        4) Paint installed insulation to match adjacent uninsulated surfaces.
        5) Color of finish coat to be manufacturer's standard **OR** custom color selected by the Owner, **as directed**.
    b. Provide the Owner with quart container of paint used in application of topcoat to use in touchup applications after Project Closeout.
19. Accessories:
    a. Flow Switches:
        1) If required and not factory installed, chiller manufacturer shall furnish a switch for each condenser **OR** evaporator and condenser, **as directed**, and verify field-mounting location before installation.
        2) Paddle Flow Switches:
            a) Vane operated to actuate a double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the BAS.
            b) Contacts: Platinum alloy, silver alloy, or gold-plated switch contacts with a rating of 10 A at 120-V ac.
            c) Pressure rating equal to pressure rating of heat exchanger.
            d) Construct body and wetted parts of Type 316 stainless steel.
            e) House switch in a NEMA 250, Type 4, **as directed**, enclosure constructed of die-cast aluminum.
            f) Vane length to suit installation.

            OR

            Pressure Differential Switches:
            g) Construction: Wetted parts of body and trim constructed of Type 316 stainless steel.
            h) Performance: Switch shall withstand, without damage, the full-pressure rating of the heat exchanger applied to either port and exhibit zero set-point shift due to variation in working pressure.
            i) Set Point: Screw type, field adjustable.
            j) Electrical Connections: Internally mounted screw-type terminal blocks.
            k) Switch Enclosure: NEMA 250, Type 4, **as directed**.

l) Switch Action: Double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the BAS.

b. Vibration Isolation:

c. Chiller manufacturer shall furnish vibration isolation for each chiller.

1) Neoprene Pad:

a) Two layers of 0.375-inch- (10-mm-) thick, ribbed- or waffle-pattern neoprene pads separated by a 16-gage, stainless-steel plate.

b) Fabricate pads from 40- to 50-durometer neoprene.

c) Provide stainless-steel square bearing plate to load the pad uniformly between 20 and 40 psig (138 and 276 kPa) with a 0.12- to 0.16-inch (3- to 4-mm) deflection.

OR

Spring Isolator:

d) Stable in operation and designed for not less than 30 percent reserve deflection beyond actual operating conditions. Isolators shall be designed such that the Kx/Ky ratio shall be 1.0 or more for stability.

e) Provide PVC or neoprene-coated springs and hot-dip, galvanized-steel components. Aluminum components shall be etched and painted. Nuts, bolts, and washers shall be zinc electroplated.

f) Isolators shall be adjustable and with an open spring, having one or more coil springs attached to a top compression plate and a baseplate. An elastomeric pad with a minimum thickness of 0.25 inch (6 mm) shall be bonded to the baseplate.

g) Spring assembly shall be removable and shall fit within a welded steel enclosure consisting of a top plate and rigid lower housing, which serves as a blocking device during installation. Isolated restraining bolts shall not be engaged during normal operation and shall connect the top plate and lower housing to prevent the isolated equipment from rising when drained of fluid.

h) Isolators shall be selected for a nominal 1-inch (25-mm) **OR** 2-inch (50-mm), **as directed**, deflection.

d. Sound Barrier:

1) Furnish removable and reusable sound-barrier covers over the compressor housing, hermetic motor, compressor suction and discharge piping, and condenser shell.

2) Provide for repeated installation and removal without use of tape or calk.

3) Inner and outer cover shall consist of a PTFE-impregnated fiberglass cloth enclosing heavy-density, needled fiberglass insulation material with a mass-loaded vinyl acoustic barrier.

4) Covers shall be double sewn and lock stitched with edges folded and sewn so no raw cut edges are exposed.

5) Form covers around control devices, gages, conduit, piping, and supports without degrading sound-barrier performance.

6) Continuously lap all exposed seams at least 2 inches (50 mm) for better sound containment.

7) Permanently label each section of cover to indicate its location, description, size, and number sequence.

8) Randomly place stainless-steel quilting pins to prevent covers from shifting and sagging.

B. Packaged, Water-Cooled, Multiple-Compressor Chillers

1. Description: Factory-assembled and -tested **OR** run-tested, **as directed**, chiller with compressor(s), compressor motors and motor controllers, evaporator, condenser where indicated, electrical power, controls, and indicated accessories.

a. Disassemble chiller into major assemblies as required by the installation after factory testing and before packaging for shipment.

2. Fabricate chiller mounting base with reinforcement strong enough to resist chiller movement during a seismic event when chiller is anchored to field support structure.
3. Compressors:
   a. Description: Positive displacement, hermetically sealed.
   b. Casing: Cast iron, precision machined for minimum clearance about periphery of rotors.
   c. Rotors: Manufacturer's standard one- or two-rotor design.
4. Service: Easily accessible for inspection and service.
   a. Compressor's internal components shall be accessible without having to remove compressor-drive assembly from chiller.
   b. Provide lifting lugs or eyebolts attached to casing.
5. Capacity Control: On-off compressor cycling and modulating slide-valve assembly or port unloaders combined with hot-gas bypass, if necessary, to achieve performance indicated.
   a. Maintain stable operation throughout range of operation. Configure to achieve most energy-efficient operation possible.
   b. Operating Range: From 100 to 20 **OR** 15 **OR** 10 **OR** 5 **OR** zero, **as directed**, percent of design capacity.
   c. Condenser-Fluid Unloading Requirements over Operating Range: Constant-design entering condenser-fluid temperature **OR** Drop-in entering condenser-fluid temperature of 2.5 deg F (1.4 deg C) drop for each 10 percent in capacity reduction, **as directed**.
6. Oil Lubrication System: Consisting of pump if required, filtration, heater, cooler, factory-wired power connection, and controls.
   a. Provide lubrication to bearings, gears, and other rotating surfaces at all operating, startup, shutdown, and standby conditions including power failure.
   b. Thermostatically controlled oil heater properly sized to remove refrigerant from oil.
   c. Factory-installed and pressure-tested piping with isolation valves and accessories.
   d. Oil compatible with refrigerant and chiller components.
   e. Positive visual indication of oil level.
7. Vibration Control:
   a. Vibration Balance: Balance chiller compressor and drive assembly to provide a precision balance that is free of noticeable vibration over the entire operating range.
      1) Overspeed Test: 25 percent above design operating speed.
   b. Isolation: Mount individual compressors on vibration isolators.
8. Sound Control: Sound-reduction package shall consist of removable acoustic enclosures around the compressors and drive assemblies that are designed to reduce sound levels without affecting performance.
9. Compressor Motors:
   a. Hermetically sealed and cooled by refrigerant suction gas.
   b. High-torque, induction type with inherent thermal-overload protection on each phase.
10. Refrigerant Circuits:
   a. Refrigerant: Type as indicated on Drawings.
      OR
      Refrigerant Type: R-134a **OR** HFC, **as directed**. Classified as Safety Group A1 according to ASHRAE 34.
   b. Refrigerant Compatibility: Chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
   c. Refrigerant Circuit: Each shall include a thermal- or electronic-expansion valve, refrigerant charging connections, a hot-gas muffler, compressor suction, **as directed**, and discharge shutoff valves, a liquid-line shutoff valve, a replaceable-core, **as directed**, filter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.
   d. Pressure Relief Device:
      1) Comply with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
      2) ASME-rated, spring-loaded pressure relief valve; single- or multiple-reseating type.

e. Refrigerant Isolation: Factory install positive shutoff isolation valves in the compressor discharge line to the condenser and the refrigerant liquid-line leaving the condenser to allow for isolation and storage of full refrigerant charge in the chiller condenser shell.

11. Evaporator:
    a. Description: Shell-and-tube design.
        1) Direct-expansion (DX) type with fluid flowing through the shell, and refrigerant flowing through the tubes within the shell.
        2) Flooded type with fluid flowing through tubes and refrigerant flowing around tubes within the shell.
    b. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
    c. Shell Material: Carbon steel.
    d. Shell Heads: Removable carbon-steel heads with multipass baffles, and located at each end of the tube bundle.
    e. Fluid Nozzles: Terminated with mechanical-coupling or flanged end connections for connection to field piping.
    f. Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
12. Condenser:
    a. Shell and tube, or without integral condenser; as indicated.
       OR
       Shell and Tube:
        1) Description: Shell-and-tube design with refrigerant flowing through shell, and fluid flowing through tubes within shell.
        2) Provides positive subcooling of liquid refrigerant.
        3) Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
        4) Shell Material: Carbon steel.
        5) Water Boxes: Removable, of carbon-steel construction, located at each end of the tube bundle with fluid nozzles terminated with mechanical-coupling end connections for connection to field piping.
        6) Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
        7) Provide each condenser with a pressure relief device, purge cock, and liquid-line shutoff valve.
    b. Provide chiller without an integral condenser and design chiller for field connection to remote condenser. Coordinate requirements with Division 23 Section "Air-cooled Refrigerant Condensers".
13. Electrical Power:
    a. Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a multipoint **OR** single-point, **as directed**, field-power connection to chiller.
    b. House in a unit-mounted, NEMA 250, Type 1, **as directed**, enclosure with hinged access door with lock and key or padlock and key, **as directed**.
    c. Wiring shall be numbered and color-coded, **as directed**, to match wiring diagram.
    d. Install factory wiring outside of an enclosure in a raceway.
    e. Field-power interface shall be to wire lugs **OR** NEMA KS 1, heavy-duty, nonfused disconnect switch **OR** NEMA AB 1, instantaneous-trip circuit breaker with lockable handle, **as directed**.
        1) Disconnect means shall be interlocked with door operation.
        2) Minimum withstand rating shall be as required by electrical power distribution system, but not less than 42,000 **OR** 65,000 **OR** 100,000, **as directed**, A.
    f. Provide branch power circuit to each motor and to controls with one of the following disconnecting means:
        1) NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.

2) NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit-trip set point.

g. Provide each motor with overcurrent protection.

h. Overload relay sized according to UL 1995 or an integral component of chiller control microprocessor.

i. Phase-Failure and Undervoltage Relays: Solid-state sensing with adjustable settings.

j. Control Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.

k. Control Relays: Auxiliary and adjustable time-delay relays.

l. For chiller electrical power supply, indicate the following:

1) Current and phase to phase for all three phases.
2) Voltage, phase to phase, and phase to neutral for all three phases.
3) Three-phase real power (kilowatts).
4) Three-phase reactive power (kilovolt amperes reactive).
5) Power factor.
6) Running log of total power versus time (kilowatt-hours).
7) Fault log, with time and date of each.

14. Compressor Motor Controllers:

a. Across the Line: NEMA ICS 2, Class A, full voltage, nonreversing, or solid state, **as directed**.

b. Star-Delta, Reduced-Voltage Controller: NEMA ICS 2, closed or open transition, or solid state, **as directed**.

15. Controls:

a. Standalone and microprocessor based.

b. Enclosure: Share enclosure with electrical-power devices or provide a separate enclosure of matching construction.

c. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. In either imperial or metric units, display the following information:

1) Date and time.
2) Operating or alarm status.
3) Fault history with not less than last 10 faults displayed.
4) Set points of controllable parameters.
5) Trend data.
6) Operating hours.
7) Number of chiller starts.
8) Outdoor-air temperature or space temperature if required for chilled-water reset.
9) Temperature and pressure of operating set points.
10) Entering- and leaving-fluid temperatures of evaporator and condenser.
11) Difference in fluid temperatures of evaporator and condenser.
12) Refrigerant pressures in evaporator and condenser.
13) Refrigerant saturation temperature in evaporator and condenser.
14) No cooling load condition.
15) Elapsed time meter (compressor run status).
16) Pump status.
17) Antirecycling timer status.
18) Percent of maximum motor amperage.
19) Current-limit set point.
20) Number of compressor starts.
21) Compressor refrigerant suction and discharge temperature.
22) Oil temperature.
23) Oil discharge pressure.
24) Phase current.
25) Percent of motor rated load amperes.
26) Phase voltage.

d. Control Functions:
   1) Manual or automatic startup and shutdown time schedule.
   2) Entering and leaving chilled-water temperatures, control set points, and motor load limits. Chilled-water leaving temperature shall be reset based on return-water **OR** outdoor-air **OR** space, **as directed**, temperature.
   3) Current limit and demand limit.
   4) Condenser-fluid temperature.
   5) External chiller emergency stop.
   6) Antirecycling timer.
   7) Automatic lead-lag switching.
   8) Variable evaporator flow.
   9) Thermal storage.

e. Manually Reset Safety Controls: The following conditions shall shut down chiller and require manual reset:
   1) Low evaporator pressure, or high condenser pressure.
   2) Low chilled-water temperature.
   3) Refrigerant high pressure.
   4) High or low oil pressure.
   5) High oil temperature.
   6) Loss of chilled-water flow.
   7) Loss of condenser-fluid flow.
   8) Control device failure.

f. Trending: Capability to trend analog data of up to five parameters simultaneously over an adjustable period and frequency of polling.

g. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: view only; view and operate; and view, operate, and service.

h. Control Authority: At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.

i. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display chiller status and alarms.
   1) Hardwired Points:
      a) Monitoring: On-off status, common trouble alarm **OR** electrical power demand (kilowatts) **OR** electrical power consumption (kilowatt-hours), **as directed**.
      b) Control: On-off operation, chilled-water, discharge temperature set-point adjustment **OR** electrical power demand limit, **as directed**.
   2) ASHRAE 135 (BACnet) **OR** LonTalk **OR** Modbus **OR** Industry-accepted, open-protocol, **as directed**, communication interface with the BAS shall enable the BAS operator to remotely control and monitor the chiller from an operator workstation. Control features and monitoring points displayed locally at chiller control panel shall be available through the BAS.

16. Insulation:
   a. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type I for tubular materials and Type II for sheet materials.
   b. Thickness: 3/4 inch (19 mm).
   c. Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.
   d. Factory-applied insulation over cold surfaces of chiller capable of forming condensation. Components shall include, but not be limited to, evaporator shell and end tube sheets, evaporator water boxes including nozzles, refrigerant suction pipe from evaporator to compressor, cold surfaces of compressor, refrigerant-cooled motor, and auxiliary piping.
      1) Before insulating steel surfaces, prepare surfaces for paint, prime and paint as indicated for other painted components. Do not insulate unpainted steel surfaces.
      2) Seal seams and joints to provide a vapor barrier.

3) After adhesive has fully cured, paint exposed surfaces of insulation to match other painted parts.

17. Finish:
    a. Paint chiller, using manufacturer's standard procedures, except comply with the following minimum requirements:
        1) Provide at least one coat of primer.
        2) Provide finish coat of alkyd-modified, vinyl enamel, **as directed**.
        3) Paint surfaces that are to be insulated before applying the insulation.
        4) Paint installed insulation to match adjacent uninsulated surfaces.
18. Accessories:
    a. Factory-furnished, chilled- and condenser-, **as directed**,water flow switches for field installation.
    b. Individual compressor suction and discharge pressure gages with shutoff valves for each refrigerant circuit.
    c. Factory-furnished neoprene **OR** spring, **as directed**, isolators for field installation.

C. Packaged, Air-Cooled Chillers
1. Description: Factory-assembled and run-tested chiller complete with base and frame, condenser casing, compressors, compressor motors and motor controllers, evaporator, condenser coils, condenser fans and motors, electrical power, controls, and accessories.
2. Fabricate base, frame, and attachment to chiller components strong enough to resist chiller movement during a seismic event when chiller base is anchored to field support structure.
3. Cabinet:
    a. Base: Galvanized-steel base extending the perimeter of chiller. Secure frame, compressors, and evaporator to base to provide a single-piece unit.
    b. Frame: Rigid galvanized-steel frame secured to base and designed to support cabinet, condenser, control panel, and other chiller components not directly supported by base.
    c. Casing: Galvanized steel.
    d. Finish: Coat base, frame, and casing with a corrosion-resistant coating capable of withstanding a 500 **OR** 1000, **as directed**,-hour salt-spray test according to ASTM B 117.
    e. Sound-reduction package designed to reduce sound level without affecting performance and consisting of the following:
        1) Acoustic enclosure around compressors.
        2) Reduced-speed fans with acoustic treatment.
    f. Security Package: Provide removable grilles **OR** louvered panels, **as directed**, with fasteners for additional protection of compressors, evaporator, and condenser coils without inhibiting service access. Finish to match cabinet.
4. Compressors:
    a. Description: Positive displacement, hermetically sealed.
    b. Casing: Cast iron, precision machined for minimum clearance about periphery of rotors.
    c. Rotors: Manufacturer's standard one- or two-rotor design.
    d. Each compressor provided with suction and, **as directed**, discharge shutoff valves, crankcase oil heater, and suction strainer.
5. Service: Easily accessible for inspection and service.
6. Capacity Control: On-off compressor cycling and modulating slide-valve assembly or port unloaders combined with hot-gas bypass, if necessary, to achieve performance indicated.

7. Maintain stable operation throughout range of operation. Configure to achieve most energy-efficient operation possible.
    a. Operating Range: From 100 to 20 **OR** 15 **OR** 10 **OR** 5 **OR** zero, **as directed**, percent of design capacity.
    b. Condenser-Air Unloading Requirements over Operating Range: Constant-design entering condenser-air temperature **OR** Drop-in entering condenser-air temperature of 5 deg F (3 deg C) drop for each 10 percent in capacity reduction, **as directed**.

c. For units equipped with a variable frequency controller, capacity control shall be both "valveless" and "stepless," requiring no slide valve or capacity-control valve(s) to operate at reduced capacity.

8. Oil Lubrication System: Consisting of pump if required, filtration, heater, cooler, factory-wired power connection, and controls.
   a. Provide lubrication to bearings, gears, and other rotating surfaces at all operating, startup, shutdown, and standby conditions including power failure.
   b. Thermostatically controlled oil heater properly sized to remove refrigerant from oil.
   c. Factory-installed and pressure-tested piping with isolation valves and accessories.
   d. Oil compatible with refrigerant and chiller components.
   e. Positive visual indication of oil level.
9. Vibration Control:
   a. Vibration Balance: Balance chiller compressors and drive assemblies to provide a precision balance that is free of noticeable vibration over the entire operating range.
      1) Overspeed Test: 25 percent above design operating speed.
   b. Isolation: Mount individual compressors on vibration isolators.
10. Compressor Motors:
   a. Hermetically sealed and cooled by refrigerant suction gas.
   b. High-torque, induction type with inherent thermal-overload protection on each phase.
11. Compressor Motor Controllers:
   a. Across the Line: NEMA ICS 2, Class A, full voltage, nonreversing, or solid state, **as directed**.
   b. Star-Delta, Reduced-Voltage Controller: NEMA ICS 2, closed transition, or solid state, **as directed**.
   c. Variable Frequency Controller:
      1) Motor controller shall be factory mounted and wired on the chiller to provide a single-point, field-power termination to the chiller and its auxiliaries.
      2) Description: NEMA ICS 2; listed and labeled as a complete unit and arranged to provide variable speed by adjusting output voltage and frequency.
      3) Enclosure: Unit mounted, NEMA 250, Type 3R, **as directed**, with hinged full-front access door with lock and key.
      4) Integral Disconnecting Means: Door-interlocked, **as directed**, NEMA AB 1, instantaneous-trip circuit breaker with lockable handle. Minimum withstand rating shall be as required by electrical power distribution system, but not less than 42,000 **OR** 65,000 **OR** 100,000, **as directed**, A.
      5) Technology: Pulse width modulated (PWM) output suitable for constant or variable torque loads.
      6) Motor current at start shall not exceed the rated load amperes, providing no electrical inrush.
12. Refrigerant Circuits:
   a. Refrigerant: Type as indicated on Drawings.
      OR
      Refrigerant Type: R-134a **OR** R-407c **OR** HFC, **as directed**: Classified as Safety Group A1 according to ASHRAE 34.
   b. Refrigerant Compatibility: Chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
   c. Refrigerant Circuit: Each shall include a thermal- or electronic-expansion valve, refrigerant charging connections, a hot-gas muffler, compressor suction, **as directed**, and discharge shutoff valves, a liquid-line shutoff valve, a replaceable-core, **as directed**, filter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.
   d. Pressure Relief Device:
      1) Comply with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
      2) ASME-rated, spring-loaded pressure relief valve; single- or multiple-reseating type.
13. Evaporator:

a. Description: Shell-and-tube design.
   1) Direct-expansion (DX) type with fluid flowing through the shell, and refrigerant flowing through the tubes within the shell.
   2) Flooded type with fluid flowing through tubes and refrigerant flowing around tubes within the shell.
b. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
c. Shell Material: Carbon steel.
d. Shell Heads: Removable carbon-steel heads located at each end of the tube bundle.
e. Fluid Nozzles: Terminated with mechanical-coupling **OR** flanged, **as directed**, end connections for connection to field piping.
f. Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
g. Heater: Factory-installed and -wired electric heater with integral controls designed to protect the evaporator to minus 20 deg F (minus 29 deg C).
h. Remote Mounting: Designed for remote field mounting where indicated. Provide kit for field installation.

14. Air-Cooled Condenser:
   a. Plate-fin coil with integral subcooling on each circuit, rated at 450 psig (3103 kPa).
      1) Construct coil casing of galvanized **OR** stainless, **as directed**, steel.
      2) Construct coils of copper tubes mechanically bonded to aluminum **OR** aluminum with precoated epoxy-phenolic **OR** copper, **as directed**, fins.
      3) Coat coils with a baked-epoxy, corrosion-resistant coating after fabrication.
      4) Hail Protection: Provide condenser coils with louvers, baffles, or hoods to protect against hail damage.
   b. Fans: Direct-drive propeller type with statically and dynamically balanced fan blades, arranged for vertical air discharge.
   c. Fan Motors: Totally enclosed nonventilating (TENV) or totally enclosed air over (TEAO) enclosure, with permanently lubricated bearings. Equip each motor with overload protection integral to either the motor or chiller controls.
   d. Fan Guards: Steel safety guards with corrosion-resistant coating.

15. Electrical Power:
   a. Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a multipoint **OR** single-point, **as directed**, field-power connection to chiller.
   b. House in a unit-mounted, NEMA 250, Type 3R, **as directed**, enclosure with hinged access door with lock and key or padlock and key, **as directed**.
   c. Wiring shall be numbered and color-coded, **as directed**, to match wiring diagram.
   d. Install factory wiring outside of an enclosure in a raceway.
   e. Field-power interface shall be to wire lugs **OR** NEMA KS 1, heavy-duty, nonfused disconnect switch **OR** NEMA AB 1, instantaneous-trip circuit breaker with lockable handle, **as directed**.
      1) Disconnect means shall be interlocked with door operation.
      2) Minimum withstand rating shall be as required by electrical power distribution system, but not less than 42,000 **OR** 65,000 **OR** 100,000, **as directed**, A.
   f. Provide branch power circuit to each motor and to controls with one of the following disconnecting means:
      1) NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
      2) NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit-trip set point.
   g. Provide each motor with overcurrent protection.
   h. Overload relay sized according to UL 1995 or an integral component of chiller control microprocessor.
   i. Phase-Failure and Undervoltage Relays: Solid-state sensing with adjustable settings.

j. Provide power factor correction capacitors to correct power factor to 0.90 **OR** 0.95, **as directed**, at full load.

k. Control Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.
   1) Power unit-mounted controls where indicated.
   2) Power unit-mounted, ground fault interrupt (GFI) duplex receptacle.

l. Control Relays: Auxiliary and adjustable time-delay relays.

m. For chiller electrical power supply, indicate the following:
   1) Current and phase to phase for all three phases.
   2) Voltage, phase to phase, and phase to neutral for all three phases.
   3) Three-phase real power (kilowatts).
   4) Three-phase reactive power (kilovolt amperes reactive).
   5) Power factor.
   6) Running log of total power versus time (kilowatt-hours).
   7) Fault log, with time and date of each.

16. Controls:

a. Standalone and microprocessor based.

b. Enclosure: Share enclosure with electrical power devices or provide a separate enclosure for remote mounting in the field, **as directed**.

c. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. In either imperial or metric units, display the following information:
   1) Date and time.
   2) Operating or alarm status.
   3) Operating hours.
   4) Outdoor-air temperature if required for chilled-water reset.
   5) Temperature and pressure of operating set points.
   6) Entering and leaving temperatures of chilled water.
   7) Refrigerant pressures in evaporator and condenser.
   8) Saturation temperature in evaporator and condenser.
   9) No cooling load condition.
   10) Elapsed time meter (compressor run status).
   11) Pump status.
   12) Antirecycling timer status.
   13) Percent of maximum motor amperage.
   14) Current-limit set point.
   15) Number of compressor starts.

d. Control Functions:
   1) Manual or automatic startup and shutdown time schedule.
   2) Entering and leaving chilled-water temperatures, control set points, and motor load limits. Chilled-water leaving temperature shall be reset based on return-water **OR** outdoor-air **OR** space, **as directed**, temperature.
   3) Current limit and demand limit.
   4) External chiller emergency stop.
   5) Antirecycling timer.
   6) Automatic lead-lag switching.
   7) Variable evaporator flow.
   8) Thermal storage.

e. Manually Reset Safety Controls: The following conditions shall shut down chiller and require manual reset:
   1) Low evaporator pressure or high condenser pressure.
   2) Low chilled-water temperature.
   3) Refrigerant high pressure.
   4) High or low oil pressure.
   5) High oil temperature.
   6) Loss of chilled-water flow.

7) Control device failure.

f. Trending: Capability to trend analog data of up to five parameters simultaneously over an adjustable period and frequency of polling.

g. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: view only; view and operate; and view, operate, and service.

h. Control Authority: At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.

i. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display chiller status and alarms.

1) Hardwired Points:

a) Monitoring: On-off status, common trouble alarm **OR** electrical power demand (kilowatts) **OR** electrical power consumption (kilowatt-hours), **as directed**.

b) Control: On-off operation, chilled-water, discharge temperature set-point adjustment **OR** electrical power demand limit, **as directed**.

2) ASHRAE 135 (BACnet) **OR** LonTalk **OR** Modbus **OR** Industry-accepted, open-protocol, **as directed**, communication interface with the BAS shall enable the BAS operator to remotely control and monitor the chiller from an operator workstation. Control features and monitoring points displayed locally at chiller control panel shall be available through the BAS.

17. Insulation:

a. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type I for tubular materials and Type II for sheet materials.

b. Thickness: 3/4 inch (19 mm) **OR** 1-1/2 inches (38 mm), **as directed**.

c. Factory-applied insulation over cold surfaces of chiller components.

1) Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.

d. Apply protective coating to exposed surfaces of insulation to protect insulation from weather.

18. Accessories:

a. Factory-furnished, chilled-water flow switches for field installation.

b. Individual compressor suction and discharge pressure gages with shutoff valves for each refrigerant circuit.

c. Factory-furnished neoprene **OR** spring, **as directed**, isolators for field installation.

D. Packaged Refrigerant Recovery Units

1. Packaged portable unit consisting of compressor, air-cooled condenser, recovery system, tank pressure gages, filter-dryer, and valving that allows for switching between liquid and vapor recovery mode. Refrigerant recovery unit shall be factory mounted on an ASME-constructed and -stamped refrigerant storage vessel that is sized to hold the full refrigerant charge of the largest chiller furnished.

E. Heat-Exchanger, Brush-Cleaning System

1. Furnish for field installation a brush-cleaning system on each chiller condenser, **as directed**, for tube cleaning and improved heat transfer.

2. System shall maintain tube fouling at or below design conditions without interrupting normal equipment operation.

3. System shall consist of a brush inserted in each tube and a catch basket attached to each end of the tube. A four-way valve shall operate to reverse the direction of water flow to push the brush through the tube while removing tube deposits. Four-way reversing valve's actuator shall be controlled by a preset time cycle that provides regular tube brushing during equipment operation. Frequency of the brushing cycle shall be set up to match Project requirements.

4. Components:

a. Brush: Each brush shall have nylon bristles, titanium wires, and polypropylene tips. Brush interference fit with the ID of the tube shall not exceed 0.025 inch (0.6 mm).

b. Basket: Single-piece polypropylene basket with neck OD to press fit ID of tube. Design shall provide for insertion of eddy current probe or removal of brushes without removing baskets from the valve.

c. Four-Way Valve:

1) Construct valve body of carbon steel with internal sealing parts of hard rubber and Type 304 stainless steel.

2) Configure valve with parallel flow connections to minimize field installation piping.

3) Construct to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, at a system working pressure equal to condenser.

4) Pipe connections shall be flanged.

5) Valve manufacturer to test and certify a maximum leakage rate of less than 0.05 percent of the design flow rate at operation conditions of maximum differential pressure.

6) Hydrostatically test to 1.5 times the design working pressure.

7) Design the valve to cause no more than 0.5-psig (3-kPa) pressure drop at design flow conditions.

8) Provide valve with valve-mounted indicating/warning light, which shall light before valve begins rotation.

9) Valve Actuator: Mount electric actuator to operate valve.

OR

Valve Actuator: Mount pneumatic piston-type actuator to operate valve. Actuator shall be suitable for operation using field-supplied air pressure.

10) Position Switches: Factory mount microswitches on valve to indicate the complete turn of valve in both normal and reverse flow.

d. Control Panel: Factory or field mount a control panel on chiller. Control panel shall include the following features:

1) NEMA 250, Type 1 **OR** Type 4 **OR** Type 4x **OR** Type 12, **as directed**, enclosure.

2) Timer to automatically initiate the cleaning cycle over a 24-hour period.

3) Manual override of preset cleaning cycle.

4) Visual indication of "Power On," "Diverter Position," "Normal Flow," "Reverse Flow," and "Valve Malfunction" indicating a slow turn or incomplete valve turn.

5) For pneumatic actuators, mount four-way solenoid valve for actuator operation in the control panel.

6) Flow switch bypass.

7) Unloading signal to chiller.

F. Source Quality Control

1. Perform functional tests of chillers before shipping.

2. Factory run test each air-cooled chiller with water flowing through evaporator.

3. Factory performance test water-cooled chillers, before shipping, according to ARI 550/590.

a. Test the following conditions:

1) Design conditions indicated.

2) Reduction in capacity from design to minimum load in steps of 10 **OR** 25 **OR** 33, **as directed**, with condenser fluid at design conditions.

OR

Reduction in capacity from design to minimum load in steps of 10 **OR** 25 **OR** 33, **as directed**, with varying entering condenser-fluid temperature from design to minimum conditions in 5 deg F (3 deg C) increments.

OR

At one **OR** two **OR** three **OR** four **OR** five **OR** 10, **as directed**, point(s) of varying part-load performance to be selected by the Owner at time of test.

b. Allow the Owner access to place where chillers are being tested. Notify the Owner 14 days in advance of testing.

c. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

4. Factory performance test air-cooled chillers, **as directed**, before shipping, according to ARI 550/590.
   a. Test the following conditions:
      1) Design conditions indicated.
      2) Reduction in capacity from design to minimum load in steps of 10 **OR** 25 **OR** 33, **as directed**, with condenser air at design conditions.
         OR
         At one **OR** two **OR** three **OR** four **OR** five, **as directed**, point(s) of varying part-load performance to be selected by the Owner at time of test.
   b. Allow the Owner access to place where chillers are being tested. Notify the Owner 14 days in advance of testing.
   c. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.
5. Factory sound test water-cooled chillers, **as directed**, before shipping, according to ARI 575 **OR** air-cooled chillers, before shipping, according to ARI 370, **as directed**.
   a. Test the following conditions:
      1) Design conditions indicated.
      2) Chiller operating at calculated worst-case sound condition.
         OR
         At one **OR** two **OR** three **OR** four **OR** five, **as directed**, point(s) of varying part-load performance to be selected by the Owner at time of test.
   b. Allow the Owner access to place where chillers are being tested. Notify the Owner 14 days in advance of testing.
   c. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.
6. Factory test and inspect evaporator and condenser **OR** condenser, and heat-reclaim condenser, **as directed**, according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
7. For chillers located indoors, rate sound power level according to ARI 575.
8. For chillers located outdoors, rate sound power level according to ARI 370.

1.3 EXECUTION

A. Chiller Installation
   1. Install chillers on support structure indicated.
   2. Equipment Mounting: Install chiller on concrete bases using elastomeric pads **OR** restrained spring isolators, **as directed**. Comply with requirements for concrete bases specified in Division 03 Section "Cast-in-place Concrete". Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
      a. Minimum Deflection: 1/4 inch (6 mm) **OR** 1/2 inch (13 mm) **OR** 1 inch (25 mm) **OR** 2 inches (50 mm), **as directed**.
      b. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
      c. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
      d. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
      e. Install anchor bolts to elevations required for proper attachment to supported equipment.
   3. Equipment Mounting: Install chiller using elastomeric pads **OR** restrained spring isolators, **as directed**. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".

a. Minimum Deflection: 1/4 inch (6 mm) **OR** 1/2 inch (13 mm) **OR** 1 inch (25 mm) **OR** 2 inches (50 mm), **as directed**.

4. Equipment Mounting: Install chiller on concrete bases. Comply with requirements for concrete bases specified in Division 03 Section "Cast-in-place Concrete".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   d. Install anchor bolts to elevations required for proper attachment to supported equipment.
5. Maintain manufacturer's recommended clearances for service and maintenance.
6. Charge chiller with refrigerant and fill with oil if not factory installed.
7. Install separate devices furnished by manufacturer and not factory installed.

B. Heat-Exchanger, Brush-Cleaning System Installation
1. Install brush-cleaning system control panel adjacent to chiller control panel.
2. Arrange piping to provide service access to four-way valve assembly without affecting access to chiller. Secure valve to prevent lateral movement and vibration during operation.
3. Provide field electric power, as required, to each system control panel and electric actuated valve.
4. Provide pneumatic piping with pressure regulator and isolation valve to each pneumatic supply connection. Coordinate field source of air with manufacturer to ensure that requirements are satisfied for proper valve operation.
5. Interconnect brush-cleaning system controls with chiller controls. Coordinate requirements to ensure safe, trouble-free operation.
6. Functionally test the entire brush-cleaning system, including the valve, actuator, position indicator, and control panel, with chiller in operation.

C. Connections
1. Comply with requirements for piping specified in Division 23 Section(s) "Hydronic Piping" AND "Refrigerant Piping". Drawings indicate general arrangement of piping, fittings, and specialties.
2. Install piping adjacent to chiller to allow service and maintenance.
3. Evaporator Fluid Connections: Connect to evaporator inlet with shutoff valve, strainer, **as directed**, flexible connector, **as directed**, thermometer, and plugged tee with pressure gage. Connect to evaporator outlet with shutoff valve, balancing valve, flexible connector, **as directed**, flow switch, thermometer, plugged tee with shutoff valve and pressure gage, flow meter, **as directed**, and drain connection with valve. Make connections to chiller with a flange **OR** mechanical coupling, **as directed**.
4. Condenser Fluid Connections: Connect to condenser inlet with shutoff valve, strainer, **as directed**, flexible connector, **as directed**, thermometer, and plugged tee with pressure gage. Connect to condenser outlet with shutoff valve, balancing valve, flexible connector, **as directed**, flow switch, thermometer, plugged tee with shutoff valve and pressure gage, flow meter, **as directed**, and drain connection with valve. Make connections to chiller with a flange **OR** mechanical coupling, **as directed**.
5. Heat-Reclaim Condenser Fluid Connections: Connect to condenser inlet with shutoff valve, strainer, **as directed**, flexible connector, **as directed**, thermometer, and plugged tee with pressure gage. Connect to condenser outlet with shutoff valve, balancing valve, flexible connector, **as directed**, flow switch, thermometer, plugged tee with shutoff valve and pressure gage, flow meter, **as directed**, and drain connection with valve. Make connections to chiller with a flange **OR** mechanical coupling, **as directed**.
6. Refrigerant Pressure Relief Device Connections: For chillers installed indoors, extend vent piping **OR** separate vent piping for each chiller, **as directed**, to the outdoors without valves or restrictions. Comply with ASHRAE 15. Connect vent to chiller pressure relief device with flexible connector and dirt leg with drain valve.
7. Connect each chiller drain connection with a union and drain pipe, and extend pipe, full size of connection, to floor drain. Provide a shutoff valve at each connection.

D. Startup Service
1. Engage a factory-authorized service representative to perform startup service.
   a. Complete installation and startup checks according to manufacturer's written instructions.
   b. Verify that refrigerant charge is sufficient and chiller has been leak tested.
   c. Verify that pumps are installed and functional.
   d. Verify that thermometers and gages are installed.
   e. Operate chiller for run-in period.
   f. Check bearing lubrication and oil levels.
   g. For chillers installed indoors, verify that refrigerant pressure relief device is vented outdoors.
   h. Verify proper motor rotation.
   i. Verify static deflection of vibration isolators, including deflection during chiller startup and shutdown.
   j. Verify and record performance of fluid flow and low-temperature interlocks for evaporator and condenser **OR** condenser, and heat-reclaim condenser, **as directed**.
   k. Verify and record performance of chiller protection devices.
   l. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.
2. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assembly, installation, and connection.
3. Prepare test and inspection startup reports.

END OF SECTION 23 61 16 00a

Task	Specification	Specification Description
23 62 23 00	23 01 60 00	Condensing Units

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SECTION 23 63 13 00 - AIR-COOLED CONDENSERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for air-cooled condensers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes packaged, air-cooled condensers for outdoor and indoor installation.

C. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings: Signed and sealed by a qualified professional engineer.
   a. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints, **as directed**, and for designing vibration isolation bases.
   b. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails and equipment mounting frames.
   c. Wiring Diagrams: Power, signal, and control wiring.
3. Manufacturer Seismic Qualification Certification: Submit certification that air-cooled condensers, accessories, and components will withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment". Include the following:
   a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
4. Field quality-control test reports.
5. Operation and maintenance data.
6. LEED Submittal:
   a. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Fabricate and label refrigeration system according to ASHRAE 15, "Safety Code for Mechanical Refrigeration."
3. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

1.2 PRODUCTS

A. Manufactured Units
1. Description: Factory assembled and tested; consisting of casing, condenser coils, condenser fans and motors, and unit controls.
2. Condenser Coil: Seamless copper-tube, finned coil; factory tested at 425 psig (2930 kPa).
   a. Coil Fin: Aluminum **OR** Copper, **as directed**.
   b. Coil Coating: **As directed**.
   c. Circuit: To match compressors with liquid subcooling coil, **as directed**.
   d. Refrigerant Accessories, **as directed**: Provide receiver, pressure control, and solenoid valve for each circuit.

3. Condenser Fans and Drives: Propeller fans with aluminum or galvanized-steel **OR** galvanized-steel **OR** stainless-steel, **as directed**, fan blades, for vertical **OR** horizontal, **as directed**, air discharge; directly driven with permanently lubricated ballbearing motors with integral current- and thermal-overload protection.
   OR
   Condenser Fans and Drives: Forward-curved centrifugal fans for vertical **OR** horizontal, **as directed**, air discharge.
   a. Fan on steel shaft with self-aligning ball bearings.
   b. V-belt drive with minimum of two belts; variable pitch drive pulley.
   c. Motor mounted on adjustable slide base.
4. Operating and Safety Controls: Include condenser fan motor thermal and overload cutouts; 115-V control transformer, if required; magnetic contactors for condenser fan motors and a nonfused factory-mounted and -wired disconnect switch for single external electrical power connection.
5. Unit Casings: Galvanized or zinc-coated steel treated and finished with manufacturer's standard paint coating **OR** Stainless steel, **as directed**, designed for outdoor installation with weather protection for components and controls **OR** indoor installation, **as directed**, and with the following:
   a. Removable panels for access to controls, condenser fans, motors, and drives.
   b. Plated-steel **OR** Stainless-steel, **as directed**, fan guards.
   c. Lifting eyes.
   d. Removable legs.
   e. 1-inch- (25-mm-) thick inlet filter.

B. Motors
1. General requirements for motors are specified in Division 14 Section "Facility Chutes".
   a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
   b. Controllers, Electrical Devices, and Wiring: Electrical devices and connections are specified in Division 22.

C. Source Quality Control
1. Verification of Performance: Rate air-cooled condensers according to ARI 460.
2. Testing Requirements: Factory test sound-power-level ratings according to ARI 270.

1.3 EXECUTION

A. Installation
1. Install units level and plumb, firmly anchored in locations indicated; maintain manufacturer's recommended clearances.
2. Install air-cooled condensers on concrete base. Concrete base is specified in Division 23 Section "Common Work Results For Hvac" and concrete materials and installation requirements are specified in Division 31.
3. Concrete Bases:
   a. Install dowel rods to connect concrete base to concrete slab. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around full perimeter of the base.
   b. For equipment supported on structural slab, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   d. Install anchor bolts to elevations required for proper attachment to supported equipment.
   e. Install anchor bolts according to anchor-bolt manufacturer's written instructions.
4. Install roof-mounting units on equipment supports specified in Division 07.

5. Vibration Isolation: Mount air-cooled condensers on rubber pads with a minimum deflection of 1/4 inch (6.35 mm). Vibration isolation devices and installation requirements are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   OR
   Vibration Isolation: Mount air-cooled condensers on restrained spring isolators with a minimum deflection of <**Insert measurement**>. Vibration isolation devices and installation requirements are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
6. Support suspended units from structure using threaded steel rods and spring hangers having a static deflection of 1 inch (25 mm). Vibration- and seismic-control devices are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   a. Secure vibration and seismic controls, and suspended units to structure.
   OR
   Support suspended units from structure using threaded steel rods.
7. Maintain manufacturer's recommended clearances for service and maintenance.
8. Loose Components: Install electrical components, devices, and accessories that are not factory mounted.

B. Connections
1. Piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
2. Install piping adjacent to machine to allow service and maintenance.
3. Refrigerant Piping: Connect piping to unit with pressure relief, service valve, filter-dryer, and moisture indicator on each refrigerant-circuit liquid line. Refrigerant piping and specialties are specified in Division 23 Section "Refrigerant Piping".

C. Field Quality Control
1. Perform the following field tests and inspections and prepare test reports:
   a. Perform electrical test and visual and mechanical inspection.
   b. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
   c. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation. Complete manufacturer's starting checklist.
   d. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
   e. Verify proper airflow over coils.
2. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.
3. Remove and replace malfunctioning air-cooled condensers and retest as specified above.

D. Startup Service
1. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
   a. Inspect for physical damage to unit casing.
   b. Verify that access doors move freely and are weathertight.
   c. Clean units and inspect for construction debris.
   d. Verify that all bolts and screws are tight.
   e. Adjust vibration isolation and flexible connections.
   f. Verify that controls are connected and operational.
2. Lubricate bearings on fans.
3. Verify that fan wheel is rotating in the correct direction and is not vibrating or binding.
4. Start unit according to manufacturer's written instructions and complete manufacturer's startup checklist.
5. Measure and record airflow over coils.
6. Verify proper operation of capacity control device.

7. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.
8. After startup and performance test, lubricate bearings.

E. Demonstration
1. Train Owner's maintenance personnel to adjust, operate, and maintain air-cooled condensers.

END OF SECTION 23 63 13 00

SECTION 23 63 13 00a - SPLIT-SYSTEM AIR-CONDITIONING UNITS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for split-system air-conditioning units. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes split-system air-conditioning and heat pump units consisting of separate evaporator-fan and compressor-condenser components. Units are designed for exposed or concealed mounting, and may be connected to ducts.

C. Submittals
1. Product Data: For each unit indicated. Include performance data in terms of capacities, outlet velocities, static pressures, sound power characteristics, motor requirements, and electrical characteristics.
2. LEED Submittals:
   a. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.
   b. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
3. Shop Drawings: Diagram power, signal, and control wiring.
4. Field quality-control test reports.
5. Operation and maintenance data.
6. Warranty: Special warranty specified in this Section.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
3. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

E. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of split-system air-conditioning units that fail in materials or workmanship within five years from date of Final Completion.

1.2 PRODUCTS

A. Concealed Evaporator-Fan Components
1. Chassis: Galvanized steel with flanged edges, removable panels for servicing, and insulation on back of panel.
   a. Insulation: Faced, glass-fiber duct liner.
   b. Drain Pans: Galvanized steel, with connection for drain; insulated and complying with ASHRAE 62.1, **as directed**.
   c. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

2. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with ARI 210/240, and with thermal-expansion valve.
3. Water **OR** Steam, **as directed**, Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm); leak tested to 300 psig (2070 kPa) underwater; and having a two-position control valve.
   OR
   Electric Coil: Helical, nickel-chrome, resistance-wire heating elements with refractory ceramic support bushings; automatic-reset thermal cutout; built-in magnetic contactors; manual-reset thermal cutout; airflow proving device; and one-time fuses in terminal box for overcurrent protection.
4. Fan: Forward-curved, double-width wheel of galvanized steel; directly connected to motor.
5. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   a. Special Motor Features: Multitapped, multispeed with internal thermal protection and permanent lubrication.
6. Disposable Filters: 1 inch (25 mm) thick, in fiberboard frames with ASHRAE 52.2 MERV rating of 6 or higher, **as directed**.
7. Wiring Terminations: Connect motor to chassis wiring with plug connection.

B. Floor-Mounting, Evaporator-Fan Components
1. Cabinet: Enameled steel with removable panels on front and ends in color selected by the Owner.
   a. Discharge Grille: Steel with surface-mounted frame **OR** Welded steel bars forming a linear grille and welded into supporting panel, **as directed**.
   b. Insulation: Faced, glass-fiber, duct liner.
   c. Drain Pans: Galvanized steel, with connection for drain; insulated and complying with ASHRAE 62.1, **as directed**.
   d. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
2. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with ARI 210/240, and with thermal-expansion valve.
3. Water **OR** Steam, **as directed**, Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm); leak tested to 300 psig (2070 kPa) underwater; and having a 2-position control valve.
   OR
   Electric Coil: Helical, nickel-chrome, resistance-wire heating elements with refractory ceramic support bushings; automatic-reset thermal cutout; built-in magnetic contactors; manual-reset thermal cutout; airflow proving device; and one-time fuses in terminal box for overcurrent protection.
4. Fan: Direct drive, centrifugal, with power-induced outside air, **as directed**.
5. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   a. Special Motor Features: Multitapped, multispeed with internal thermal protection and permanent lubrication.
6. Filters: Permanent, cleanable **OR** Disposable, with ASHRAE 52.2 MERV rating of 6 or higher, **as directed**.

C. Wall-Mounting, Evaporator-Fan Components
1. Cabinet: Enameled steel with removable panels on front and ends in color selected by the Owner, and discharge drain pans with drain connection.
   a. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
   b. Drain Pan and Drain Connection: Comply with ASHRAE 62.1.
2. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with ARI 210/240, and with thermal-expansion valve.

3. Electric Coil: Helical, nickel-chrome, resistance-wire heating elements with refractory ceramic support bushings; automatic-reset thermal cutout; built-in magnetic contactors; manual-reset thermal cutout; airflow proving device; and one-time fuses in terminal box for overcurrent protection.
4. Fan: Direct drive, centrifugal fan.
5. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   a. Special Motor Features: Multitapped, multispeed with internal thermal protection and permanent lubrication.
6. Filters: Permanent, cleanable **OR** Disposable, with ASHRAE 52.2 MERV rating of 6 or higher, **as directed**.

D. Ceiling-Mounting, Evaporator-Fan Components
1. Cabinet: Enameled steel with removable panels on front and ends in color selected by the Owner, and discharge drain pans with drain connection.
   a. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
   b. Drain Pan and Drain Connection: Comply with ASHRAE 62.1.
2. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with ARI 210/240, and with thermal-expansion valve.
3. Electric Coil: Helical, nickel-chrome, resistance-wire heating elements with refractory ceramic support bushings; automatic-reset thermal cutout; built-in magnetic contactors; manual-reset thermal cutout; airflow proving device; and one-time fuses in terminal box for overcurrent protection.
4. Fan: Direct drive, centrifugal fan, with power-induced outside air, **as directed**, and integral condensate pump.
5. Fan Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   a. Special Motor Features: Multitapped, multispeed with internal thermal protection and permanent lubrication.
6. Filters: Permanent, cleanable **OR** Disposable, with ASHRAE 52.2 MERV rating of 6 or higher, **as directed**.

E. Air-Cooled, Compressor-Condenser Components
1. Casing: Steel, finished with baked enamel in color selected by the Owner, with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Provide brass service valves, fittings, and gage ports on exterior of casing.
2. Compressor: Hermetically sealed with crankcase heater and mounted on vibration isolation. Compressor motor shall have thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
   a. Compressor Type: Reciprocating **OR** Scroll, **as directed**.
   b. Two-speed compressor motor with manual-reset high-pressure switch and automatic-reset low-pressure switch.
   c. Refrigerant: R-407C **OR** R-410A, **as directed**.
3. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins, complying with ARI 210/240, and with liquid subcooler.
4. Heat Pump Components: Reversing valve and low-temperature air cut-off thermostat.
5. Fan: Aluminum-propeller type, directly connected to motor.
6. Motor: Permanently lubricated, with integral thermal-overload protection.
7. Low Ambient Kit: Permits operation down to 45 deg F (7 deg C).
8. Mounting Base: Polyethylene.
9. Minimum Energy Efficiency: Comply with ASHRAE/IESNA 90.1, "Energy Standard for Buildings except Low-Rise Residential Buildings."

F. Water-Cooled, Compressor-Condenser Components

1. Casing: Steel, with baked-enamel finish in color selected by the Owner, removable panels for access to controls, and mounting holes in base. Provide brass service valves, fittings, and gage ports on exterior of casing.
2. Compressor: Hermetically sealed with crankcase heater and mounted on vibration isolation. Compressor motor shall have thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
   a. Compressor Type: Reciprocating **OR** Scroll, **as directed**.
   b. Two-speed compressor motor with manual-reset high-pressure switch and automatic-reset low-pressure switch.
   c. Refrigerant: R-407C **OR** R-410A, **as directed**.
3. Heat Pump Components: Reversing valve.
4. Heat Exchanger: Copper tubes in copper tube or in steel shell, with water-temperature-actuated, water-regulating valve.
5. Minimum Energy Efficiency: Comply with ASHRAE/IESNA 90.1, "Energy Standard for Buildings except Low-Rise Residential Buildings."

G. Accessories
1. Control equipment and sequence of operation are specified in Division 23 Section(s) "Instrumentation And Control For Hvac" AND "Sequence Of Operations For Hvac Controls".
2. Thermostat: Low voltage with subbase to control compressor and evaporator fan.
3. Thermostat: Wireless infrared functioning to remotely control compressor and evaporator fan, with the following features:
   a. Compressor time delay.
   b. 24-hour time control of system stop and start.
   c. Liquid-crystal display indicating temperature, set-point temperature, time setting, operating mode, and fan speed.
   d. Fan-speed selection, including auto setting.
4. Automatic-reset timer to prevent rapid cycling of compressor.
5. Refrigerant Line Kits: Soft-annealed copper suction and liquid lines factory cleaned, dried, pressurized, and sealed; factory-insulated suction line with flared fittings at both ends.
   a. Minimum Insulation Thickness: 1/2 inch (13 mm) **OR** 1 inch (25 mm), **as directed**, thick.

1.3 EXECUTION

A. Installation
1. Install units level and plumb.
2. Install evaporator-fan components using manufacturer's standard mounting devices securely fastened to building structure.
3. Install ground-mounting, compressor-condenser components on 4-inch- (100-mm-) thick, reinforced concrete base; 4 inches (100 mm) larger on each side than unit. Concrete, reinforcement, and formwork are specified in Division 03 Section "Cast-in-place Concrete". Coordinate anchor installation with concrete base.
   OR
   Install ground-mounting, compressor-condenser components on polyethylene mounting base.
4. Install roof-mounting compressor-condenser components on equipment supports specified in Division 07 Section "Roof Accessories". Anchor units to supports with removable, cadmium-plated fasteners.
5. Install seismic restraints.
6. Install compressor-condenser components on restrained, spring isolators with a minimum static deflection of 1 inch (25 mm). Refer to Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
7. Install and connect precharged refrigerant tubing to component's quick-connect fittings. Install tubing to allow access to unit.

B. Connections
   1. Piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
      a. Water Coil Connections: Comply with requirements in Division 23 Section "Hydronic Piping". Connect to supply and return coil with shutoff-duty valve and union or flange on the supply connection and with throttling-duty valve and union or flange on the return connection.
      b. Remote Water-Cooled Condenser Connections: Comply with requirements in Division 23 Section "Hydronic Piping". Connect to supply and return with shutoff-duty valve and union or flange on the supply connection and with throttling-duty valve and union or flange on the return connection.
      c. Steam Coil Connections: Comply with requirements in Division 23 Section "Steam And Condensate Heating Piping". Connect to steam piping with shutoff valve and union or flange; for condensate piping, starting from the coil connection, connect with union or flange, strainer, trap, and shutoff valve.
   2. Install piping adjacent to unit to allow service and maintenance.
   3. Duct Connections: Duct installation requirements are specified in Division 23 Section "Metal Ducts". Drawings indicate the general arrangement of ducts. Connect supply and return, **as directed**, ducts to split-system air-conditioning units with flexible duct connectors. Flexible duct connectors are specified in Division 23 Section "Air Duct Accessories".
   4. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
   5. Electrical Connections: Comply with requirements in Division 22 for power wiring, switches, and motor controls.

C. Field Quality Control
   1. Perform the following field tests and inspections and prepare test reports:
      a. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
      b. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
      c. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
   2. Remove and replace malfunctioning units and retest as specified above.

D. Startup Service
   1. Engage a factory-authorized service representative to perform startup service.
      a. Complete installation and startup checks according to manufacturer's written instructions.

E. Demonstration
   1. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain units.

END OF SECTION 23 63 13 00a

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Task	Specification	Specification Description
23 63 13 00	23 01 60 00	Condensing Units

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SECTION 23 64 13 16 - INDIRECT-FIRED ABSORPTION WATER CHILLERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for indirect-fired absorption water chillers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Packaged, water-cooled, single-effect and double-effect absorption chillers.
b. Heat-exchanger, brush-cleaning system.

C. Definitions
1. BAS: Building automation system.
2. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input using consistent units for any given set of rating conditions.
3. IPLV: Integrated part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 560 and referenced to ARI standard rating conditions.
4. NPLV: Nonstandard part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 560 and intended for operating conditions other than the ARI standard rating conditions.

D. Performance Requirements
1. Seismic Performance: Indirect-fired absorption chillers shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
2. Condenser-Fluid Temperature Performance:
a. Startup Condenser-Fluid Temperature: Chiller shall be capable of starting with an entering condenser-fluid temperature of 60 deg F (16 deg C) **OR** 55 deg F (13 deg C) **OR** 40 deg F (4.4 deg C), **as directed**, and providing stable operation until the system temperature is elevated to the minimum operating entering condenser-fluid temperature.
b. Minimum Operating Condenser-Fluid Temperature: Chiller shall be capable of continuous operation over the entire capacity range indicated with an entering condenser-fluid temperature of 65 deg F (18 deg C) **OR** 60 deg F (16 deg C) **OR** 55 deg F (13 deg C), **as directed**.
c. Make factory modifications to standard chiller design if necessary to comply with performance indicated.
3. Site Altitude: Chiller shall be suitable for altitude at which installed without affecting performance indicated. Make adjustments to affected chiller components to account for site altitude.
4. Performance Tolerance: Comply with the following in lieu of ARI 560, **as directed**:
a. Allowable Capacity Tolerance: Zero percent.
b. Allowable IPLV/NPLV Performance Tolerance: Zero percent.

E. Submittals
1. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, furnished specialties and accessories.
2. LEED Submittals:
a. Product Data for LEED-NC Prerequisite EA 2: Documentation indicating that units comply with ASHRAE 90.1.

b. Product Data for LEED-NC Prerequisite EA 3: Documentation indicating that refrigerants comply.
c. Product Data for LEED-NC Credit EA 4: Documentation indicating that equipment and refrigerants comply.

3. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
4. Certificates: For certification required in "Quality Assurance" Article.
5. Seismic Qualification Certificates: For chillers, accessories, and components, from manufacturer.
   a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
   c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
6. Startup service reports.
7. Operation and maintenance data.
8. Warranty: Sample of special warranty.

F. Quality Assurance
1. ARI Rating: Rate chiller performance according to requirements in ARI 560.
2. ASHRAE Compliance:
   a. ASHRAE 15 for safety code for mechanical refrigeration.
   b. ASHRAE/IESNA 90.1.
3. ASME Compliance: Fabricate and label chiller pressure vessels to comply with applicable portions of ASME Boiler and Pressure Vessel Code.
4. Comply with NFPA 70.
5. Comply with requirements of UL and UL Canada, and include label by a qualified testing agency showing compliance.

G. Delivery, Storage, And Handling
1. Ship chillers factory charged with nitrogen.
2. Ship absorbent and refrigerant in chillers or in containers separate from chillers.
   OR
   Ship absorbent and refrigerant, **as directed**, in containers separate from chillers.
3. Package chiller for export shipping in totally enclosed bagging **OR** crate **OR** crate with bagging, **as directed**.

H. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of chillers that fail in materials or workmanship within specified warranty period.
   a. Extended warranties include, but are not limited to, the following:
      1) Complete chiller.
         OR
         Pumps and motors **OR** Purge unit, **as directed**.
         OR
         Absorbent **OR** Absorbent and refrigerant, **as directed**, only.
      2) Parts only **OR** Parts and labor, **as directed**.
      3) Loss of absorbent and refrigerant for any reason.
2. Warranty Period: Two **OR** Three **OR** Four **OR** Five, **as directed**, years from date of Final Completion.

1.2 PRODUCTS

A. Manufactured Unit

1. Description: Factory-assembled and -tested, hermetic-design chiller complete with absorber, evaporator, condenser, generator, solution heat exchanger, controls, absorbent solution pump with motor, refrigerant pump with motor, purge unit with motor, motor controllers, rupture disk, interconnecting unit piping and wiring, indicated accessories, and mounting frame.
    a. Disassemble chiller into major assemblies as required by the installation after factory testing and before packaging for shipment.
2. Absorbent and Refrigerant:
    a. Absorbent: Lithium bromide solution with corrosion inhibitor.
    b. Refrigerant: Deionized or distilled, **as directed**, water.
    c. Performance Enhancer: Heat and mass transfer enhancer to improve performance.
3. Seismic Fabrication Requirements: Fabricate mounting base and attachment to chiller, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" when mounting base is anchored to building structure.

B. Pumps
1. Hermetically sealed, self-lubricating, and fitted with self-adjusting, spring-loaded, wear-compensating tapered carbon bearings.
2. Pump motor assembly shall be designed to operate for not less than 25,000 **OR** 50,000, **as directed**, hours between inspections.
3. Pump motors cooled, and bearings lubricated, either by fluid being pumped or by a filtered supply of liquid refrigerant.
4. Pump suction and discharge equipped with isolation valves.
5. Separate and dedicated pumps for absorbent solution and refrigerant.
    a. Absorbent solution and refrigerant flow-control method shall be manufacturer's choice to comply with operating requirements indicated.
6. Purge System: Unit mounted and factory wired, equipped with controls and a pump to automatically remove noncondensable vapors.
    a. Purge Pump Motor: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
        1) Enclosure: Open dripproof **OR** Totally enclosed, **as directed**.

C. Heat-Exchanger Shells
1. Configuration for Single-Effect Chillers: Two shells; one shell consists of the absorber/evaporator and the other shell consists of the condenser/generator.
2. Configuration for Double-Effect Chillers: Two shells; one shell consists of the absorber/evaporator, low-stage generator/condenser and the other shell consists of the high-stage generator.
3. Construction: Fabricated from continuously welded carbon-steel sheet or plate, or from seamless pipe.
4. Design Pressure and Temperature Rating: Comply with applicable requirements in ASME Boiler and Pressure Vessel Code.
5. End Tube Sheets: Carbon-steel plates continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.
6. Intermediate Tube Sheets: Carbon-steel plates installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.
7. Generator/Condenser Shell Pressure Relief Device: Manufacturers standard rupture disk complying with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.

D. Absorber
1. Nozzle or Dispersion Trays: Designed to evenly distribute absorbent solution over tubes. Constructed of brass, stainless steel, or another material that will not corrode.
2. Tubes:

a. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end and without damage to tube sheets and other tubes.
b. Material: Copper **OR** Copper-nickel alloy **OR** Stainless steel **OR** Titanium, **as directed**.
c. Minimum Wall Thickness: Manufacturer's choice **OR** 0.025 inch (0.6 mm) **OR** 0.028 inch (0.7 mm) **OR** 0.035 inch (0.9 mm), **as directed**.
d. External Finish: Manufacturer's standard.
e. Internal Finish: Enhanced **OR** Smooth, **as directed**.

3. Water Boxes:
   a. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
   b. Standard **OR** Marine, **as directed**, type for water box with piping connections.
      1) Water boxes and marine water-box covers, **as directed**, shall have lifting lugs or eyebolts.
      2) Hinged **OR** davited, **as directed**, water boxes.
         OR
         Hinged **OR** davited, **as directed**, marine water-box covers.

      OR
      Standard type for water box without piping connections.
      1) Water boxes shall have lifting lugs or eyebolts.
      2) Hinged **OR** davited, **as directed**, water boxes.
         OR
         Hinged **OR** davited, **as directed**, marine water-box covers.
   c. Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.
   d. Thermistor or RTD temperature sensor factory installed in each nozzle.
   e. Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm) **OR** 3/4- or 1-inch (19- or 25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.
4. Additional Corrosion Protection:
   a. Electrolytic corrosion-inhibitor anode.
   b. Coat wetted surfaces with a corrosion-resistant finish.
      OR
      Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.
5. Absorber/Condenser Crossover Piping: Factory furnished **OR** installed, **as directed**, piping connecting fluid connection of absorber discharge to condenser inlet.

E. Evaporator
1. Nozzle or Dispersion Trays: Designed to evenly distribute refrigerant over tubes. Constructed of brass, stainless steel, or another material that will not corrode.
2. Refrigerant Holding Pan: Steel **OR** Stainless steel, **as directed**.
3. Tubes:
   a. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end and without damage to tube sheets and other tubes.
   b. Material: Copper **OR** Copper-nickel alloy **OR** Stainless steel **OR** Titanium, **as directed**.
   c. Minimum Wall Thickness: Manufacturer's choice **OR** 0.025 inch (0.6 mm) **OR** 0.028 inch (0.7 mm) **OR** 0.035 inch (0.9 mm), **as directed**.
   d. External Finish: Manufacturer's standard.
   e. Internal Finish: Enhanced **OR** Smooth, **as directed**.
4. Water Boxes:
   a. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
   b. Standard **OR** Marine, **as directed**, type for water box with piping connections.

1) Water boxes and marine water-box covers, **as directed**, shall have lifting lugs or eyebolts.
2) Hinged **OR** davited, **as directed**, water boxes.
OR
Hinged **OR** davited, **as directed**, marine water-box covers.

OR
Standard type for water box without piping connections.
1) Water boxes shall have lifting lugs or eyebolts.
2) Hinged **OR** davited, **as directed**, water boxes.
OR
Hinged **OR** davited, **as directed**, marine water-box covers.

c. Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.
d. Thermistor or RTD temperature sensor factory installed in each nozzle.
e. Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm) **OR** 3/4- or 1-inch (19- or 25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.

F. Condenser
1. Refrigerant Holding Pan: Steel **OR** Stainless steel, **as directed**.
2. Tubes:
a. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end and without damage to tube sheets and other tubes.
b. Material: Copper **OR** Copper-nickel alloy **OR** Stainless steel **OR** Titanium, **as directed**.
c. Minimum Wall Thickness: Manufacturer's choice **OR** 0.025 inch (0.6 mm) **OR** 0.028 inch (0.7 mm) **OR** 0.035 inch (0.9 mm), **as directed**.
d. External Finish: Manufacturer's standard.
e. Internal Finish: Enhanced **OR** Smooth, **as directed**.
3. Water Boxes:
a. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
b. Standard **OR** Marine, **as directed**, type for water box with piping connections.
1) Water boxes and marine water-box covers, **as directed**, shall have lifting lugs or eyebolts.
2) Hinged **OR** davited, **as directed**, water boxes.
OR
Hinged **OR** davited, **as directed**, marine water-box covers.

OR
Standard type for water box without piping connections.
1) Water boxes shall have lifting lugs or eyebolts.
2) Hinged **OR** davited, **as directed**, water boxes.
OR
Hinged **OR** davited, **as directed**, marine water-box covers.

c. Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.
d. Thermistor or RTD temperature sensor factory installed in each nozzle.
e. Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.
4. Additional Corrosion Protection:
a. Electrolytic corrosion-inhibitor anode.
b. Coat wetted surfaces with a corrosion-resistant finish.
OR
Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

G. Generator For Single-Effect Chillers
1. Tubes:
   a. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end and without damage to tube sheets and other tubes.
   b. Material: 90/10 copper-nickel alloy **OR** Stainless steel **OR** Titanium**,** as directed.
   c. Minimum Wall Thickness: Manufacturer's choice **OR** 0.035 inch (0.9 mm), **as directed**.
   d. External Finish: Manufacturer's standard.
   e. Internal Finish: Smooth **OR** Enhanced, **as directed**
2. Water Boxes:
   a. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
   b. Standard type water box.
   c. Water boxes shall have lifting lugs or eyebolts.
   d. Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.
   e. Thermistor or RTD temperature sensor factory installed in each nozzle.
   f. Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.
3. Additional Corrosion Protection:
   a. Electrolytic corrosion-inhibitor anode.
   b. Coat wetted surfaces with a corrosion-resistant finish.
      OR
      Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

H. First-Stage Generator For Double-Effect Chillers
1. Tubes:
   a. Replaceable, straight, or U tubes expanded into tube sheets.
   b. Material: Manufacturer's standard **OR** 70/30 copper-nickel alloy **OR** Type 409 stainless steel **OR** Titanium, **as directed**.
   c. Minimum Wall Thickness: Manufacturer's choice **OR** 0.028 inch (0.7 mm) **OR** 0.035 inch (0.9 mm), **as directed**.
   d. External Finish: Manufacturer's standard.
   e. Internal Finish: Smooth **OR** Enhanced, **as directed**.
2. Water Boxes:
   a. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
   b. Standard type water box.
   c. Water boxes shall have lifting lugs or eyebolts.
   d. Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.
   e. Thermistor or RTD temperature sensor factory installed in each nozzle.
   f. Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.
3. Additional Corrosion Protection:
   a. Electrolytic corrosion-inhibitor anode.
   b. Coat wetted surfaces with a corrosion-resistant finish.
      OR
      Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

I. Second-Stage Generator For Double-Effect Chillers
1. Tubes:

a. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end and without damage to tube sheets and other tubes.
b. Material: Copper **OR** Copper-nickel alloy **OR** Stainless steel **OR** Titanium, **as directed**.
c. Minimum Wall Thickness: Manufacturer's choice **OR** 0.025 inch (0.6 mm) **OR** 0.028 inch (0.7 mm) **OR** 0.035 inch (0.9 mm), **as directed**.
d. External Finish: Manufacturer's standard.
e. Internal Finish: Smooth **OR** Enhanced, **as directed**.

2. Water Boxes:
   a. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
   b. Standard type water box.
   c. Water boxes shall have lifting lugs or eyebolts.
   d. Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.
   e. Thermistor or RTD temperature sensor factory installed in each nozzle.
   f. Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.
3. Additional Corrosion Protection:
   a. Electrolytic corrosion-inhibitor anode.
   b. Coat wetted surfaces with a corrosion-resistant finish.
      OR
      Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

J. Solution Heat Exchanger
1. Description: Shell-and-tube or brazed-plate heat exchanger; integral part of chiller to increase cycle efficiency by preheating the weak solution on its way to the generator while precooling the strong solution returning from the generator.

K. Steam Condensate Drain Cooler
1. Description: Shell-and-tube heat exchanger constructed of carbon-steel shell and copper-nickel-alloy or stainless-steel tubes.

L. Factory-Applied Insulation
1. Factory-Applied Insulation on Cold Surfaces:
   a. Closed-cell, flexible elastomeric thermal insulation complying with ASTM C 534, Type I for tube and Type II for sheet materials.
      1) Thickness: 3/4 inch (19 mm) **OR** 1-1/2 inches (38 mm), **as directed**.
   b. Adhesive: As recommended by insulation manufacturer.
   c. Factory apply insulation over all cold surfaces of chiller capable of forming condensation. Components shall include, but not be limited to, evaporator shell and end tube sheets; evaporator water boxes including nozzles; refrigerant pump; cold surfaces of motor; and cold piping.
      1) Apply adhesive to 100 percent of insulation contact surface.
      2) Before insulating steel surfaces, prepare surfaces for paint, and prime and paint as indicated for other painted components. Do not insulate unpainted steel surfaces.
      3) Seal seams and joints to provide a vapor barrier.
      4) After adhesive has fully cured, paint exposed surfaces of insulation to match other painted parts.
2. Factory-Applied Insulation on Hot Surfaces:
   a. Mineral-fiber board, pipe or tank insulation complying with one of following:
      1) ASTM C 547, Type I or Type II, Grade A.
      2) ASTM C 612, Type IB.
      3) ASTM C 1393, Type II or Type IIIA, Category 2.
      4) Thickness: 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**.

b. Adhesive: As recommended by insulation manufacturer.
c. Factory apply materials over all hot surfaces to provide smooth, straight, and even surfaces; free of voids.
   1) Apply adhesive to insulation contact surface as recommended by insulation manufacturer.
   2) Install insulation anchor pins and washers if required by insulation manufacturer to secure insulation to surfaces to be insulated.
   3) Completely encapsulate insulation with metal jacket, leaving no exposed insulation. Provide removable jacket on components requiring access for service and inspection.
   4) Paint exposed surfaces of metal jacket to match other painted parts unless jacket material is aluminum or stainless steel.

M. Electrical
1. Factory installed and wired, and functionally tested at factory before shipment.
2. Single-point, field-power connection to fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**. Minimum withstand rating shall be as required by electrical power distribution system, but not less than 42,000 **OR** 65,000, **as directed**, A.
   a. Branch power circuit to each motor, dedicated electrical load, and controls with disconnect switch or circuit breaker, **as directed**.
      1) NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
      2) NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit-trip set point.
   b. NEMA ICS 2, Class A, full-voltage, nonreversing motor controller, hand-off-auto switch, and overcurrent protection for each motor.
   c. Control-circuit transformer with primary and secondary side fuses.
3. Terminal blocks with numbered and color-coded, **as directed**, wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
4. Wiring Outside of Enclosures: Factory installed in metal raceway except make terminal connections with not more than a 24-inch (610-mm) length of liquidtight **OR** flexible metallic, **as directed**, conduit.

N. Controls
1. Control: Standalone and microprocessor based, with all memory stored in nonvolatile memory so that reprogramming is not required on loss of electrical power.
2. Enclosure: Unit mounted, NEMA 250, Type 1 **OR** Type 4 **OR** Type 4x, **as directed**, hinged or lockable.
3. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. In either imperial or metric units selectable through the interface, display the following information:
   a. Date and time.
   b. Operating or alarm status.
   c. Operating hours.
   d. Outdoor-air temperature if required for chilled-water reset.
   e. Temperature and pressure of operating set points.
   f. Entering and leaving temperatures of chilled and condenser water.
   g. Refrigerant temperature.
   h. Solution concentration and temperature.
   i. Indication of solution and purge-pump operation.
   j. Generator shell pressure.
   k. Number of starts.
   l. Number of purge cycles.
   m. Hot-water valve actuator potentiometer position (percentage).
   n. Entering and leaving hot-water temperatures.

o. Steam demand limit.
p. Inlet steam pressure and temperature.
q. Steam valve actuator potentiometer position (percentage).
r. First-stage generator pressure and temperature.

4. Control Functions:
   a. Manual or automatic startup and shutdown time schedule.
   b. Automatic cycle to prevent crystallization.
   c. Entering and leaving chilled-water temperatures and control set points. Chilled-water temperature shall be reset based on return-water **OR** outdoor-air **OR** space, **as directed**, temperature.
   d. Condenser-fluid temperature.
   e. Cooling provided and heating energy used within programmable time periods, minimum monthly.
5. Capacity Control: Automatically controls input flow rate of heat source to maintain chilled-water temperature set point for cooling loads ranging from 10 to 100 percent.
6. Control Valve Package: Factory-furnished, for field installation, **OR** Factory-installed, **as directed**, control valve package suitable for energy source indicated.
   a. Body: Cast-iron, carbon-steel, or stainless-steel body with flanged connections.
   b. Type: Manufacturer's choice **OR** V-notch ball **OR** Butterfly **OR** Globe style with cage-guide plug, **as directed**, constructed of stainless steel.
   c. Rating: Pressure and temperature rating to match heat exchanger.
   d. Shutoff: Capable of bubble-tight shutoff against maximum system pressure.
   e. Size: Determined by chiller manufacturer.
   f. Modulation: Two-way **OR** Three-way, **as directed**.
   g. Turndown: As required to achieve stable control through the indicated operating range.
   h. Actuator: Electric powered from chiller control panel and installed on valve.
7. Safety Shutdowns:
   a. Crystallization.
   b. Low refrigerant temperature.
   c. Loss of chilled- or condenser-water flow.
   d. Low leaving chilled-water temperature, 2 deg F (1 deg C) below set point, **as directed**.
   e. First-stage generator low-solution level.
   f. First-stage generator high temperature or pressure.
   g. Power failure.
   h. Solution pump overloads.
   i. External auxiliary safety shutdown.
   j. High solution concentration.
   k. Incomplete dilution cycle.
   l. High entering-water temperature.
   m. High inlet steam pressure and temperature.
8. Warning Conditions: Control panel shall close warning contacts and generate a message when one of the following operating conditions is detected:
   a. Low refrigerant temperature.
   b. High generator temperature or pressure.
   c. High entering generator-water temperature (single-stage generator only).
   d. High or low entering condenser-water temperature.
   e. Solution temperature sensor failure.
   f. Low chilled-water flow.
9. Trending: Capability to trend analog data of up to five parameters simultaneously over an adjustable period and frequency of polling.
10. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: view only; view and operate; and view, operate, and service.
11. Control Authority: At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.

12. Communication Port: RS-232 port, USB 2.0 port, or equivalent connection capable of connecting a printer and a notebook computer, **as directed**.
13. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display chiller status and alarms.
    a. Hardwired Points:
        1) Monitoring: On-off status, common trouble alarm.
        2) Control: On-off operation, chilled-water, discharge temperature set-point adjustment **OR** generator heat source capacity limiting, **as directed**.
    b. ASHRAE 135 (BACnet) **OR** LonTalk **OR** Modbus **OR** Industry-accepted, open-protocol, **as directed**, communication interface with the BAS shall enable the BAS operator to remotely control and monitor the chiller from an operator workstation. Control features and monitoring points displayed locally at chiller control panel shall be available through the BAS.

O. Finish
1. Paint chiller, using manufacturer's standard procedures, except comply with the following minimum requirements:
    a. Provide at least one coat of primer with a total dry film thickness of at least 2 mils (0.05 mm).
    b. Provide at least two coats of alkyd-modified, vinyl enamel **OR** epoxy **OR** polyurethane, **as directed**, finish with a total dry film thickness of at least 4 mils (0.10 mm).
    c. Paint surfaces that are to be insulated before applying the insulation.
    d. Paint installed insulation to match adjacent uninsulated surfaces.
    e. Color of finish coat to be manufacturer's standard **OR** custom color selected by the Owner.
2. Provide the Owner with quart container of paint used in application of topcoat to use in touchup applications after Project Closeout.

P. Accessories
1. Sight Glasses: Equip unit with sight glasses for visual inspection of absorbent solution and refrigerant levels. Provide at least one sight glass in absorber and evaporator sections.
2. Flow Switches:
    a. Chiller manufacturer shall furnish a switch for each condenser **OR** evaporator and condenser, **as directed**, and verify field-mounting location before installation.
    b. Paddle Flow Switches:
        1) Vane operated to actuate a double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the BAS.
        2) Contacts: Platinum alloy, silver alloy, or gold-plated switch contacts with a rating of 10 A at 120-V ac.
        3) Pressure rating equal to pressure rating of heat exchanger.
        4) Construct body and wetted parts of Type 316 stainless steel.
        5) House switch in a NEMA 250, Type 4 enclosure constructed of die-cast aluminum.
        6) Vane length to suit installation.

        OR

        Pressure Differential Switches:
        1) Construction: Wetted parts of body and trim constructed of Type 316 stainless steel.
        2) Performance: Switch shall withstand, without damage, the full-pressure rating of the heat exchanger applied to either port and exhibit zero set-point shift due to variation in working pressure.
        3) Set Point: Screw type, field adjustable.
        4) Electrical Connections: Internally mounted screw-type terminal blocks.
        5) Switch Enclosure: NEMA 250, Type 4.
        6) Switch Action: Double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the BAS.
3. Vibration Isolation:
    a. Chiller manufacturer shall furnish neoprene-pad vibration isolation for each chiller.

1) Two layers of 0.375-inch- (10-mm-) thick, ribbed- or waffle-pattern neoprene pads separated by a 16-gage, stainless-steel plate.
2) Fabricate pads from 40- to 50-durometer neoprene.
3) Provide stainless-steel square bearing plate to load the pad uniformly between 20 and 40 psig (138 and 276 kPa) with a 0.12- to 0.16-inch (3- to 4-mm) deflection.

4. Lithium Bromide Filter, **as directed**:
   a. Factory install a filter, isolation valves, and associated piping.
   b. Filter shall consist of a stainless-steel body, with removable and cleanable 150-micron, stainless-steel element.
   c. Isolation valves shall provide isolation for filter servicing without disturbing operation of chiller.

Q. Heat-Exchanger, Brush-Cleaning System
1. Furnish for field installation a brush-cleaning system on each chiller condenser, **as directed**, for tube cleaning and improved heat transfer.
2. System shall maintain tube fouling at or below design conditions without interrupting normal equipment operation.
3. System shall consist of a brush inserted in each tube and a catch basket attached to each end of the tube. A four-way valve shall operate to reverse the direction of water flow to push the brush through the tube while removing tube deposits. Four-way reversing valve's actuator shall be controlled by a preset time cycle that provides regular tube brushing during equipment operation. Frequency of the brushing cycle shall be set up to match Project requirements.
4. Components:
   a. Brush: Each brush shall have nylon bristles, titanium wires, and polypropylene tips. Brush interference fit with the ID of the tube shall not exceed 0.025 inch (0.6 mm).
   b. Basket: Single-piece polypropylene basket with neck OD to press fit inner diameter of tube. Design shall provide for insertion of eddy current probe or removal of brushes without removing baskets from the valve.
   c. Four-Way Valve:
      1) Construct valve body of carbon steel with internal sealing parts of hard rubber and Type 304 stainless steel.
      2) Configure valve with parallel flow connections to minimize field installation piping.
      3) Construct to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, at a system working pressure equal to condenser.
      4) Pipe connections shall be flanged.
      5) Valve manufacturer to test and certify a maximum leakage rate of less than 0.05 percent of the design flow rate at operation conditions of maximum differential pressure.
      6) Hydrostatically test to 1.5 times the design working pressure.
      7) Design the valve to cause no more than 0.5-psig (3-kPa) pressure drop at design flow conditions.
      8) Provide valve with valve-mounted indicating/warning light, which shall light before the valve begins rotation.
      9) Valve Actuator: Mount electric actuator to operate valve.
         OR
         Valve Actuator: Mount pneumatic piston-type actuator to operate valve. Actuator shall be suitable for operation using field-supplied air pressure.
      10) Position Switches: Factory mount microswitches on the valve to indicate the complete turn of valve in both normal and reverse flow.
   d. Control Panel: Factory or field mount a control panel on chiller. Control panel shall include the following features:
      1) NEMA 250, Type 1 **OR** Type 4 **OR** Type 4x **OR** Type 12, **as directed**, enclosure.
      2) Timer to automatically initiate the cleaning cycle over a 24-hour period.
      3) Manual override of preset cleaning cycle.
      4) Visual indication of "Power On," "Diverter Position," "Normal Flow," "Reverse Flow," and "Valve Malfunction" indicating a slow turn or incomplete valve turn.

5) For pneumatic actuators, mount four-way solenoid valve for actuator operation in the control panel.
6) Flow-switch bypass.
7) Unloading signal to chiller.

R. Source Quality Control
1. Perform functional tests **OR** run tests, **as directed**, of chillers before shipping.
2. Factory test and inspect absorber, generator, evaporator and condenser according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1. Pressure test tube-side of heat exchangers, including water boxes, to 1.5 times the rated pressure. Vacuum and pressure test shells for leaks.
3. Rate sound power level according to ARI 575.
4. Factory performance test chillers, before shipping, according to ARI 560, **as directed**.
   a. Test the following conditions:
      1) Design conditions indicated.
      2) Reduction in capacity from design to minimum load in steps of 10 **OR** 25 **OR** 33, **as directed**, with condenser fluid at design conditions.
      OR
      Reduction in capacity from design to minimum load in steps of 10 **OR** 25 **OR** 33, **as directed**, with varying entering condenser-fluid temperature from design to minimum conditions in 5 deg F (3 deg C) increments.
      OR
      At one **OR** two **OR** three **OR** four **OR** five **OR** 10, **as directed**, point(s) of varying part-load performance to be selected by the Owner at time of test.
5. Factory sound test chillers, before shipping, according to ARI 575, **as directed**.
   a. Test the following conditions:
      1) Design conditions indicated.
      2) Chiller operating at calculated worst-case sound condition.
      3) At one **OR** two **OR** three **OR** four **OR** five, **as directed**, point(s) of varying part-load performance to be selected by the Owner at time of test.
6. Allow the Owner access to place where chillers are being tested. Notify the Owner 14 days in advance of testing.
7. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

1.3 EXECUTION

A. Chiller Installation
1. Install chillers on support structure indicated.
2. Equipment Mounting: Install chiller on concrete bases using elastomeric pads. Comply with requirements for concrete bases specified in Division 03 Section "Cast-in-place Concrete". Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   a. Minimum Deflection: 1/4 inch (6 mm) **OR** 1/2 inch (13 mm), **as directed**.
   b. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   c. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   d. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   e. Install anchor bolts to elevations required for proper attachment to supported equipment.
3. Equipment Mounting: Install chiller using elastomeric pads. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".

a. Minimum Deflection: 1/4 inch (6 mm) **OR** 1/2 inch (13 mm), **as directed**.

4. Equipment Mounting: Install chiller on concrete bases. Comply with requirements for concrete bases specified in Division 03 Section "Cast-in-place Concrete".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   d. Install anchor bolts to elevations required for proper attachment to supported equipment.
5. Install chillers with seismic-restraint device. Comply with requirements for seismic-restraint devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
6. Install seismic restraints on piping. Comply with requirements for seismic-restraint devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
7. Maintain manufacturer's recommended clearances for service and maintenance.
8. Charge chiller with absorbent and refrigerant if not factory charged.
9. Install separate devices furnished by manufacturer and not factory installed.
10. Insulate hot and cold chiller surfaces that are recommended by chiller manufacturer to be insulated, and are not factory insulated. Comply with requirements in Division 23 Section "Hvac Insulation".

B. Heat-Exchanger, Brush-Cleaning System Installation
1. Install brush-cleaning system control panel adjacent to chiller control panel.
2. Arrange piping to provide service access to four-way valve assembly without affecting access to chiller. Secure valve to prevent lateral movement and vibration during operation.
3. Provide field electric power, as required, to each system control panel and electric actuated valve.
4. Provide pneumatic piping with pressure regulator and isolation valve to each pneumatic supply connection. Coordinate field source of air with manufacturer to ensure that requirements are satisfied for proper valve operation.
5. Interconnect brush-cleaning system controls with chiller controls. Coordinate requirements to ensure safe, trouble-free operation.
6. Functionally test the entire brush-cleaning system, including the valve, actuator, position indicator, and control panel, with chiller in operation.

C. Connections
1. Comply with requirements in Division 23 Section "Hydronic Piping" for hydronic piping. Drawings indicate general arrangement of piping, fittings, and specialties.
2. Comply with requirements in Division 23 Section "Steam And Condensate Heating Piping" for steam and condensate piping. Drawings indicate general arrangement of piping, fittings, and specialties.
3. Install piping adjacent to chiller to allow service and maintenance.
4. Generator Steam Piping Connections:
   a. Connect steam piping with trapped drip leg, gate valve, strainer, control valve, and pressure gage. Install pressure reducing valve and safety relief valve upstream from steam-control valve to protect control valve from excessive steam pressure. Make connections to chiller with a flange **OR** union, **as directed**.
   b. Connect steam condensate piping with vacuum breaker, trapped drip leg, gate valve, strainer, float and thermostatic trap(s), condensate cooler, **as directed**, condensate receiver, **as directed**, condensate receiver and pump, **as directed**, and check valve. Make connections to chiller with a flange **OR** union, **as directed**.
5. Generator Hot-Water Connections: Connect to generator inlet with shutoff valve, strainer, **as directed**, flexible connector, **as directed**, control valve, thermometer, and plugged tee with shutoff valve and pressure gage. Connect to generator outlet with shutoff valve, check valve, balancing valve, flexible connector, **as directed**, flow switch, thermometer, plugged tee with

shutoff valve and pressure gage, flow meter, **as directed**, and drain connection with valve. Make connections to chiller with a flange **OR** mechanical coupling, **as directed**.

6. Evaporator-Fluid Connections: Connect to evaporator inlet with shutoff valve, strainer, **as directed**, flexible connector, **as directed**, thermometer, and plugged tee with shutoff valve and pressure gage. Connect to evaporator outlet with shutoff valve, balancing valve, flexible connector, **as directed**, flow switch, thermometer, plugged tee with shutoff valve and pressure gage, flow meter, **as directed**, and drain connection with valve. Make connections to chiller with a flange **OR** mechanical coupling, **as directed**.
7. Absorber/Condenser-Fluid Connections: Connect to inlet with shutoff valve, strainer, **as directed**, flexible connector, **as directed**, thermometer, and plugged tee with shutoff valve and pressure gage. Connect to outlet with shutoff valve, balancing valve, flexible connector, **as directed**, flow switch, thermometer, plugged tee with shutoff valve and pressure gage, flow meter, **as directed**, and drain connection with valve. Make connections to chiller with a flange **OR** mechanical coupling, **as directed**.
   a. If not factory furnished or installed, provide pipe connecting fluid connection of absorber discharge and condenser inlet.
8. Refrigerant Pressure Relief Device Connections: Extend vent piping **OR** separate vent piping for each chiller, **as directed**, to the outdoors without valves or restrictions. Comply with ASHRAE 15. Connect to chiller pressure relief device with flexible connector and dirt leg with drain valve.
9. Extend purge vent piping **OR** separate purge vent piping for each chiller, **as directed**, to the outdoors. Comply with ASHRAE 15.
10. Connect each chiller drain connection with a union and drain pipe, and extend pipe, full size of connection, to floor drain. Provide a shutoff valve at each connection.

D. Startup Service
1. Engage a factory-authorized service representative to perform startup service.
   a. Complete installation and startup checks according to manufacturer's written instructions.
   b. Operate chiller for run-in period.
   c. Verify that absorbent and refrigerant charge is sufficient and chiller has been leak tested.
   d. Verify that pumps are installed and functional.
   e. Verify that thermometers and gages are installed.
   f. Operate chiller for run-in period.
   g. Verify that refrigerant pressure relief device is vented outside.
   h. Verify proper motor rotation.
   i. Verify static deflection of vibration isolators including deflection during chiller startup and shutdown.
   j. Verify and record performance of fluid flow and low-temperature interlocks for evaporator and condenser.
   k. Verify and record performance of chiller protection devices.
   l. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.
2. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assembly, installation, and connection.
3. Prepare test and inspection startup reports.

E. Demonstration
1. Engage a factory-authorized service representative to train the Owner's maintenance personnel to adjust, operate, and maintain chillers.

END OF SECTION 23 64 13 16

SECTION 23 64 13 16a - DIRECT-FIRED ABSORPTION WATER CHILLERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for direct-fired absorption water chillers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Packaged, water-cooled, direct-fired absorption chillers.
b. Heat-exchanger, brush-cleaning system.

C. Definitions
1. BAS: Building automation system.
2. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input using consistent units for any given set of rating conditions.
3. IPLV: Integrated part-load value. A single-number, part-load efficiency figure of merit calculated per the method defined by ARI 560 and referenced to ARI standard rating conditions.
4. NPLV: Nonstandard part-load value. A single-number, part-load efficiency figure of merit calculated per the method defined by ARI 560 and intended for operating conditions other than the ARI standard rating conditions.

D. Performance Requirements
1. Seismic Performance: Direct-fired absorption chillers shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
2. Condenser-Fluid Temperature Performance:
a. Startup Condenser-Fluid Temperature: Chiller shall be capable of starting with an entering condenser-fluid temperature of 60 deg F (16 deg C) and providing stable operation until the system temperature is elevated to the minimum operating entering condenser-fluid temperature.
b. Minimum Operating Condenser-Fluid Temperature: Chiller shall be capable of continuous operation over the entire capacity range indicated with an entering condenser-fluid temperature of 70 deg F (21 deg C).
c. Make factory modifications to standard chiller design if necessary to comply with performance indicated.
3. Site Altitude: Chiller shall be suitable for altitude at which it is installed without affecting performance indicated. Make adjustments to affected chiller components to account for site altitude.
4. Performance Tolerance: Comply with the following in lieu of ARI 560:
a. Allowable Capacity Tolerance: Zero percent.
b. Allowable IPLV/NPLV Performance Tolerance: Zero percent.

E. Submittals
1. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, furnished specialties and accessories, and the following:
a. Performance at ARI standard conditions and at conditions indicated.
b. Performance at ARI standard unloading conditions.
c. Minimum evaporator flow rate.

d. Absorbent capacity of chiller.
e. Refrigerant capacity of chiller.
f. Fluid capacity of evaporator and condenser.
g. Fluid capacity of generator.
h. Characteristics of safety relief devices.
i. Minimum entering condenser-fluid temperature.
j. Performance at varying capacities with constant design condenser-fluid temperature. Repeat performance at varying capacities for different condenser-fluid temperatures from design to minimum in 5 deg F (3 deg C) increments.
k. If equipped, fluid capacity of dedicated hot-water heater exchanger.
l. Combustion-air flow.
m. Exhaust gas airflow.
n. Exhaust gas minimum and maximum operating temperature.

2. LEED Submittals:
   a. Product Data for Prerequisite EA 2: Documentation indicating that units comply with applicable requirements in ASHRAE/IESNA 90.1.
   b. Product Data for Prerequisite EA 3: Documentation indicating that refrigerants comply.
   c. Product Data for Credit EA 4: Documentation indicating that equipment and refrigerants comply.
3. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
   a. Detail equipment assemblies and indicate dimensions, weights, load distribution, required clearances, method of field assembly, components, and location and size of each field connection.
   b. Wiring Diagrams: For power, signal, and control wiring.
   c. Insulated Surface Diagrams: Indicating cold and hot surfaces requiring field-applied insulation with area tabulated for each.
4. Coordination Drawings: Floor plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
   a. Structural supports.
   b. Piping roughing-in requirements.
   c. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
   d. Access requirements, including working clearances for mechanical controls and electrical equipment, and clearances for tube pull and service.
5. Certificates: For certification required in "Quality Assurance" Article.
6. Seismic Qualification Certificates: For chillers, accessories, and components, from manufacturer.
   a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
   c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
7. Source quality-control reports.
8. Startup service reports.
9. Operation and Maintenance Data: For each chiller to include in emergency, operation, and maintenance manuals.
10. Warranty: Sample of special warranty.

F. Quality Assurance
   1. ARI Rating: Rate chiller performance according to requirements in ARI 560.
   2. ASHRAE Compliance:
      a. ASHRAE 15 for safety code for mechanical refrigeration.
      b. ASHRAE/IESNA 90.1.
   3. ASME Compliance: Fabricate and label chiller pressure vessels to comply with applicable portions of ASME Boiler and Pressure Vessel Code.
   4. Comply with NFPA 70.

5. Comply with requirements of UL and UL Canada, and include label by a qualified testing agency showing compliance.
   a. UL Compliance: UL 726, "Oil-Fired Boiler Assemblies" **OR** UL 726, "Oil-Fired Boiler Assemblies"; and UL 795, "Commercial-Industrial Gas Heating Equipment" **OR** UL 795, "Commercial-Industrial Gas Heating Equipment", **as directed**.

G. Delivery, Storage, And Handling
1. Ship chillers factory charged with nitrogen.
2. Ship absorbent and refrigerant in chillers or in containers separate from chillers.
   OR
   Ship absorbent and refrigerant in containers separate from chillers.
3. Package chiller for export shipping in totally enclosed bagging **OR** crate **OR** crate with bagging, **as directed**.

H. Coordination
1. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.
2. Coordinate sizes, locations, and anchoring attachments of structural-steel support structures.

I. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of chillers that fail in materials or workmanship within specified warranty period.
   a. Extended warranties include, but are not limited to, the following:
      1) Complete chiller.
         OR
         Pumps and motors **OR** Purge unit **OR** Burner assembly, **as directed**.
         OR
         Absorbent **OR** Absorbent and refrigerant, **as directed**, only.
      2) Parts only **OR** only and labor, **as directed**.
      3) Loss of absorbent and refrigerant for any reason.
   b. Warranty Period: Two **OR** Three **OR** Four **OR** Five, **as directed**, years from date of Final Completion.

1.2 PRODUCTS

A. Manufactured Unit
1. Description: Factory-assembled and -tested, hermetic-design chiller complete with absorber, evaporator, condenser, generator, solution heat exchanger, controls, absorbent solution pump with motor, refrigerant pump with motor, purge unit with motor, burner assembly, motor controllers, rupture disk, interconnecting unit piping and wiring, indicated accessories, and mounting frame.
   a. Disassemble chiller into major assemblies, as required by the installation, after factory testing and before packaging for shipment.
2. Absorbent and Refrigerant:
   a. Absorbent: Lithium bromide solution with corrosion inhibitor.
   b. Refrigerant: Deionized or distilled, **as directed**, water.
   c. Performance Enhancer: Heat and mass transfer enhancer to improve performance.
3. Seismic Fabrication Requirements: Fabricate mounting base and attachment to chiller, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" when mounting base is anchored to building structure.

B. Pumps

1. Hermetically sealed, self-lubricating, and fitted with self-adjusting, spring-loaded, wear-compensating, tapered carbon bearings.
2. Pump motor assembly shall be designed to operate for not less than 50,000 hours between inspections.
3. Pump motors shall be cooled and bearings lubricated, either by fluid being pumped or by a filtered supply of liquid refrigerant.
4. Pump suction and discharge shall be equipped with isolation valves.
5. Absorbent solution and refrigerant shall have separate and dedicated pumps.
   a. Absorbent solution and refrigerant flow-control method shall be manufacturer's choice to comply with operating requirements indicated.
6. Purge System: Unit mounted and factory wired, equipped with controls and a pump to automatically remove noncondensable vapors.
   a. Purge Pump Motor: Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
      1) Enclosure: Open dripproof **OR** Totally enclosed, **as directed**.

C. Heat-Exchanger Shells
1. Configuration: Two shells; one shell consists of the absorber/evaporator, low-stage generator/condenser and the other shell consists of the high-stage generator. Where indicated, equip chiller with a dedicated hot-water heat exchanger.
2. Construction: Fabricated from continuously welded carbon-steel sheet or plate, or from seamless pipe.
3. Design Pressure and Temperature Rating: Comply with applicable requirements in ASME Boiler and Pressure Vessel Code.
4. End Tube Sheets: Carbon-steel plates continuously welded to each end of shell; drilled and reamed to accommodate tubes, with positive seal between fluid in tubes and refrigerant in shell.
5. Intermediate Tube Sheets: Carbon-steel plates installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid tube contact resulting in abrasion and wear.
6. Generator/Condenser Shell Pressure Relief Device: Manufacturer's standard rupture disk complying with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code.

D. Absorber
1. Nozzle or Dispersion Trays: Designed to evenly distribute absorbent solution over tubes; constructed of brass, stainless steel, or another material that will not corrode.
2. Tubes:
   a. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end without damage to tube sheets and other tubes.
   b. Material: Copper **OR** Copper-nickel alloy, **as directed**.
   c. Minimum Wall Thickness: Manufacturer's choice **OR** 0.025 inch (0.6 mm) **OR** 0.028 inch (0.7 mm) **OR** 0.035 inch (0.9 mm), **as directed**.
   d. External Finish: Manufacturer's standard.
   e. Internal Finish: Enhanced **OR** Smooth, **as directed**.
3. Water Boxes:
   a. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
   b. Standard **OR** Marine-type, **as directed**, water box with piping connections.
      1) Water boxes and marine-type water-box covers, **as directed**, shall have lifting lugs or eyebolts.
      2) Hinged **OR** Davited, **as directed**, water boxes.
         OR
         Hinged **OR** Davited, **as directed**, marine-type water-box covers.
   c. Standard water box without piping connections.

1) Water boxes shall have lifting lugs or eyebolts.
2) Hinged **OR** Davited, **as directed**, water boxes.

d. Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.

e. Thermistor or RTD temperature sensor factory installed in each nozzle.

f. Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.

4. Additional Corrosion Protection:

a. Electrolytic corrosion-inhibitor anode.

b. Coat wetted surfaces with a corrosion-resistant finish.

OR

Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

5. Absorber/Condenser Crossover Piping: Factory-furnished and -installed piping connecting fluid connection of absorber discharge to condenser inlet.

E. Evaporator

1. Nozzle or Dispersion Trays: Designed to evenly distribute refrigerant over tubes; constructed of brass, stainless steel, or another material that will not corrode.

2. Refrigerant Holding Pan: Steel or stainless steel.

3. Tubes:

a. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end without damage to tube sheets and other tubes.

b. Material: Copper **OR** Copper-nickel alloy, **as directed**.

c. Minimum Wall Thickness: Manufacturer's choice **OR** 0.025 inch (0.6 mm) **OR** 0.028 inch (0.7 mm) **OR** 0.035 inch (0.9 mm), **as directed**.

d. External Finish: Manufacturer's standard.

e. Internal Finish: Enhanced **OR** Smooth, **as directed**.

4. Water Boxes:

a. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.

b. Standard **OR** Marine-type, **as directed**, water box with piping connections.

1) Water boxes and marine-type water-box covers, **as directed**, shall have lifting lugs or eyebolts.
2) Hinged **OR** Davited, **as directed**, water boxes.

OR

Hinged **OR** Davited, **as directed**, marine-type water-box covers.

c. Standard water box without piping connections.

1) Water boxes shall have lifting lugs or eyebolts.
2) Hinged **OR** Davited, **as directed**, water boxes.

d. Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.

e. Thermistor or RTD temperature sensor factory installed in each nozzle.

f. Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.

F. Condenser

1. Refrigerant Holding Pan: Steel or stainless steel.

2. Tubes:

a. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end without damage to tube sheets and other tubes.

b. Material: Copper **OR** Copper-nickel alloy, **as directed**.

c. Minimum Wall Thickness: Manufacturer's choice **OR** 0.025 inch (0.6 mm) **OR** 0.028 inch (0.7 mm) **OR** 0.035 inch (0.9 mm), **as directed**.

d. External Finish: Manufacturer's standard.
e. Internal Finish: Enhanced **OR** Smooth, **as directed**.

3. Water Boxes:
   a. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
   b. Standard **OR** Marine-type, **as directed**, water box with piping connections.
      1) Water boxes and marine-type water-box covers, **as directed**, shall have lifting lugs or eyebolts.
      2) Hinged **OR** Davited, **as directed**, water boxes.
         OR
         Hinged **OR** Davited, **as directed**, marine-type water-box covers.
   c. Standard water box without piping connections.
      1) Water boxes shall have lifting lugs or eyebolts.
      2) Hinged **OR** Davited, **as directed**, water boxes.
   d. Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.
   e. Thermistor or RTD temperature sensor factory installed in each nozzle.
   f. Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.
4. Additional Corrosion Protection:
   a. Electrolytic corrosion-inhibitor anode.
   b. Coat wetted surfaces with a corrosion-resistant finish.
      OR
      Using same material as tubes, clad surfaces of end tube sheets in contact with fluid. Coat other wetted surfaces, including water boxes, with a corrosion-resistant finish.

G. First-Stage Generator
1. Tubes:
   a. Replaceable, **as directed**, straight, or U tubes expanded into tube sheets.
   b. Material: Manufacturer's standard **OR** Steel, **as directed**.
   c. Minimum Wall Thickness: Manufacturer's choice.
   d. External Finish: Manufacturer's standard.
   e. Internal Finish: Manufacturer's choice; enhanced or smooth.
2. Water Boxes:
   a. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
   b. Standard water box.
   c. Water boxes shall have lifting lugs or eyebolts.
   d. Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.
   e. Thermistor or RTD temperature sensor factory installed in each nozzle.
   f. Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.

H. Second-Stage Generator
1. Tubes:
   a. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end without damage to tube sheets and other tubes.
   b. Material: Copper **OR** Copper-nickel alloy, **as directed**.
   c. Minimum Wall Thickness: Manufacturer's choice **OR** 0.025 inch (0.6 mm) **OR** 0.028 inch (0.7 mm) **OR** 0.035 inch (0.9 mm), **as directed**.
   d. External Finish: Manufacturer's standard.
   e. Internal Finish: Manufacturer's standard.

2. Water Boxes:
   a. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
   b. Standard type.
   c. Water boxes shall have lifting lugs or eyebolts.
   d. Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.
   e. Thermistor or RTD temperature sensor factory installed in each nozzle.
   f. Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.

I. Dedicated Hot-Water Heat Exchanger
1. Tubes:
   a. Individually replaceable, straight tubes expanded into tube sheets. Replaceable from either end without damage to tube sheets and other tubes.
   b. Material: Copper **OR** Copper-nickel alloy, **as directed**.
   c. Minimum Wall Thickness: Manufacturer's choice **OR** 0.025 inch (0.6 mm) **OR** 0.028 inch (0.7 mm) **OR** 0.035 inch (0.9 mm), **as directed**.
   d. External Finish: Manufacturer's standard.
   e. Internal Finish: Manufacturer's standard.
2. Water Boxes:
   a. Carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
   b. Standard type.
   c. Water boxes shall have lifting lugs or eyebolts.
   d. Nozzle Pipe Connections: Welded, ASME B16.5, flat-face flange **OR** Welded, ASME B16.5, raised-face flange **OR** Grooved for mechanical-joint coupling **OR** Grooved with mechanical-joint coupling and flange adapter, **as directed**.
   e. Thermistor or RTD temperature sensor factory installed in each nozzle.
   f. Fit each water box with 3/4-inch (19-mm) **OR** 1-inch (25-mm), **as directed**, drain connection at low point and vent connection at high point, each with threaded plug.

J. Solution Heat Exchanger
1. Description: Shell-and-tube or brazed-plate heat exchanger, an integral part of chiller, increases cycle efficiency by preheating the weak solution on its way to the generator while precooling the strong solution returning from the generator.

K. Burner Assembly
1. Burner: Welded construction with multivane, stainless-steel, flame-retention diffuser suitable for natural gas **OR** propane **OR** fuel oil, **as directed**. Mount burner on hinged access door to permit access to combustion chamber, **as directed**.
2. Blower: Centrifugal fan integral to burner, directly driven by motor; with adjustable damper assembly and locking quadrant to set air-fuel ratio.
   a. Motors: Comply with requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
      1) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
3. Oil Supply: Control devices and modulating control sequence shall comply with requirements of ASME CSD-1 **OR** FMG **OR** IRI **OR** UL, **as directed**.
   a. Oil Pump: Two-stage, gear-type oil pump shall be capable of producing 300-psig (2070-kPa) discharge pressure and 15-in. Hg (50.7-kPa) vacuum.
   b. Oil Piping Specialties:
      1) Suction-line, manual, gate valve.
      2) Removable-mesh oil strainer.

3) 0- to 30-in. Hg (0- to 101.3-kPa) vacuum; 0- to 30-psig (0- to 207-kPa) vacuum-pressure gage.
4) 0- to 300-psig (0- to 2070-kPa) oil-nozzle pressure gage.
5) Nozzle-line, solenoid-safety-shutoff oil valve.

4. Oil Pilot: Intermittent-electric-spark **OR** Interrupted-electric-spark, **as directed**, pilot ignition with 100 percent main-valve and pilot-safety shutoff solenoid with cadmium sulfide **OR** UV scanner, **as directed**, flame-safety control.
5. Gas Train: Control devices and modulating control sequence shall comply with requirements of ASME CSD-1 **OR** FMG **OR** IRI **OR** UL, **as directed**.
6. Gas Pilot: Intermittent-electric-spark **OR** Interrupted-electric-spark, **as directed**, pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.
7. Burner assembly shall be equipped to limit nitrogen oxide emissions to 20 **OR** 30, **as directed**, ppm.

L. Electrical
1. Factory installed and wired, and functionally tested at factory before shipment.
2. Single-point, field-power connection to fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**. Minimum withstand rating shall be as required by electrical power distribution system, but not less than 42,000 **OR** 65,000, **as directed**, A.
   a. Branch power circuit to each motor, dedicated electrical load, and to controls with disconnect switch or circuit breaker, **as directed**.
      1) NEMA KS 1, heavy-duty fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
      2) NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit-trip set point.
   b. NEMA ICS 2, Class A, full-voltage, nonreversing motor controller, hand-off-auto switch, and overcurrent protection for each motor.
   c. Control-circuit transformer with primary and secondary side fuses.
3. Terminal blocks with numbered and color-coded, **as directed**, wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
4. Wiring Outside of Enclosures: Factory installed in metal raceway except make terminal connections with not more than a 24-inch (610-mm) length of liquidtight **OR** flexible metallic, **as directed**, conduit.

M. Controls
1. Chiller control panel shall be separate from burner control panel.
2. Burner Control Panel: Factory or field, **as directed**, mounted. Maintains safe operating conditions, burner safety limits, burner operation, and interface with chiller controls; include the following components:
   a. On-off switch.
   b. Flame safeguard.
   c. Contacts for remote monitoring of flame failure.
   d. Contacts for proof of combustion air.
   e. Exhaust gas temperature limit switch.
   f. Control-circuit transformer.
   g. Burner motor controls.
   h. Fuel-oil pump controls, if chiller is equipped with fuel-oil pump.
   i. Visual indication of on/off status of ignition, blower, and main fuel.
   j. Alarm bell.
3. Control: Standalone and microprocessor based, with all memory stored in nonvolatile memory so that reprogramming is not required on loss of electrical power.
4. Enclosure: Unit mounted, NEMA 250, Type 1 **OR** Type 4 **OR** Type 4x, **as directed**, hinged or lockable.

5. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. Display the following information in either imperial or metric units selectable through the interface:
   a. Date and time.
   b. Operating or alarm status.
   c. Operating hours.
   d. Outdoor-air temperature if required for chilled-water reset.
   e. Temperature and pressure of operating set points.
   f. Entering and leaving temperatures of chilled and condenser water.
   g. Refrigerant temperature.
   h. Solution concentration and temperature.
   i. Indication of solution and purge-pump operation.
   j. Generator shell pressure.
   k. Number of starts.
   l. Number of purge cycles.
   m. Entering and leaving hot-water temperatures.
   n. Burner firing rate displayed in percent.
6. Control Functions:
   a. Manual or automatic startup and shutdown time schedule.
   b. Automatic cycle to prevent crystallization.
   c. Entering and leaving chilled-water temperatures and control set points. Chilled-water temperature shall be reset based on return-water **OR** outdoor-air **OR** space, **as directed**, temperature.
   d. Entering and leaving hot-water temperatures and control set points. Hot-water temperature shall be reset based on return-water **OR** outdoor-air **OR** space, **as directed**, temperature.
   e. Condenser-fluid temperature.
   f. Cooling provided and heating energy used within programmable time periods, minimum monthly.
   g. Heating provided and heating energy used within programmable time periods, minimum monthly.
7. Capacity Control: Automatically controls burner firing rate to maintain chilled-water temperature set point for cooling loads and heating-water temperature set point for heating loads ranging from 30 to 100 percent.
8. Safety Shutdowns: Chiller shall automatically shut down and require manual restart. Display a message following each safety shutdown.
   a. Crystallization.
   b. Low refrigerant temperature.
   c. Loss of chilled- or condenser-water flow.
   d. Low leaving chilled-water temperature, 2 deg F (1 deg C) below set point.
   e. First-stage generator low-solution level.
   f. First-stage generator high temperature or pressure.
   g. Burner alarm or control malfunction.
   h. Power failure.
   i. Solution pump overloads.
   j. External auxiliary safety shutdown.
   k. High solution concentration.
   l. Incomplete dilution cycle.
9. Warning Conditions: Chiller shall remain operational but inhibit burner firing rate to prevent safety shutdown. Control panel shall close warning contacts and generate a message when one of the following operating conditions is detected:
   a. Low refrigerant temperature.
   b. High generator temperature or pressure.
   c. High or low entering condenser-water temperature.
   d. Solution temperature sensor failure.
   e. Low chilled-water flow.

f. Purge-pump current overload.

10. Cycling Shutdowns: Permit automatic restart when preprogrammed limits are reached. Display a message following each cycle shutdown.
    a. Cooling Mode:
        1) Loss of condenser-water flow.
        2) Low leaving chilled-water temperature.
        3) Power failure.
    b. Heating Mode:
        1) Loss of hot-water flow.
        2) High leaving hot-water temperature.
        3) Power failure.
11. Trending: Capability to trend analog data up to five parameters simultaneously over an adjustable period and frequency of polling.
12. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: view only; view and operate; and view, operate, and service.
13. Control Authority: At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.
14. Communication Port: RS-232 port, USB 2.0 port, or equivalent connection capable of connecting a printer and a notebook computer.
15. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display chiller status and alarms.
    a. Hardwired Points:
        1) Monitoring: On-off status, common trouble alarm.
        2) Control: On-off operation, chilled-water, discharge temperature set-point adjustment **OR** hot-water, discharge temperature set-point adjustment, **as directed**.
    b. ASHRAE 135 (BACnet) **OR** LonTalk **OR** Modbus **OR** Industry-accepted, open-protocol, **as directed**, communication interface with the BAS shall enable the BAS operator to remotely control and monitor the chiller from an operator workstation. Control features and monitoring points displayed locally at chiller control panel shall be available through the BAS.

N. Finish
1. Paint chiller, using manufacturer's standard procedures, except comply with the following minimum requirements:
    a. Provide at least one coat of primer with a total dry film thickness of at least 2 mils (0.05 mm).
    b. Provide at least two coats of alkyd-modified, vinyl enamel **OR** epoxy **OR** polyurethane, **as directed**, finish with a total dry film thickness of at least 4 mils (0.10 mm).
    c. Paint surfaces that are to be insulated before applying the insulation.
    d. Paint installed insulation to match adjacent uninsulated surfaces.
    e. Color of finish coat to be manufacturer's standard **OR** custom color selected by the Owner.

O. Accessories
1. Sight Glasses: Equip unit with sight glasses for visual inspection of absorbent solution and refrigerant levels. Provide at least one sight glass in absorber and evaporator sections.
2. Flow Switches:
    a. Chiller manufacturer shall furnish a switch for each condenser **OR** evaporator and condenser, **as directed**, and shall verify field-mounting location before installation.
    b. Paddle Flow Switches:
        1) Vane operated to actuate a double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the BAS.
        2) Contacts: Platinum alloy, silver alloy, or gold-plated switch contacts with a rating of 10 A at 120-V ac.
        3) Pressure rating equal to pressure rating of heat exchanger.

4) Construct body and wetted parts of Type 316 stainless steel.
5) House switch in an NEMA 250, Type 4 enclosure constructed of die-cast aluminum.
6) Vane length to suit installation.

c. Pressure Differential Switches:
1) Construction: Wetted parts of body and trim constructed of Type 316 stainless steel.
2) Performance: Switch shall withstand, without damage, the full-pressure rating of the heat exchanger applied to either port and exhibit zero set point shift due to variation in working pressure.
3) Set Point: Screw type, field adjustable.
4) Electrical Connections: Internally mounted, screw-type terminal blocks.
5) Switch Enclosure: NEMA 250, Type 4.
6) Switch Action: Double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the BAS.

3. Vibration Isolation:
a. Chiller manufacturer shall furnish neoprene-pad vibration isolation for each chiller.
1) Two layers of 0.375-inch- (10-mm-) thick, ribbed- or waffle-pattern neoprene pads separated by a 16-gage, stainless-steel plate.
2) Fabricate pads from 40- to 50-durometer neoprene.
3) Provide stainless-steel square bearing plate to load the pad uniformly between 20 and 40 psig (138 and 276 kPa) with a 0.12- to 0.16-inch (3- to 4-mm) deflection.

P. Heat-Exchanger, Brush-Cleaning System
1. Furnish for field installation a brush-cleaning system on each chiller condenser for tube cleaning and improved heat transfer.
2. System shall maintain tube fouling at or below design conditions without interrupting normal equipment operation.
3. System shall consist of a brush inserted in each tube and a catch basket attached to each end of the tube. A four-way valve shall operate to reverse the direction of water flow to push the brush through the tube while removing tube deposits. Four-way reversing valve's actuator shall be controlled by a preset time cycle that provides regular tube brushing during equipment operation. Frequency of the brushing cycle shall be set up to match Project requirements.
4. Components:
a. Brush: Each brush shall have nylon bristles, titanium wires, and polypropylene tips. Brush interference fit with the ID of the tube shall not exceed 0.025 inch (0.6 mm).
b. Basket: Single-piece polypropylene basket with neck OD to press fit inner diameter of tube. Design shall provide for insertion of eddy current probe or removal of brushes without removing baskets from the valve.
c. Four-Way Valve:
1) Construct valve body of carbon steel with internal sealing parts of hard rubber and Type 304 stainless steel.
2) Configure valve with parallel flow connections to minimize field installation piping.
3) Construct valve to comply with ASME Boiler and Pressure Vessel Code , at a system working pressure equal to condenser.
4) Pipe connections shall be flanged.
5) Valve manufacturer to test and certify a maximum leakage rate of less than 0.05 percent of the design flow rate at operation conditions of maximum differential pressure.
6) Hydrostatically test valve to 1.5 times the design working pressure.
7) Design the valve to cause no more than 0.5-psig (3-kPa) pressure drop at design flow conditions.
8) Provide valve with valve-mounted indicating/warning light, which shall light before the valve begins rotation.
9) Valve Actuator: Mount electric actuator to operate valve.
OR
Valve Actuator: Mount pneumatic piston-type actuator to operate valve. Actuator shall be suitable for operation using field-supplied air pressure.

10) Position Switches: Factory mount microswitches on valve to indicate the complete turn of valve in both normal and reverse flow.

d. Control Panel: Factory or field mount a control panel on chiller. Control panel shall include the following features:
1) NEMA 250, Type 1 **OR** Type 4 **OR** Type 4x **OR** Type 12, **as directed**, enclosure.
2) Timer to automatically initiate the cleaning cycle over a 24-hour period.
3) Manual override of preset cleaning cycle.
4) Visual indication of "Power On," "Diverter Position," "Normal Flow," "Reverse Flow," and "Valve Malfunction" indicating a slow or incomplete valve turn.
5) For pneumatic actuators, mount four-way solenoid valve for actuator operation in the control panel.
6) Flow-switch bypass.
7) Unloading signal to chiller.

Q. Source Quality Control
1. Perform functional run tests of chillers before shipping.
2. Factory test and inspect absorber, generator, evaporator, and condenser according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1. Pressure test tube-side of heat exchangers, including water boxes, to 1.5 times the rated pressure. Vacuum and pressure test shells for leaks.
3. Rate sound power level according to ARI 575.
4. Burner Test: Factory adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion requirements indicated.
5. Factory performance test chillers, before shipping, according to ARI 560.
a. Test the following conditions:
1) Design conditions indicated.
2) Reduction in capacity from design to minimum load in steps of 10 **OR** 25 **OR** 33, **as directed**, with condenser fluid at design conditions.
OR
Reduction in capacity from design to minimum load in steps of 10 **OR** 25 **OR** 33, **as directed**, with varying entering condenser-fluid temperature from design to minimum conditions in 5 deg F (3 deg C) increments.
OR
At one **OR** two **OR** three **OR** four **OR** five **OR** 10, **as directed**, point(s) of varying part-load performance to be selected by the Owner at time of test.
6. Factory sound test chillers, before shipping, according to ARI 575.
a. Test the following conditions:
1) Design conditions indicated.
2) Chiller operating at calculated worst-case sound condition.
3) At one **OR** two **OR** three **OR** four **OR** five, **as directed**, point(s) of varying part-load performance to be selected by the Owner at time of test.
7. Allow the Owner access to place where chillers are being tested. Notify the Owner 14 days in advance of testing.
8. Prepare test report indicating test procedures, instrumentation, test conditions, and results. Submit copy of results within one week of test date.

1.3 EXECUTION

A. Examination
1. Examine chillers before installation. Reject chillers that are damaged.
2. Examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting chiller performance, maintenance, and operations before equipment installation.

a. Final chiller locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.

3. Proceed with installation only after unsatisfactory conditions have been corrected.

B. Chiller Installation

1. Install chillers on support structure indicated.
2. Equipment Mounting (for equipment supported on concrete bases and vibration isolation devices): Install chiller on concrete bases using elastomeric pads. Comply with requirements for concrete bases specified in Division 03 Section "Cast-in-place Concrete". Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   a. Minimum Deflection: 1/4 inch (6 mm) **OR** 1/2 inch (13 mm), **as directed**.
   b. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   c. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base, and anchor into structural concrete floor.
   d. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   e. Install anchor bolts to elevations required for proper attachment to supported equipment.
3. Equipment Mounting (for equipment supported on vibration isolation devices without a concrete base): Install chiller using elastomeric pads. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   a. Minimum Deflection: 1/4 inch (6 mm) **OR** 1/2 inch (13 mm), **as directed**.
4. Equipment Mounting (for equipment installed on concrete bases without vibration isolation devices): Install chiller on concrete bases. Comply with requirements for concrete bases specified in Division 03 Section "Cast-in-place Concrete".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base, and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   d. Install anchor bolts to elevations required for proper attachment to supported equipment.
5. Install chillers with seismic-restraint device. Comply with requirements for seismic-restraint devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
6. Install seismic restraints on piping. Comply with requirements for seismic-restraint devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
7. Maintain manufacturer's recommended clearances for service and maintenance.
8. Charge chiller with absorbent and refrigerant if not factory charged.
9. Install separate devices furnished by manufacturer and not factory installed.
10. Insulate hot and cold chiller surfaces that are recommended by chiller manufacturer to be insulated. Comply with requirements in Division 23 Section "Hvac Insulation".
11. Install electrical devices furnished with chiller but not specified to be factory mounted.
12. Install control wiring to field-mounted electrical devices.

C. Heat-Exchanger, Brush-Cleaning System Installation

1. Install brush-cleaning system control panel adjacent to chiller control panel.
2. Arrange piping to provide service access to four-way valve assembly without affecting access to chiller. Secure valve to prevent lateral movement and vibration during operation.
3. Provide field electric power, as required, to each system control panel and electric-actuated valve.

4. Provide pneumatic piping with pressure regulator and an isolation valve to each pneumatic supply connection. Coordinate field source of air with manufacturer to ensure that requirements are satisfied for proper valve operation.
5. Interconnect brush-cleaning system controls with chiller controls. Coordinate requirements to ensure safe, trouble-free operation.
6. Functionally test the entire brush-cleaning system, including the valve, actuator, position indicator, and control panel, with chiller in operation.

D. Connections
1. Comply with requirements for hydronic piping in Division 23 Section "Hydronic Piping". Drawings indicate general arrangement of piping, fittings, and specialties.
2. Comply with requirements for gas piping in Division 23 Section(s) "Facility Natural-gas Piping" OR "Facility Liquefied-petroleum Gas Piping". Drawings indicate general arrangement of piping, fittings, and specialties.
3. Connect gas piping full size to gas-train inlet with shutoff valve and union.
4. Install gas-fired boilers according to NFPA 54.
5. Comply with requirements for fuel-oil piping in Division 23 Section "Facility Fuel-oil Piping". Drawings indicate general arrangement of piping, fittings, and specialties.
6. Connect oil piping full size to burner inlet with shutoff valve and union.
7. Install oil-fired boilers according to NFPA 31.
8. Install piping adjacent to chiller to allow service and maintenance.
9. Hot-Water Heat-Exchanger Connections: Connect to heat-exchanger inlet with shutoff valve, strainer, flexible connector, thermometer, and plugged tee with shutoff valve and pressure gage. Connect to heat-exchanger outlet with shutoff valve, check valve, balancing valve, flexible connector, flow switch, thermometer, plugged tee with shutoff valve and pressure gage, flow meter, and drain connection with valve. Make connections to chiller with a flange or mechanical coupling.
10. Evaporator-Fluid Connections: Connect to evaporator inlet with shutoff valve, strainer, flexible connector, thermometer, and plugged tee with shutoff valve and pressure gage. Connect to evaporator outlet with shutoff valve, balancing valve, flexible connector, flow switch, thermometer, plugged tee with shutoff valve and pressure gage, flow meter, and drain connection with valve. Make connections to chiller with a flange or mechanical coupling.
11. Absorber/Condenser-Fluid Connections: Connect to inlet with shutoff valve, strainer, flexible connector, thermometer, and plugged tee with shutoff valve and pressure gage. Connect to outlet with shutoff valve, balancing valve, flexible connector, flow switch, thermometer, plugged tee with shutoff valve and pressure gage, flow meter, and drain connection with valve. Make connections to chiller with a flange or mechanical coupling.
    a. If not factory furnished or installed, provide pipe connecting fluid connection of absorber discharge and condenser inlet.
12. Refrigerant Pressure Relief Device Connections: Extend vent piping **OR** separate vent piping for each chiller, **as directed**, to the outdoors without valves or restrictions. Comply with ASHRAE 15. Connect to chiller pressure relief device with flexible connector and dirt leg with drain valve.
13. Extend purge vent piping **OR** separate purge vent piping for each chiller, **as directed**, to the outdoors. Comply with ASHRAE 15.
14. Connect each chiller drain connection with a union and drain pipe, and extend pipe, full size of connection, to floor drain. Provide a shutoff valve at each connection.
15. Comply with requirements for chimney system in Division 23 Section "Breechings, Chimneys, And Stacks". Drawings indicate general arrangement of pipe, fittings, and specialties. Connect chimney system to chiller burner outlet and extend to the outdoors.
16. Connect fuel-fired burner assembly and blower and associated damper for combustion air.

E. Startup Service
1. Perform startup service.
    a. Complete installation and startup checks according to manufacturer's written instructions.

b. Operate chiller for run-in period.
c. Verify that absorbent and refrigerant charge is sufficient and chiller has been leak tested.
d. Verify that pumps are installed and functional.
e. Verify that thermometers and gages are installed.
f. Operate chiller for run-in period.
g. Verify that refrigerant pressure relief device is vented to the outdoors.
h. Verify proper motor rotation.
i. Verify proper fuel supply. Adjust air-fuel ratio and combustion.
j. Verify proper combustion-air source.
k. Verify proper exhaust emissions.
l. Verify static deflection of vibration isolators including deflection during chiller startup and shutdown.
m. Verify and record performance of fluid flow and low-temperature interlocks for evaporator and condenser.
n. Verify and record performance of chiller protection devices.
o. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.
p. Burner Test: Adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas.

2. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assembly, installation, and connection.
3. Prepare test and inspection startup reports.

F. Demonstration
1. Train the Owner's maintenance personnel to adjust, operate, and maintain chillers. Video record the training sessions, **as directed**.

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SECTION 23 64 16 16 - FAN-COIL UNITS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for fan-coil units. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes fan-coil units and accessories.

C. Definitions
1. BAS: Building automation system.

D. Submittals
1. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories.
2. LEED Submittals:
   a. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.
   b. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
3. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   a. Wiring Diagrams: Power, signal, and control wiring.
4. Manufacturer Seismic Qualification Certification: Submit certification that fan-coil units, accessories, and components will withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
5. Field quality-control test reports.
6. Operation and maintenance data.
7. Warranty: Special warranty specified in this Section.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
3. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

F. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of condensing units that fail in materials or workmanship within specified warranty period.
   a. Failures include, but are not limited to, the following:
      1) Compressor failure.
      2) Condenser coil leak.
   b. Warranty Period: Four **OR** Five **OR** 10, **as directed**, years from date of Final Completion.
   c. Warranty Period (Compressor Only): Five **OR** 10, **as directed**, years from date of Final Completion.

d. Warranty Period (Condenser Coil Only): Five years from date of Final Completion.

1.2 PRODUCTS

A. Fan-Coil Units
1. Description: Factory-packaged and -tested units rated according to ARI 440, ASHRAE 33, and UL 1995.
2. Coil Section Insulation: 1/2-inch (13-mm) **OR** 1-inch (25-mm), **as directed**, thick, coated glass fiber **OR** foil-covered, closed-cell foam **OR** matte-finish, closed-cell foam, **as directed**, complying with ASTM C 1071 and attached with adhesive complying with ASTM C 916.
   a. Fire-Hazard Classification: Insulation and adhesive shall have a combined maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.
   b. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
3. Main and Auxiliary Drain Pans: Plastic **OR** Stainless steel **OR** Insulated galvanized steel with plastic liner, **as directed**. Fabricate pans and drain connections to comply with ASHRAE 62.1. Drain pans shall be removable, **as directed**.
4. Chassis: Galvanized steel where exposed to moisture. Floor-mounting units shall have leveling screws.
5. Cabinet: Steel with factory prime coating, ready for field painting **OR** baked-enamel finish in manufacturer's standard paint color as selected by the Owner **OR** baked-enamel finish in manufacturer's custom paint color as selected by the Owner, **as directed**.
   a. Vertical Unit Front Panels: Removable, steel, with integral stamped **OR** polyethylene **OR** steel, **as directed**, discharge grille and channel-formed edges, cam fasteners, and insulation on back of panel.
   b. Horizontal Unit Bottom Panels: Fastened to unit with cam fasteners and hinge and attached with safety chain; with integral stamped **OR** cast-aluminum, **as directed**, discharge grilles.
   c. Stack Unit Discharge and Return Grille: Aluminum double-deflection discharge grille, and louvered- or panel-type return grille; color as selected by the Owner from manufacturer's standard **OR** custom, **as directed**, colors. Return grille shall provide maintenance access to fan-coil unit.
   d. Steel recessing flanges for recessing fan-coil units into ceiling or wall.
6. Outdoor-Air Wall Box: Minimum 0.1265-inch- (3.2-mm-) thick, aluminum, rain-resistant louver and box with integral eliminators and bird screen.
   a. Louver Configuration: Horizontal **OR** Vertical, **as directed**, rain-resistant louver.
   b. Louver Material: Aluminum **OR** Steel, **as directed**.
   c. Bird Screen: 1/2-inch (13-mm) mesh screen on interior side of louver.
   d. Decorative Grille: On outside of intake.
   e. Finish: Anodized aluminum **OR** Baked enamel, **as directed**, color as selected by the Owner from manufacturer's standard **OR** custom, **as directed**, colors.
7. Outdoor-Air Damper: Galvanized-steel blades with edge and end seals and nylon bearings; with electronic **OR** pneumatic, **as directed**, two-position **OR** modulating, **as directed**, actuators.
8. Filters: Minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.
   a. Washable Foam: 70 percent arrestance and 3 MERV.
   b. Glass Fiber Treated with Adhesive: 80 percent arrestance and 5 MERV.
   c. Pleated Cotton-Polyester Media: 90 percent arrestance and 7 MERV.
9. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), rated for a minimum working pressure of 200 psig (1378 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain valve.

10. Steam Coils: Copper distributing, **as directed**, tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), rated for a minimum working pressure of 75 psig (517 kPa).
11. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with fuses in terminal box for overcurrent protection and limit controls for high-temperature protection. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.
12. Fan and Motor Board: Removable.
    a. Fan: Forward curved, double width, centrifugal; directly connected to motor. Thermoplastic or painted-steel wheels, and aluminum, painted-steel, or galvanized-steel fan scrolls.
    b. Motor: Permanently lubricated, multispeed; resiliently mounted on motor board. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
    c. Wiring Termination: Connect motor to chassis wiring with plug connection.
13. Factory, Hydronic Piping Package: ASTM B 88, Type L (ASTM B 88M, Type B) **OR** ASTM B 88, Type M (ASTM B 88M Type C), **as directed**, copper tube with wrought-copper fittings and brazed joints. Label piping to indicate service, inlet, and outlet.
    a. Two **OR** Three, **as directed**,-way, two-position **OR** modulating, **as directed**, control valve for dual-temperature coil.
    b. Two **OR** Three, **as directed**,-way, two-position **OR** modulating, **as directed**, control valve for chilled-water coil.
    c. Two **OR** Three, **as directed**,-way, two-position **OR** modulating, **as directed**, control valve for heating coil.
    d. Two **OR** Three, **as directed**,-way two-position **OR** modulating, **as directed**, control valve for hot-water reheat coil.
    e. Hose Kits: Minimum 400-psig (2758-kPa) working pressure, and operating temperatures from 33 to 211 deg F (0.5 to 99 deg C). Tag hose kits to equipment designations.
        1) Length: 24 inches (600 mm) **OR** 36 inches (900 mm), **as directed**.
        2) Minimum Diameter: Equal to fan-coil-unit connection size.
    f. Two-Piece Ball Valves: Bronze body with full-port, chrome-plated bronze ball; PTFE or TFE seats; and 600-psig (4140-kPa) minimum CWP rating and blowout-proof stem.
    g. Calibrated-Orifice Balancing Valves: Bronze body, ball type; 125-psig (860-kPa) working pressure, 250-deg F (121-deg C) maximum operating temperature; with calibrated orifice or venturi, connections for portable differential pressure meter with integral seals, threaded ends, and equipped with a memory stop to retain set position.
    h. Automatic Flow-Control Valve: Brass or ferrous-metal body; 300-psig (2070-kPa) working pressure at 250 deg F (121 deg C), with removable, corrosion-resistant, tamperproof, self-cleaning piston spring; factory set to maintain constant indicated flow with plus or minus 10 percent over differential pressure range of 2 to 80 psig (13.8 to 552 kPa).
    i. Y-Pattern Hydronic Strainers: Cast-iron body (ASTM A 126, Class B); 125-psig (860-kPa) working pressure; with threaded connections, bolted cover, perforated stainless-steel basket, and bottom drain connection. Include minimum NPS 1/2 (DN 15) hose-end, full-port, ball-type blowdown valve in drain connection.
    j. Wrought-Copper Unions: ASME B16.22.
    k. Risers: ASTM B 88, Type L (ASTM B 88M, Type B) **OR** ASTM B 88, Type M (ASTM B 88M Type C), **as directed**, copper pipe with hose and ball valve for system flushing.
14. Control devices and operational sequences are specified in Division 23 Section(s) "Instrumentation And Control For Hvac" AND "Sequence Of Operations For Hvac Controls".
15. Basic Unit Controls:
    a. Control voltage transformer.
    b. Wall-mounting **OR** Unit-mounted, **as directed**, thermostat with the following features:
        1) Heat-cool-off switch.
        2) Fan on-auto switch.
        3) Fan-speed switch.

4) Manual **OR** Automatic, **as directed**, changeover.
5) Adjustable deadband.
6) Concealed **OR** Exposed, **as directed**, set point.
7) Concealed **OR** Exposed, **as directed**, indication.
8) Degree F **OR** Degree C, **as directed**, indication.

c. Wall-mounting **OR** Unit-mounted, **as directed**, humidistat.
1) Concealed **OR** Exposed, **as directed**, set point.
2) Concealed **OR** Exposed, **as directed**, indication.

d. Wall-mounting **OR** Unit-mounted, **as directed**, temperature sensor.

e. Unoccupied-period-override push button.

f. Data entry and access port.
1) Input data includes room temperature, and humidity set points and occupied and unoccupied periods.
2) Output data includes room temperature and humidity, supply-air temperature, entering-water temperature, operating mode, and status.

16. DDC, **as directed**, Terminal Controller:

a. Scheduled Operation: Occupied and unoccupied periods on seven-day clock with a minimum of four programmable periods per day.

b. Unoccupied Period Override Operation: Two, **as directed**, hours.

c. Unit Supply-Air Fan Operation:
1) Occupied Periods: Fan runs continuously.
2) Unoccupied Periods: Fan cycles to maintain room setback temperature.

d. Hydronic-Cooling-Coil Operation:
1) Occupied Periods: Open **OR** Modulate, **as directed**, control valve to maintain room temperature.
2) Unoccupied Periods: Close control valve.

e. Heating-Coil Operation:
1) Occupied Periods: Open control valve **OR** Modulate control valve **OR** Energize electric-resistance coil, **as directed**, to provide heating if room temperature falls below thermostat set point.
2) Unoccupied Periods: Start fan and open control valve **OR** modulate control valve **OR** energize electric-resistance coil, **as directed**, if room temperature falls below setback temperature.

f. Dual-Temperature Hydronic-Coil Operation:
1) Occupied Periods: When chilled water is available, open **OR** modulate, **as directed**, control valve if room temperature exceeds thermostat set point. When hot water is available, open control valve if temperature falls below thermostat set point.
2) Unoccupied Periods: When chilled water is available, close control valve. When hot water is available, open **OR** modulate, **as directed**, control valve if room temperature falls below thermostat setback temperature.

g. Reheat-Coil Operation:
1) Humidity Control for Occupied Periods:
a) Humidistat opens control valve **OR** modulates control valve **OR** energizes electric-resistance coil, **as directed**, to provide heating. As space temperature rises above the set point, cooling coil valve opens **OR** modulates, **as directed**, to maintain room temperature.
2) Humidity Control for Unoccupied Periods: Close control valve **OR** De-energize, **as directed**.
3) Occupied Periods:
a) Heating Operations: Open control valve **OR** Modulate control valve **OR** Energize electric-resistance coil, **as directed**, to provide heating if room temperature falls below thermostat set point.
b) Humidity-Control Operations: Humidistat opens control valve **OR** modulates control valve **OR** energizes electric-resistance coil, **as directed**, to provide

heating. As space temperature rises above the set point, cooling coil valve opens **OR** modulates, **as directed**, to maintain room temperature.

4) Unoccupied Periods: Start fan and open control valve **OR** modulate control valve **OR** energize electric-resistance coil, **as directed**, if room temperature falls below setback temperature. Humidity control is not available.

h. Outdoor-Air Damper Operation:

1) Occupied Periods: Open damper to fixed position for 25 percent outdoor air.

2) Unoccupied periods: Close damper.

i. Outdoor-Air Damper Operation:

1) Occupied Periods:

a) Outdoor-Air Temperature below Room Temperature: If room temperature is above thermostat set point, modulate outdoor-air damper to maintain room temperature (outdoor-air economizer). If room temperature is below thermostat set point, position damper to fixed minimum position.

b) Outdoor-Air Temperature above Room Temperature: Position damper to fixed minimum position for 25 percent outdoor air.

2) Unoccupied Periods: Close damper.

j. Controller shall have volatile-memory backup.

17. BAS Interface Requirements:

a. Interface relay for scheduled operation.

b. Interface relay to provide indication of fault at the central workstation.

c. Provide BACnet **OR** LonWorks, **as directed**, interface for central BAS workstation for the following functions:

1) Adjust set points.

2) Fan-coil-unit start, stop, and operating status.

3) Data inquiry, including outdoor-air damper position, **as directed**, supply- and room-air temperature and humidity, **as directed**.

4) Occupied and unoccupied schedules.

18. Electrical Connection: Factory wire motors and controls for a single electrical connection.

B. Ducted Fan-Coil Units

1. Description: Factory-packaged and -tested units rated according to ARI 440, ASHRAE 33, and UL 1995.

2. Coil Section Insulation: 1/2-inch (13-mm) **OR** 1-inch (25-mm), **as directed**, thick coated **OR** foil-faced, **as directed**, glass fiber complying with ASTM C 1071 and attached with adhesive complying with ASTM C 916.

a. Fire-Hazard Classification: Insulation and adhesive shall have a combined maximum flame-spread index of 25 and smoke-developed index of 50 when tested according to ASTM E 84.

b. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

3. Drain Pans: Plastic **OR** Stainless steel **OR** Insulated galvanized steel with plastic liner, **as directed**. Fabricate pans and drain connections to comply with ASHRAE 62.1.

4. Chassis: Galvanized steel where exposed to moisture, with baked-enamel finish and removable access panels.

5. Cabinets: Steel with baked-enamel finish in manufacturer's standard paint color.

a. Supply-Air Plenum: Sheet metal plenum finished and insulated to match the chassis with mill-finish, aluminum, double-deflection grille, **as directed**.

b. Return-Air Plenum: Sheet metal plenum finished to match the chassis.

c. Mixing Plenum: Sheet metal plenum finished and insulated to match the chassis with outdoor- and return-air, formed-steel dampers.

d. Dampers: Galvanized steel with extruded-vinyl blade seals, flexible-metal jamb seals, and interlocking linkage.

6. Filters: Minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

a. Washable Foam: 70 percent arrestance and 3 MERV.

b. Glass Fiber Treated with Adhesive: 80 percent arrestance and 5 MERV.
c. Pleated Cotton-Polyester Media: 90 percent arrestance and 7 MERV.

7. Hydronic Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), rated for a minimum working pressure of 200 psig (1378 kPa) and a maximum entering-water temperature of 220 deg F (104 deg C). Include manual air vent and drain.
8. Indoor Refrigerant Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), and brazed joints at fittings. Comply with ARI 210/240, and leak test to minimum 450 psig (3105 kPa) for a minimum 300-psig (2070-kPa) working pressure. Include thermal expansion valve.
9. Steam Coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), rated for a minimum working pressure of 75 psig (517 kPa).
10. Electric-Resistance Heating Coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized-steel housing; with fuses in terminal box for overcurrent protection and limit controls for high-temperature protection of heaters. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.
11. Direct-Driven Fans: Double width, forward curved, centrifugal; with permanently lubricated, multispeed motor resiliently mounted in the fan inlet. Aluminum or painted-steel wheels, and painted-steel or galvanized-steel fan scrolls.

    OR

    Belt-Driven Fans: Double width, forward curved, centrifugal; with permanently lubricated, single-speed motor installed on an adjustable fan base resiliently mounted in the cabinet. Aluminum or painted-steel wheels, and painted-steel or galvanized-steel fan scrolls.
    a. Motors: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
12. Factory, Hydronic Piping Package: ASTM B 88, Type L (ASTM B 88M, Type B) **OR** ASTM B 88, Type M (ASTM B 88M Type C), **as directed**, copper tube with wrought-copper fittings and brazed joints. Label piping to indicate service, inlet, and outlet.
    a. Two **OR** Three, **as directed**,-way, two-position **OR** modulating, **as directed**, control valve for chilled-water coil.
    b. Two **OR** Three, **as directed**,-way, two-position **OR** modulating, **as directed**, control valve for heating coil.
    c. Two **OR** Three, **as directed**,-way, two-position **OR** modulating, **as directed**, control valve for dual-temperature coil.
    d. Two **OR** Three, **as directed**,-way, two-position **OR** modulating, **as directed**, control valve for reheat coil.
    e. Hose Kits: Minimum 400-psig (2758-kPa) working pressure, and operating temperatures from 33 to 211 deg F (0.5 to 99 deg C). Tag hose kits to equipment designations.
        1) Length: 24 inches (600 mm) **OR** 36 inches (900 mm), **as directed**.
        2) Minimum Diameter: Equal to fan-coil-unit connection size.
    f. Two-Piece Ball Valves: Bronze body with full-port, chrome-plated bronze ball; PTFE or TFE seats; and 600-psig (4140-kPa) minimum CWP rating and blowout-proof stem.
    g. Calibrated-Orifice Balancing Valves: Bronze body, ball type; 125-psig (860-kPa) working pressure, 250 deg F (121 deg C) maximum operating temperature; with calibrated orifice or venturi, connections for portable differential pressure meter with integral seals, threaded ends, and equipped with a memory stop to retain set position.
    h. Automatic Flow-Control Valve: Brass or ferrous-metal body; 300-psig (2070-kPa) working pressure at 250 deg F (121 deg C); with removable, corrosion-resistant, tamperproof, self-cleaning piston spring; factory set to maintain constant indicated flow with plus or minus 10 percent over differential pressure range of 2 to 80 psig (13.8 to 552 kPa).
    i. Y-Pattern Hydronic Strainers: Cast-iron body (ASTM A 126, Class B); 125-psig (860-kPa) working pressure, with threaded connections, bolted cover, perforated stainless-steel basket, and bottom drain connection. Include minimum NPS 1/2 (DN 15) hose-end, full-port, ball-type blowdown valve in drain connection.
    j. Wrought-Copper Unions: ASME B16.22.

13. Remote condensing units are specified in Division 23 Section "Packaged Compressor And Condenser Units".
14. Remote Condensing Units: Factory assembled and tested, consisting of compressors, condenser coils, fans, motors, refrigerant receiver, and operating controls. Construct, test, and rate condensing units according to ARI 210/240 and ASHRAE 15.
    a. Casing: Steel with baked-enamel finish, removable panels for access to controls, weep holes for water drainage, and mounting holes in base.
    b. Compressor: Hermetic, scroll **OR** reciprocating, **as directed**, type; internally isolated for vibration with factory-installed safety devices as follows:
        1) Antirecycle timer.
        2) High-pressure cutout.
        3) Low-pressure cutout or loss-of-charge switch.
        4) Internal thermal-overload protection.
        5) Current and voltage sensitive safety devices.
    c. Compressor Motor: Start capacitor, relay, and contactor. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
    d. Energy Efficiency: Equal to or greater than prescribed by ASHRAE/IESNA 90.1, "Energy Standard for Buildings except Low-Rise Residential Buildings."
    e. Refrigerant Piping Materials: ASTM B 743 copper tube with wrought-copper fittings and brazed joints.
    f. Refrigerant: R-407C **OR** R-410A, **as directed**.
    g. Low ambient controls to permit operation down to 45 deg F (7 deg C).
    h. Crankcase heater.
    i. Charging and service fittings on exterior of casing.
    j. Filter dryer.
    k. Air-to-Air Heat Pump: Pilot-operated, sliding-type reversing valve with replaceable magnetic coil, and controls for air-to-air heat pump operation with supplemental heat operation.
    l. Hot-gas-bypass, constant-pressure expansion valve and controls to maintain continuous refrigeration system operation at 10 percent of full load.
    m. Condenser: Copper-tube, aluminum-fin coil, with liquid subcooler.
    n. Condenser Fan: Direct-drive, aluminum propeller fan.
        1) Motor: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
    o. Accessories: Polyethylene mounting base to provide a permanent foundation.
15. Control devices and operational sequence are specified in Division 23 Section(s) "Instrumentation And Control For Hvac" AND "Sequence Of Operations For Hvac Controls".
16. Basic Unit Controls:
    a. Control voltage transformer.
    b. Wall-mounting **OR** Unit-mounted, **as directed**, thermostat with the following features.
        1) Heat-cool-off switch.
        2) Fan on-auto switch.
        3) Fan-speed switch.
        4) Manual **OR** Automatic, **as directed**, changeover.
        5) Adjustable deadband.
        6) Concealed **OR** Exposed, **as directed**, set point.
        7) Concealed **OR** Exposed, **as directed**, indication.
        8) Degree F **OR** Degree C, **as directed**, indication.
    c. Wall-mounting **OR** Unit-mounted, **as directed**, humidistat.
        1) Concealed **OR** Exposed, **as directed**, set point.
        2) Concealed **OR** Exposed, **as directed**, indication.
    d. Wall-mounting **OR** Unit-mounted, **as directed**, temperature sensor.
    e. Unoccupied-period-override push button.
    f. Data entry and access port.
        1) Input data includes room temperature, and humidity set points and occupied and unoccupied periods.

2) Output data includes room temperature and humidity, supply-air temperature, entering-water temperature, operating mode, and status.

17. DDC, **as directed**, Terminal Controller:
    a. Scheduled Operation: Occupied and unoccupied periods on seven-day clock with a minimum of four programmable periods per day.
    b. Unoccupied Period Override Operation: Two, **as directed**, hours.
    c. Unit Supply-Air Fan Operation:
        1) Occupied Periods: Fan runs continuously.
        2) Unoccupied Periods: Fan cycles to maintain room setback temperature.
    d. Hydronic-Cooling-Coil Operation:
        1) Occupied Periods: Open **OR** Modulate, **as directed**, control valve to maintain room temperature.
        2) Unoccupied Periods: Close control valve.
    e. Refrigerant-Coil Operation:
        1) Occupied Periods: Start compressor to maintain room temperature or humidistat set point.
        2) Unoccupied Periods: Stop compressor cooling and cycle compressor for heating to maintain setback temperature.
    f. Supplemental, **as directed**, Heating-Coil Operation:
        1) Occupied Periods: Open control valve **OR** Modulate control valve **OR** Energize electric-resistance coil, **as directed**, to provide heating if room temperature falls below thermostat set point.
        2) Unoccupied Periods: Start fan and open control valve **OR** modulate control valve **OR** energize electric-resistance coil, **as directed**, if room temperature falls below setback temperature.
        3) Switch refrigerant-reversing valve to operate supplemental coil for heating when outdoor temperature is below 25 deg F (4 deg C).
    g. Dual-Temperature Hydronic-Coil Operation:
        1) Occupied Periods: When chilled water is available, open **OR** modulate, **as directed**, control valve if room temperature exceeds thermostat set point. When hot water is available, open **OR** modulate, **as directed**, control valve if temperature falls below thermostat set point.
        2) Unoccupied Periods: When chilled water is available, close valve. When hot water is available, open **OR** modulate, **as directed**, control valve if room temperature falls below thermostat setback temperature.
    h. Reheat-Coil Operation:
        1) Humidity Control for Occupied Periods: Humidistat opens control valve **OR** modulates control valve **OR** energizes electric-resistance coil, **as directed**, to provide heating. As room temperature rises above the set point, cooling coil valve opens **OR** modulates, **as directed**, to maintain room temperature.
        2) Humidity Control for Unoccupied Periods: Close control valve **OR** De-energize, **as directed**.
        3) Occupied Periods:
            a) Heating Operations: Open control valve **OR** Modulate control valve **OR** Energize electric-resistance coil, **as directed**, to provide heating if room temperature falls below thermostat set point.
            b) Humidity-Control Operations: Humidistat opens control valve **OR** modulates control valve **OR** energizes electric-resistance coil, **as directed**, to provide heating. As room temperature rises above the set point, cooling coil valve opens **OR** modulates, **as directed**, to maintain room temperature.
        4) Unoccupied Periods: Start fan and open control valve **OR** modulate control valve **OR** energize electric-resistance coil, **as directed**, if room temperature falls below setback temperature. Humidity control is not available.
    i. Outdoor-Air Damper Operation (for fixed, minimum outdoor-air intake):
        1) Occupied Periods: Open damper to fixed position for 25 percent outdoor air.

2) Unoccupied Periods: Close damper.

j. Outdoor-Air Damper Operation (for outdoor-air economizer cycle based on temperature):

1) Occupied Periods:

a) Outdoor-Air Temperature below Room Temperature: If room temperature is above room-temperature set point, modulate outdoor- and return-air dampers to maintain room-temperature set point (outdoor-air economizer). If room temperature is below set point, position damper to fixed minimum setting.

b) Outdoor-Air Temperature above Room Temperature: Position damper to fixed minimum position for 25 percent outdoor air.

2) Unoccupied Periods: Close outdoor-air damper and open return-air damper.

k. Outdoor-Air Damper Operation (for outdoor-air economizer cycle based on enthalpy):

1) Occupied Periods:

a) Outdoor-Air Enthalpy below Room Enthalpy: If room temperature is above room-temperature set point, modulate outdoor-air damper to maintain room temperature (outdoor-air economizer). If room temperature is below set point, position damper to fixed minimum position for 25 percent outdoor air.

b) Outdoor-Air Enthalpy above Room Enthalpy: Position damper to fixed minimum position for 25 percent outdoor air.

2) Unoccupied Periods: Close outdoor-air damper and open return-air damper.

l. Controller shall have volatile-memory backup.

18. BAS Interface Requirements:

a. Interface relay for scheduled operation.

b. Interface relay to provide indication of fault at the central workstation.

c. Provide BACnet **OR** LonWorks, **as directed**, interface for central BAS workstation for the following functions:

1) Adjust set points.

2) Fan-coil-unit start, stop, and operating status.

3) Data inquiry including outdoor-air damper position,, **as directed** supply- and room-air temperature and humidity, **as directed**.

4) Occupied and unoccupied schedules.

19. Electrical Connection: Factory wire motors and controls for a single electrical connection.

1.3 EXECUTION

A. Installation

1. Install fan-coil units level and plumb.
2. Install fan-coil units to comply with NFPA 90A.
3. Suspend fan-coil units from structure with elastomeric hangers. Vibration isolators are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
4. Verify locations of thermostats, humidistats, and other exposed control sensors with Drawings and room details before installation. Install devices 48 inches (1220 mm) **OR** 60 inches (1525 mm), **as directed**, above finished floor.
5. Install new filters in each fan-coil unit within two weeks after Final Completion.

B. Connections

1. Piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties. Specific connection requirements are as follows:

a. Install piping adjacent to machine to allow service and maintenance.

b. Connect piping to fan-coil-unit factory hydronic piping package. Install piping package if shipped loose.

c. Connect condensate drain to indirect waste.

1) Install condensate trap of adequate depth to seal against the pressure of fan. Install cleanouts in piping at changes of direction.

2. Connect supply and return ducts to fan-coil units with flexible duct connectors specified in Division 23 Section "Air Duct Accessories". Comply with safety requirements in UL 1995 for duct connections.
3. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
4. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

C. Field Quality Control
1. Perform the following field tests and inspections and prepare test reports:
   a. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   b. Operate electric heating elements through each stage to verify proper operation and electrical connections.
   c. Test and adjust controls and safety devices. Replace damaged and malfunctioning controls and equipment.
2. Remove and replace malfunctioning units and retest as specified above.

D. Adjusting
1. Adjust initial temperature and humidity set points.
2. Occupancy Adjustments: When requested within 12 months of date of Final Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other than normal occupancy hours for this purpose.

E. Demonstration
1. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain fan-coil units.

END OF SECTION 23 64 16 16

Task	Specification	Specification Description
23 64 16 16	23 61 16 00	Centrifugal Water Chillers

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SECTION 23 64 19 00 - RECIPROCATING WATER CHILLERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for reciprocating water chillers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Packaged, water-cooled, electric-motor-driven, reciprocating water chillers.
b. Packaged, air-cooled, electric-motor-driven, reciprocating water chillers.
c. Packaged refrigerant recovery units.

C. Definitions
1. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input using consistent units for any given set of rating conditions.
2. EER: Energy-efficiency ratio. The ratio of the cooling capacity given in terms of Btu/h to the total power input given in terms of watts at any given set of rating conditions.
3. IPLV: Integrated part-load value. A single number part-load efficiency figure of merit calculated per the method defined by ARI 550/590 and referenced to ARI standard rating conditions.
4. kW/Ton: The ratio of total power input of the chiller in kilowatts to the net refrigerating capacity in tons at any given set of rating conditions.
5. NPLV: Nonstandard part-load value. A single number part-load efficiency figure of merit calculated per the method defined by ARI 550/590 and intended for operating conditions other than the ARI standard rating conditions.

D. Performance Requirements
1. Seismic Performance: Reciprocating water chillers shall withstand the effects of earthquake motions determined according to SEI/ASCE 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

E. Submittals
1. Product Data: Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.
2. Seismic Qualification Certificates: For water chillers, accessories, and components, from manufacturer.
a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
3. Source quality-control test reports.
4. Startup service reports.
5. Operation and maintenance data.
6. Warranty: Sample of special warranty.

F. Quality Assurance
1. ARI Certification: Certify chiller according to ARI 590 certification program.

2. ARI Rating: Rate water chiller performance according to requirements in ARI 550/590, "Water Chilling Packages Using the Vapor Compression Cycle."
3. ASHRAE Compliance: ASHRAE 15 for safety code for mechanical refrigeration.
4. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
5. ASME Compliance: Fabricate and stamp water chiller heat exchangers to comply with ASME Boiler and Pressure Vessel Code.
6. Comply with NFPA 70.

G. Delivery, Storage, And Handling
1. Ship water chillers from the factory fully charged with refrigerant and filled with oil.
2. Package water chiller for export shipping.

H. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of water chillers that fail in materials or workmanship within five years from date of Final Completion.

1.2 PRODUCTS

A. Packaged Water-Cooled Water Chillers
1. Description: Factory-assembled and run-tested water chiller complete with compressor(s), compressor motors and motor controllers, evaporator, condenser where indicated, electrical power, controls, and indicated accessories.
2. Fabricate water chiller mounting base with reinforcement strong enough to resist water chiller movement during a seismic event when water chiller is anchored to field support structure.
3. Compressors:
   a. Description: Positive-displacement direct drive with semihermetically sealed and accessible bolted casings.
   b. Each compressor provided with suction and discharge service valves, crankcase oil heater, and suction strainer.
   c. Operating Speed: 1750 rpm for 60-Hz applications.
   d. Capacity Control: Combinations of cylinder unloading and on-off compressor cycling of multiple compressors, **as directed**, plus hot-gas bypass, **as directed**. Compressor shall be capable of operating at part-load conditions without increased vibration over normal vibration at full-load operation and shall be capable of continuous operation at its lowest step of unloading.
   e. Oil Lubrication System: Automatically reversible, positive-displacement pump with strainer, sight glass, filling connection, filter with magnetic plug, and initial oil charge.
   f. Vibration Isolation: Mount individual compressors on either neoprene or spring isolators.
   g. Sound-reduction package shall consist of acoustic enclosures around the compressors that are designed to reduce sound level without affecting performance.
4. Compressor Motors:
   a. Hermetically sealed and cooled by refrigerant suction gas.
   b. High-torque, four-pole induction type with inherent thermal-overload protection on each phase.
5. Compressor Motor Controllers:
   a. Across the Line: NEMA ICS 2, Class A, full voltage, nonreversing.
      OR
      Part-Wind Start: NEMA ICS 2, Class A, reduced voltage, nonreversing.
6. Refrigeration:
   a. Refrigerant: R-407C **OR** R-410A, **as directed.** Classified as Safety Group A1 according to ASHRAE 34.

b. Refrigerant Compatibility: Parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
c. Refrigerant Circuit: Each circuit shall include a thermal **OR** an electronic, **as directed**, expansion valve, refrigerant charging connections, a hot-gas muffler, compressor suction and discharge shutoff valves, a liquid-line shutoff valve, a replaceable-core filter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.
d. Refrigerant Isolation: Factory install positive shutoff isolation valves in the compressor discharge line and the refrigerant liquid-line to allow the isolation and storage of the refrigerant charge in the chiller condenser.

7. Evaporator:
   a. Brazed-plate or shell-and-tube design, as indicated.
   b. Shell and Tube:
      1) Description: Direct-expansion, shell-and-tube design with fluid flowing through the shell and refrigerant flowing through the tubes within the shell.
      2) Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
      3) Shell Material: Carbon steel.
      4) Shell Heads: Removable carbon-steel heads with multipass baffles designed to ensure positive oil return and located at each end of the tube bundle.
      5) Shell Nozzles: Fluid nozzles located along the side of the shell and terminated with mechanical-coupling end connections for connection to field piping.
      6) Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
   c. Brazed Plate:
      1) Direct-expansion, single-pass, brazed-plate design.
      2) Type 316 stainless-steel construction.
      3) Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
      4) Fluid Nozzles: Terminate with mechanical-coupling end connections for connection to field piping.
8. Condenser:
   a. Shell and tube, brazed plate, or without integral condenser; as indicated.
   b. Shell and Tube:
      1) Description: Shell-and-tube design with refrigerant flowing through the shell and fluid flowing through the tubes within the shell.
      2) Provides positive subcooling of liquid refrigerant.
      3) Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
      4) Shell Material: Carbon steel.
      5) Water Boxes: Removable, of carbon-steel construction, located at each end of the tube bundle with fluid nozzles terminated with mechanical-coupling end connections for connection to field piping.
      6) Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
      7) Provide each condenser with a pressure relief device, purge cock, and liquid-line shutoff valve.
   c. Brazed Plate:
      1) Single-pass, brazed-plate design provides positive subcooling of liquid refrigerant.
      2) Type 316 stainless-steel construction.
      3) Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
      4) Fluid Nozzles: Terminate with mechanical-coupling end connections for connection to field piping.
      5) Provide each condenser with a liquid-line shutoff valve.

d. Provide water chiller without an integral condenser and design chiller for field connection to remote condenser. Coordinate requirements with Division 23 Section "Air-cooled Refrigerant Condensers".

9. Electrical Power:
   a. Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to water chiller.
   b. House in a unit-mounted, NEMA 250, Type 1, **as directed**, enclosure with hinged access door with lock and key or padlock and key.
   c. Wiring shall be numbered and color-coded to match wiring diagram.
   d. Install factory wiring outside of an enclosure in a raceway.
   e. Field power interface shall be to wire lugs **OR** NEMA KS 1, heavy-duty, nonfused disconnect switch, **as directed**.
   f. Provide branch power circuit to each motor and to controls with one of the following disconnecting means:
      1) NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
      2) NEMA KS 1, heavy-duty, nonfusible switch.
      3) NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
   g. Provide each motor with overcurrent protection.
   h. Overload relay sized according to UL 1995, or an integral component of water chiller control microprocessor.
   i. Phase-Failure and Undervoltage: Solid-state sensing with adjustable settings.
   j. Controls Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.
   k. Control Relays: Auxiliary and adjustable time-delay relays.
   l. Indicate the following for water chiller electrical power supply:
      1) Current, phase to phase, for all three phases.
      2) Voltage, phase to phase and phase to neutral for all three phases.
      3) Three-phase real power (kilowatts).
      4) Three-phase reactive power (kilovolt amperes reactive).
      5) Power factor.
      6) Running log of total power versus time (kilowatt hours).
      7) Fault log, with time and date of each.

10. Controls:
   a. Stand-alone, microprocessor based.
   b. Enclosure: Share enclosure with electrical power devices or provide a separate enclosure of matching construction.
   c. Operator Interface: Keypad or pressure-sensitive touch screen. Multiple-character, backlit, liquid-crystal display or light-emitting diodes. Display the following:
      1) Date and time.
      2) Operating or alarm status.
      3) Operating hours.
      4) Outside-air temperature if required for chilled-water reset.
      5) Temperature and pressure of operating set points.
      6) Entering and leaving temperatures of chilled water.
      7) Entering and leaving temperatures of condenser water.
      8) Refrigerant pressures in evaporator and condenser.
      9) Saturation temperature in evaporator and condenser.
      10) No cooling load condition.
      11) Elapsed time meter (compressor run status).
      12) Pump status.
      13) Antirecycling timer status.
      14) Percent of maximum motor amperage.
      15) Current-limit set point.

16) Number of compressor starts.

d. Control Functions:
1) Manual or automatic startup and shutdown time schedule.
2) Entering and leaving chilled-water temperatures, control set points, and motor load limit. Chilled-water leaving temperature shall be reset based on return-water **OR** outside-air **OR** space, **as directed**, temperature.
3) Current limit and demand limit.
4) Condenser-water temperature.
5) External water chiller emergency stop.
6) Antirecycling timer.
7) Automatic lead-lag switching.

e. Manual-Reset Safety Controls: The following conditions shall shut down water chiller and require manual reset:
1) Low evaporator pressure or high condenser pressure.
2) Low chilled-water temperature.
3) Refrigerant high pressure.
4) High or low oil pressure.
5) High oil temperature.
6) Loss of chilled-water flow.
7) Loss of condenser-water flow.
8) Control device failure.

f. Building Automation System Interface: Factory-installed hardware and software to enable building automation system to monitor, control, and display water chiller status and alarms.
1) Hardwired Points:
a) Monitoring: On/off status, common trouble alarm **OR** electrical power demand (kilowatts) **OR** electrical power consumption (kilowatt hours), **as directed**.
b) Control: On/off operation, chilled-water discharge temperature set-point adjustment **OR** electrical power demand limit, **as directed**.
2) ASHRAE 135 (BACnet) **OR** LonTalk **OR** Industry-accepted open-protocol, **as directed**, communication interface with building automation system shall enable building automation system operator to control and monitor the water chiller from a remote operator workstation. Control features and monitoring points displayed locally at water chiller control panel shall be available through building automation system.

11. Insulation:
a. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type I, for tubular materials and Type II, for sheet materials.
b. Thickness: 3/4 inch (19 mm).
c. Factory-applied insulation over cold surfaces of water chiller components.
1) Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.
d. Apply protective coating to exposed surfaces of insulation.

12. Accessories:
a. Factory-furnished, chilled-water and condenser-water, **as directed**, flow switches for field installation.
b. Individual compressor suction and discharge pressure gages with shutoff valves.
c. Factory-furnished spring isolators for field installation.

B. Packaged Air-Cooled Water Chillers
1. Description: Factory-assembled and run-tested water chiller complete with base and frame, condenser casing, compressors, compressor motors and motor controllers, evaporator, condenser coils, condenser fans and motors, electrical power, controls, and accessories.
2. Fabricate base, frame, and attachment to water chiller components strong enough to resist movement during a seismic event when water chiller base is anchored to field support structure.
3. Cabinet:

a. Base: Galvanized-steel base extending the perimeter of water chiller. Secure frame, compressors, and evaporator to base to provide a single-piece unit. Base shall be designed to limit deflection to L/200 and shall be a minimum of 4 inches (100 mm) high.
b. Frame: Rigid galvanized-steel frame secured to base and designed to support cabinet, condenser, control panel, and other chiller components not directly supported from base.
c. Casing: Galvanized steel.
d. Finish: Coat base, frame, and casing with a corrosion-resistant coating capable of withstanding a 500-hour salt-spray test according to ASTM B 117.
e. Sound-reduction package consisting of the following:
   1) Acoustic enclosure around compressors.
   2) Reduced-speed fans with acoustic treatment.
   3) Designed to reduce sound level without affecting performance.
f. Security Package: Provide security grilles with fasteners for additional protection of compressors, evaporator, and condenser coils. Grilles shall be coated for corrosion resistance and shall be removable for service access.

4. Compressors:
   a. Description: Positive-displacement direct drive with semihermetically sealed and accessible bolted casings.
   b. Each compressor provided with suction and discharge service valves, crankcase oil heater, and suction strainer.
   c. Operating Speed: 1750 rpm for 60-Hz applications.
   d. Capacity Control: Combinations of cylinder unloading and on-off compressor cycling of multiple compressors, plus hot-gas bypass, **as directed**. Compressor shall be capable of operating at part-load conditions without increased vibration over normal vibration at full-load operation and shall be capable of continuous operation at its lowest step of unloading.
   e. Oil Lubrication System: Automatically reversible, positive-displacement pump with strainer, sight glass, filling connection, filter with magnetic plug, and initial oil charge.
   f. Vibration Isolation: Mount individual compressors on spring isolators with an isolation efficiency of 95 percent.
5. Compressor Motors:
   a. Hermetically sealed and cooled by refrigerant suction gas.
   b. High-torque, four-pole induction type with inherent thermal-overload protection on each phase.
6. Compressor Motor Controllers:
   a. Across the Line: NEMA ICS 2, Class A, full voltage, nonreversing.
      OR
      Part-Wind Start: NEMA ICS 2, Class A, reduced voltage, nonreversing.
7. Refrigeration:
   a. Refrigerant: R-407C **OR** R-410A, **as directed**. Classified as Safety Group A1 according to ASHRAE 34.
   b. Refrigerant Compatibility: Parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
   c. Refrigerant Circuit: Each circuit shall include a thermal **OR** an electronic, **as directed**, expansion valve, refrigerant charging connections, a hot-gas muffler, compressor suction and discharge shutoff valves, a liquid-line shutoff valve, a replaceable-core filter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.
   d. Refrigerant Isolation: Factory install positive shutoff isolation valves in the compressor discharge line and the refrigerant liquid-line to allow the isolation and storage of the refrigerant charge in the chiller condenser.
8. Evaporator:
   a. Description: Direct-expansion shell-and-tube design with fluid flowing through the shell and refrigerant flowing through the tubes within the shell.
   b. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.

c. Shell Material: Carbon steel.
d. Shell Heads: Removable carbon-steel heads with multipass baffles designed to ensure positive oil return and located at each end of the tube bundle.
e. Shell Nozzles: Fluid nozzles located along the side of the shell and terminated with mechanical-coupling end connections for connection to field piping.
f. Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
g. Heater: Factory-installed and -wired electric heater with integral controls designed to protect the evaporator to minus 20 deg F (minus 29 deg C).
h. Remote Mounting: Designed for remote field mounting where indicated. Provide kit for field installation.

9. Air-Cooled Condenser:
   a. Plate-fin coil with integral subcooling circuit, leak tested at 150 psig (1034 kPa).
      1) Construct coils of copper tubes mechanically bonded to aluminum **OR** aluminum with precoated epoxy-phenolic **OR** copper, **as directed**, fins.
      2) Coat coils with a baked epoxy corrosion-resistant coating after fabrication.
      3) Hail Protection: Provide condenser coils with louvers, baffles, or hoods to protect against hail damage.
   b. Fans: Direct-drive propeller type with statically and dynamically balanced fan blades, arranged for vertical air discharge.
   c. Fan Motors: Totally enclosed air over (TEAO) enclosure, with permanently lubricated bearings, and having built-in overcurrent- and thermal-overload protection.
   d. Fan Guards: Steel safety guards with corrosion-resistant coating.

10. Electrical Power:
   a. Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to water chiller.
   b. House in a unit-mounted, NEMA 250, Type 3R **OR** Type 4, **as directed**, enclosure with hinged access door with lock and key or padlock and key.
   c. Wiring shall be numbered and color-coded to match wiring diagram.
   d. Install factory wiring outside of an enclosure in a raceway.
   e. Field power interface shall be to wire lugs **OR** NEMA KS 1, heavy-duty, nonfused disconnect switch, **as directed**.
   f. Provide branch power circuit to each motor and to controls with one of the following disconnecting means:
      1) NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
      2) NEMA KS 1, heavy-duty, nonfusible switch.
      3) NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
   g. Provide each motor with overcurrent protection.
   h. Overload relay sized according to UL 1995, or an integral component of water chiller control microprocessor.
   i. Phase-Failure and Undervoltage: Solid-state sensing with adjustable settings.
   j. Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.
      1) Power unit-mounted controls where indicated.
      2) Power unit-mounted, ground-fault interrupt (GFI) duplex receptacle.
   k. Control Relays: Auxiliary and adjustable time-delay relays.
   l. Indicate the following for water chiller electrical power supply:
      1) Current, phase to phase, for all three phases.
      2) Voltage, phase to phase and phase to neutral for all three phases.
      3) Three-phase real power (kilowatts).
      4) Three-phase reactive power (kilovolt amperes reactive).
      5) Power factor.
      6) Running log of total power versus time (kilowatt hours).
      7) Fault log, with time and date of each.

11. Controls:
    a. Stand-alone, microprocessor based.
    b. Enclosure: Share enclosure with electrical power devices or provide a separate enclosure of matching construction.
    c. Operator Interface: Keypad or pressure-sensitive touch screen. Multiple-character, backlit, liquid-crystal display or light-emitting diodes. Display the following:
        1) Date and time.
        2) Operating or alarm status.
        3) Operating hours.
        4) Outside-air temperature if required for chilled-water reset.
        5) Temperature and pressure of operating set points.
        6) Entering and leaving temperatures of chilled water.
        7) Refrigerant pressures in evaporator and condenser.
        8) Saturation temperature in evaporator and condenser.
        9) No cooling load condition.
        10) Elapsed time meter (compressor run status).
        11) Pump status.
        12) Antirecycling timer status.
        13) Percent of maximum motor amperage.
        14) Current-limit set point.
        15) Number of compressor starts.
    d. Control Functions:
        1) Manual or automatic startup and shutdown time schedule.
        2) Entering and leaving chilled-water temperature, control set points, and motor load limit. Chilled-water leaving temperature shall be reset based on return-water **OR** outside-air **OR** space, **as directed**, temperature.
        3) Current limit and demand limit.
        4) External water chiller emergency stop.
        5) Antirecycling timer.
        6) Automatic lead-lag switching.
    e. Manual-Reset Safety Controls: The following conditions shall shut down water chiller and require manual reset:
        1) Low evaporator pressure or high condenser pressure.
        2) Low chilled-water temperature.
        3) Refrigerant high pressure.
        4) High or low oil pressure.
        5) High oil temperature.
        6) Loss of chilled-water flow.
        7) Control device failure.
    f. Building Automation System Interface: Factory-installed hardware and software to enable building automation system to monitor, control, and display water chiller status and alarms.
        1) Hardwired Points:
            a) Monitoring: On/off status, common trouble alarm **OR** electrical power demand (kilowatts) **OR** electrical power consumption (kilowatt hours), **as directed**.
            b) Control: On/off operation, chilled-water discharge temperature set-point adjustment **OR** electrical power demand limit, **as directed**.
        2) ASHRAE 135 (BACnet) **OR** LonTalk **OR** Industry-accepted open-protocol, **as directed**, communication interface with building automation system shall enable building automation system operator to control and monitor the water chiller from a remote operator workstation. Control features and monitoring points displayed locally at water chiller control panel shall be available through building automation system.
12. Insulation:

a. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type I, for tubular materials and Type II, for sheet materials.
b. Thickness: 3/4 inch (19 mm).
c. Factory-applied insulation over cold surfaces of water chiller components.
1) Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.
d. Apply protective coating to exposed surfaces of insulation.

13. Accessories:
a. Factory-furnished, chilled-water and condenser-water, **as directed**, flow switches for field installation.
b. Individual compressor suction and discharge pressure gages with shutoff valves.
c. Factory-furnished spring isolators for field installation.

C. Packaged Refrigerant Recovery Units
1. Packaged portable unit shall consist of compressor, air-cooled condenser, recovery system, tank pressure gages, filter-dryer, and valving that allows for switching between liquid and vapor recovery mode. Refrigerant recovery unit shall be factory mounted on an ASME-constructed and -stamped refrigerant storage vessel that is sized to hold the full refrigerant charge of the largest water chiller.

D. Source Quality Control
1. Perform functional test of water chillers before shipping.
2. Factory performance test water chillers, **as directed**, before shipping, according to ARI 550/590, "Water Chilling Packages Using the Vapor Compression Cycle."
a. Allow the Owner access to place where water chillers are being tested. Notify the Owner 14 days in advance of testing.
3. Factory test and inspect evaporator and water-cooled condenser, **as directed**, according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1. Stamp with ASME label.
4. For water chillers located indoors, rate sound power level according to ARI 575 procedure.
5. For water chillers located outdoors, rate sound power level according to ARI 370 procedure.

1.3 EXECUTION

A. Water Chiller Installation
1. Install water chillers on support structure indicated.
2. Equipment Mounting: Install water chiller on concrete bases using elastomeric pads **OR** elastomeric mounts **OR** restrained spring isolators, **as directed**. Comply with requirements in Division 03 Section "Cast-in-place Concrete". Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
a. Minimum Deflection: 1/4 inch (6 mm) **OR** 1 inch (25 mm), **as directed**.
b. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
c. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
d. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
e. Install anchor bolts to elevations required for proper attachment to supported equipment.
3. Equipment Mounting: Install water chiller using elastomeric pads **OR** elastomeric mounts **OR** restrained spring isolators, **as directed**. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
a. Minimum Deflection: 1/4 inch (6 mm) **OR** 1 inch (25 mm), **as directed**.

4. Equipment Mounting: Install water chiller on vibration isolation inertia bases. Comply with requirements specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
5. Equipment Mounting: Install water chiller on concrete bases. Comply with requirements in Division 03 Section "Cast-in-place Concrete".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   d. Install anchor bolts to elevations required for proper attachment to supported equipment.
6. Maintain manufacturer's recommended clearances for service and maintenance.
7. Charge water chiller with refrigerant if not factory charged and fill with oil if not factory installed.
8. Install separate devices furnished by manufacturer and not factory installed.

B. Connections
1. Comply with requirements in Division 23 Section "Hydronic Piping". Drawings indicate general arrangement of piping, fittings, and specialties.
2. Comply with requirements in Division 23 Section "Refrigerant Piping". Drawings indicate general arrangement of piping, fittings, and specialties.
3. Install piping adjacent to chiller to allow service and maintenance.
4. Evaporator Fluid Connections: Connect to evaporator inlet with shutoff valve, strainer, **as directed**, flexible connector, **as directed**, thermometer, and plugged tee with pressure gage. Connect to evaporator outlet with shutoff valve, balancing valve, flexible connector, **as directed**, flow switch, thermometer, plugged tee with pressure gage, flow meter, **as directed**, and drain connection with valve. Make connections to water chiller with a union **OR** flange **OR** mechanical coupling, **as directed**.
5. Condenser Fluid Connections: Connect to condenser inlet with shutoff valve, strainer, **as directed**, flexible connector, **as directed**, thermometer, and plugged tee with pressure gage. Connect to condenser outlet with shutoff valve, balancing valve, flexible connector, **as directed**, flow switch, thermometer, plugged tee with pressure gage, flow meter, **as directed**, and drain connection with valve. Make connections to water chiller with a union **OR** flange **OR** mechanical coupling, **as directed**.
6. Refrigerant Pressure Relief Valve Connections: For water chillers installed indoors, extend vent piping to the outside without valves or restrictions. Comply with ASHRAE 15, **as directed**.
7. Connect each drain connection with a union and drain pipe, and extend pipe, full size of connection, to floor drain. Provide a shutoff valve at each connection if required.

C. Startup Service
1. Perform startup service.
2. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assemblies, installations, and connections.
3. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
   a. Verify that refrigerant charge is sufficient and water chiller has been leak tested.
   b. Verify that pumps are installed and functional.
   c. Verify that thermometers and gages are installed.
   d. Operate water chiller for run-in period.
   e. Check bearing lubrication and oil levels.
   f. Verify that refrigerant pressure relief for chillers installed indoors is vented outside.
   g. Verify proper motor rotation.
   h. Verify static deflection of vibration isolators, including deflection during water chiller startup and shutdown.

i. Verify and record performance of chilled-water and condenser-water, **as directed**, flow and low-temperature interlocks.
j. Verify and record performance of water chiller protection devices.
k. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.

4. Prepare a written startup report that records results of tests and inspections.

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SECTION 23 64 23 00 - SCROLL WATER CHILLERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for scroll water chillers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Packaged, water-cooled, electric-motor-driven, scroll water chillers.
b. Packaged, air-cooled, electric-motor-driven, scroll water chillers.
c. Packaged refrigerant recovery units.

C. Definitions
1. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input using consistent units for any given set of rating conditions.
2. EER: Energy-efficiency ratio. The ratio of the cooling capacity given in terms of Btu/h to the total power input given in terms of watts at any given set of rating conditions.
3. IPLV: Integrated part-load value. A single number part-load efficiency figure of merit calculated per the method defined by ARI 550/590 and referenced to ARI standard rating conditions.
4. kW/Ton: The ratio of total power input of the chiller in kilowatts to the net refrigerating capacity in tons at any given set of rating conditions.
5. NPLV: Nonstandard part-load value. A single number part-load efficiency figure of merit calculated per the method defined by ARI 550/590 and intended for operating conditions other than the ARI standard rating conditions.

D. Performance Requirements
1. Seismic Performance: Scroll water chillers shall withstand the effects of earthquake motions determined according to SEI/ASCE 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

E. Submittals
1. Product Data: Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.
2. LEED Submittal:
a. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.
3. Certificates: For certification required in "Quality Assurance" Article.
4. Seismic Qualification Certificates: For water chillers, accessories, and components from manufacturers.
a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
5. Startup service reports.
6. Operation and maintenance data.
7. Warranty: Sample of special warranty.

F. Quality Assurance
1. ARI Certification: Certify chiller according to ARI 590 certification program.
2. ARI Rating: Rate water chiller performance according to requirements in ARI 550/590, "Water Chilling Packages Using the Vapor Compression Cycle."
3. ASHRAE Compliance: ASHRAE 15 for safety code for mechanical refrigeration.
4. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
5. ASME Compliance: Fabricate and stamp water chiller heat exchangers to comply with ASME Boiler and Pressure Vessel Code.
6. Comply with NFPA 70.

G. Delivery, Storage, And Handling
1. Ship water chillers from the factory fully charged with refrigerant and filled with oil.
2. Package water chiller for export shipping.

H. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of water chillers that fail in materials or workmanship within five years from date of Final Completion.

1.2 PRODUCTS

A. Packaged Water-Cooled Water Chillers
1. Description: Factory-assembled and run-tested water chiller complete with compressor(s), compressor motors and motor controllers, evaporator, condenser where indicated, electrical power, controls, and indicated accessories.
2. Fabricate water chiller mounting base with reinforcement strong enough to resist water chiller movement during a seismic event when water chiller is anchored to field support structure.
3. Compressors:
   a. Description: Positive-displacement direct drive with hermetically sealed casing.
   b. Each compressor provided with suction and discharge service valves, crankcase oil heater, and suction strainer.
   c. Operating Speed: Nominal 3600 rpm for 60-Hz applications.
   d. Capacity Control: On-off compressor cycling, plus hot-gas bypass, **as directed**.
   e. Oil Lubrication System: Automatic pump with strainer, sight glass, filling connection, filter with magnetic plug, and initial oil charge.
   f. Vibration Isolation: Mount individual compressors on vibration isolators.
   g. Sound-reduction package shall consist of acoustic enclosures around the compressors that are designed to reduce sound level without affecting performance.
4. Compressor Motors:
   a. Hermetically sealed and cooled by refrigerant suction gas.
   b. High-torque, two-pole induction type with inherent thermal-overload protection on each phase.
5. Compressor Motor Controllers:
   a. Across the Line: NEMA ICS 2, Class A, full voltage, nonreversing.
6. Refrigeration:
   a. Refrigerant: R-407C **OR** R-410A, **as directed**2. Classified as Safety Group A1 according to ASHRAE 34.
   b. Refrigerant Compatibility: Parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
   c. Refrigerant Circuit: Each circuit shall include a thermal-expansion valve, refrigerant charging connections, a hot-gas muffler, compressor suction and discharge shutoff valves, a liquid-line shutoff valve, a replaceable-core filter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.

d. Refrigerant Isolation: Factory install positive shutoff isolation valves in the compressor discharge line and the refrigerant liquid-line to allow the isolation and storage of the refrigerant charge in the chiller condenser.

7. Evaporator:
   a. Brazed-plate or shell-and-tube design, as indicated.
   b. Shell and Tube:
      1) Description: Direct-expansion, shell-and-tube design with fluid flowing through the shell and refrigerant flowing through the tubes within the shell.
      2) Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
      3) Shell Material: Carbon steel.
      4) Shell Heads: Removable carbon-steel heads with multipass baffles designed to ensure positive oil return and located at each end of the tube bundle.
      5) Shell Nozzles: Fluid nozzles located along the side of the shell and terminated with mechanical-coupling end connections for connection to field piping.
      6) Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
   c. Brazed Plate:
      1) Direct-expansion, single-pass, brazed-plate design.
      2) Type 316 stainless-steel construction.
      3) Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
      4) Fluid Nozzles: Terminate with mechanical-coupling end connections for connection to field piping.
8. Condenser:
   a. Shell and tube or without integral condenser; as indicated.
   b. Shell and Tube:
      1) Description: Shell-and-tube design with refrigerant flowing through the shell and fluid flowing through the tubes within the shell.
      2) Provides positive subcooling of liquid refrigerant.
      3) Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
      4) Shell Material: Carbon steel.
      5) Water Boxes: Removable, of carbon-steel construction, located at each end of the tube bundle with fluid nozzles terminated with mechanical-coupling end connections for connection to field piping.
      6) Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
      7) Provide each condenser with a pressure relief device, purge cock, and liquid-line shutoff valve.
   c. Provide water chiller without an integral condenser and design chiller for field connection to remote condenser. Coordinate requirements with Division 23 Section "Air-cooled Refrigerant Condensers".
9. Electrical Power:
   a. Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to water chiller.
   b. House in a unit-mounted, NEMA 250, Type 1, **as directed**, enclosure with hinged access door with lock and key or padlock and key.
   c. Wiring shall be numbered and color-coded to match wiring diagram.
   d. Install factory wiring outside of an enclosure in a raceway.
   e. Field power interface shall be to wire lugs **OR** NEMA KS 1, heavy-duty, nonfused disconnect switch, **as directed**.
   f. Provide branch power circuit to each motor and to controls with one of the following disconnecting means:
      1) NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.

2) NEMA KS 1, heavy-duty, nonfusible switch.
3) NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.

g. Provide each motor with overcurrent protection.
h. Overload relay sized according to UL 1995, or an integral component of water chiller control microprocessor.
i. Phase-Failure and Undervoltage: Solid-state sensing with adjustable settings.
j. Controls Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.
k. Control Relays: Auxiliary and adjustable time-delay relays.
l. Indicate the following for water chiller electrical power supply:
1) Current, phase to phase, for all three phases.
2) Voltage, phase to phase and phase to neutral for all three phases.
3) Three-phase real power (kilowatts).
4) Three-phase reactive power (kilovolt amperes reactive).
5) Power factor.
6) Running log of total power versus time (kilowatt hours).
7) Fault log, with time and date of each.

10. Controls:
a. Stand-alone, microprocessor based.
b. Enclosure: Share enclosure with electrical power devices or provide a separate enclosure of matching construction.
c. Operator Interface: Keypad or pressure-sensitive touch screen. Multiple-character, backlit, liquid-crystal display or light-emitting diodes. Display the following:
1) Date and time.
2) Operating or alarm status.
3) Operating hours.
4) Outside-air temperature if required for chilled-water reset.
5) Temperature and pressure of operating set points.
6) Entering and leaving temperatures of chilled water.
7) Entering and leaving temperatures of condenser water.
8) Refrigerant pressures in evaporator and condenser.
9) Saturation temperature in evaporator and condenser.
10) No cooling load condition.
11) Elapsed time meter (compressor run status).
12) Pump status.
13) Antirecycling timer status.
14) Percent of maximum motor amperage.
15) Current-limit set point.
16) Number of compressor starts.
d. Control Functions:
1) Manual or automatic startup and shutdown time schedule.
2) Entering and leaving chilled-water temperatures, control set points, and motor load limit. Chilled-water leaving temperature shall be reset based on return-water **OR** outside-air **OR** space, **as directed**, temperature.
3) Current limit and demand limit.
4) Condenser-water temperature.
5) External water chiller emergency stop.
6) Antirecycling timer.
7) Automatic lead-lag switching.
e. Manual-Reset Safety Controls: The following conditions shall shut down water chiller and require manual reset:
1) Low evaporator pressure or high condenser pressure.
2) Low chilled-water temperature.
3) Refrigerant high pressure.

4) High or low oil pressure.
5) High oil temperature.
6) Loss of chilled-water flow.
7) Loss of condenser-water flow.
8) Control device failure.

f. Building Automation System Interface: Factory-installed hardware and software to enable building automation system to monitor, control, and display water chiller status and alarms.
1) Hardwired Points:
a) Monitoring: On/off status, common trouble alarm **OR** electrical power demand (kilowatts) **OR** electrical power consumption (kilowatt hours), **as directed**.
b) Control: On/off operation, chilled-water discharge temperature set-point adjustment **OR** electrical power demand limit, **as directed**.
2) ASHRAE 135 (BACnet) **OR** LonTalk **OR** Modbus **OR** Industry-accepted open-protocol, **as directed**, communication interface with building automation system shall enable building automation system operator to remotely control and monitor the water chiller from an operator workstation. Control features and monitoring points displayed locally at water chiller control panel shall be available through building automation system.

11. Insulation:
a. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type I, for tubular materials and Type II, for sheet materials.
b. Thickness: 3/4 inch (19 mm).
c. Factory-applied insulation over cold surfaces of water chiller components.
1) Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.
d. Apply protective coating to exposed surfaces of insulation.

12. Accessories:
a. Factory-furnished, chilled-water and condenser-water, **as directed**, flow switches for field installation.
b. Individual compressor suction and discharge pressure gages with shutoff valves for each refrigeration circuit.
c. Factory-furnished neoprene **OR** spring, **as directed**, isolators for field installation.

B. Packaged Air-Cooled Water Chillers
1. Description: Factory-assembled and run-tested water chiller complete with base and frame, condenser casing, compressors, compressor motors and motor controllers, evaporator, condenser coils, condenser fans and motors, electrical power, controls, and accessories.
2. Fabricate base, frame, and attachment to water chiller components strong enough to resist movement during a seismic event when water chiller base is anchored to field support structure.
3. Cabinet:
a. Base: Galvanized-steel base extending the perimeter of water chiller. Secure frame, compressors, and evaporator to base to provide a single-piece unit.
b. Frame: Rigid galvanized-steel frame secured to base and designed to support cabinet, condenser, control panel, and other chiller components not directly supported from base.
c. Casing: Galvanized steel.
d. Finish: Coat base, frame, and casing with a corrosion-resistant coating capable of withstanding a 500-hour salt-spray test according to ASTM B 117.
e. Sound-reduction package consisting of the following:
1) Acoustic enclosure around compressors.
2) Reduced-speed fans with acoustic treatment.
3) Designed to reduce sound level without affecting performance.
f. Security Package: Provide security grilles with fasteners for additional protection of compressors, evaporator, and condenser coils. Grilles shall be coated for corrosion resistance and shall be removable for service access.
4. Compressors:

a. Description: Positive-displacement direct drive with hermetically sealed casing.
b. Each compressor provided with suction and discharge service valves, crankcase oil heater, and suction strainer.
c. Operating Speed: Nominal 3600 rpm for 60-Hz applications.
d. Capacity Control: On-off compressor cycling, plus hot-gas bypass, **as directed**.
e. Oil Lubrication System: Automatic pump with strainer, sight glass, filling connection, filter with magnetic plug, and initial oil charge.
f. Vibration Isolation: Mount individual compressors on vibration isolators.

5. Compressor Motors:
   a. Hermetically sealed and cooled by refrigerant suction gas.
   b. High-torque, two-pole induction type with inherent thermal-overload protection on each phase.
6. Compressor Motor Controllers:
   a. Across the Line: NEMA ICS 2, Class A, full voltage, nonreversing.
7. Refrigeration:
   a. Refrigerant: R-407c **OR** R-410a, **as directed**. Classified as Safety Group A1 according to ASHRAE 34.
   b. Refrigerant Compatibility: Parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
   c. Refrigerant Circuit: Each circuit shall include a thermal-expansion valve, refrigerant charging connections, a hot-gas muffler, compressor suction and discharge shutoff valves, a liquid-line shutoff valve, a replaceable-core filter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.
   d. Refrigerant Isolation: Factory install positive shutoff isolation valves in the compressor discharge line and the refrigerant liquid-line to allow the isolation and storage of the refrigerant charge in the chiller condenser.
8. Evaporator:
   a. Brazed-plate or shell-and-tube design, as indicated.
   b. Shell and Tube:
      1) Description: Direct-expansion, shell-and-tube design with fluid flowing through the shell and refrigerant flowing through the tubes within the shell.
      2) Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
      3) Shell Material: Carbon steel.
      4) Shell Heads: Removable carbon-steel heads with multipass baffles designed to ensure positive oil return and located at each end of the tube bundle.
      5) Shell Nozzles: Fluid nozzles located along the side of the shell and terminated with mechanical-coupling end connections for connection to field piping.
      6) Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
   c. Brazed Plate:
      1) Direct-expansion, single-pass, brazed-plate design.
      2) Type 316 stainless-steel construction.
      3) Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
      4) Fluid Nozzles: Terminate with mechanical-coupling end connections for connection to field piping.
   d. Heater: Factory-installed and -wired electric heater with integral controls designed to protect the evaporator to minus 20 deg F (minus 29 deg C).
   e. Remote Mounting: Designed for remote field mounting where indicated. Provide kit for field installation.
9. Air-Cooled Condenser:
   a. Plate-fin coil with integral subcooling on each circuit, rated at 450 psig (3103 kPa).
      1) Construct coils of copper tubes mechanically bonded to aluminum **OR** aluminum with precoated epoxy-phenolic **OR** copper, **as directed**, fins.

2) Coat coils with a baked epoxy corrosion-resistant coating after fabrication.
3) Hail Protection: Provide condenser coils with louvers, baffles, or hoods to protect against hail damage.

b. Fans: Direct-drive propeller type with statically and dynamically balanced fan blades, arranged for vertical air discharge.

c. Fan Motors: Totally enclosed nonventilating (TENV) or totally enclosed air over (TEAO) enclosure, with permanently lubricated bearings, and having built-in overcurrent- and thermal-overload protection.

d. Fan Guards: Steel safety guards with corrosion-resistant coating.

10. Electrical Power:

a. Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to water chiller.

b. House in a unit-mounted, NEMA 250, Type 3R, **as directed**, enclosure with hinged access door with lock and key or padlock and key.

c. Wiring shall be numbered and color-coded to match wiring diagram.

d. Install factory wiring outside of an enclosure in a raceway.

e. Field power interface shall be to wire lugs **OR** NEMA KS 1, heavy-duty, nonfused disconnect switch, **as directed**.

f. Provide branch power circuit to each motor and to controls with one of the following disconnecting means:

1) NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
2) NEMA KS 1, heavy-duty, nonfusible switch.
3) NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.

g. Provide each motor with overcurrent protection.

h. Overload relay sized according to UL 1995, or an integral component of water chiller control microprocessor.

i. Phase-Failure and Undervoltage: Solid-state sensing with adjustable settings.

j. Provide power factor correction capacitors to correct power factor to 0.90 **OR** 0.95, **as directed**, at full load.

k. Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.

1) Power unit-mounted controls where indicated.
2) Power unit-mounted, ground fault interrupt (GFI) duplex receptacle.

l. Control Relays: Auxiliary and adjustable time-delay relays.

m. Indicate the following for water chiller electrical power supply:

1) Current, phase to phase, for all three phases.
2) Voltage, phase to phase and phase to neutral for all three phases.
3) Three-phase real power (kilowatts).
4) Three-phase reactive power (kilovolt amperes reactive).
5) Power factor.
6) Running log of total power versus time (kilowatt hours).
7) Fault log, with time and date of each.

11. Controls:

a. Stand-alone, microprocessor based.

b. Enclosure: Share enclosure with electrical power devices or provide a separate enclosure of matching construction.

c. Operator Interface: Keypad or pressure-sensitive touch screen. Multiple-character, backlit, liquid-crystal display or light-emitting diodes. Display the following:

1) Date and time.
2) Operating or alarm status.
3) Operating hours.
4) Outside-air temperature if required for chilled-water reset.
5) Temperature and pressure of operating set points.
6) Entering and leaving temperatures of chilled water.

7) Refrigerant pressures in evaporator and condenser.
8) Saturation temperature in evaporator and condenser.
9) No cooling load condition.
10) Elapsed time meter (compressor run status).
11) Pump status.
12) Antirecycling timer status.
13) Percent of maximum motor amperage.
14) Current-limit set point.
15) Number of compressor starts.

d. Control Functions:
1) Manual or automatic startup and shutdown time schedule.
2) Entering and leaving chilled-water temperatures, control set points, and motor load limit. Chilled-water leaving temperature shall be reset based on return-water **OR** outside-air **OR** space, **as directed**, temperature.
3) Current limit and demand limit.
4) External water chiller emergency stop.
5) Antirecycling timer.
6) Automatic lead-lag switching.

e. Manual-Reset Safety Controls: The following conditions shall shut down water chiller and require manual reset:
1) Low evaporator pressure or high condenser pressure.
2) Low chilled-water temperature.
3) Refrigerant high pressure.
4) High or low oil pressure.
5) High oil temperature.
6) Loss of chilled-water flow.
7) Control device failure.

f. Building Automation System Interface: Factory-installed hardware and software to enable building automation system to monitor, control, and display water chiller status and alarms.
1) Hardwired Points:
a) Monitoring: On/off status, common trouble alarm **OR** electrical power demand (kilowatts) **OR** electrical power consumption (kilowatt hours), **as directed**.
b) Control: On/off operation, chilled-water discharge temperature set-point adjustment **OR** electrical power demand limit, **as directed**.
2) ASHRAE 135 (BACnet) **OR** LonTalk **OR** Industry-accepted open-protocol, **as directed**, communication interface with building automation system shall enable building automation system operator to remotely control and monitor the water chiller from an operator workstation. Control features and monitoring points displayed locally at water chiller control panel shall be available through building automation system.

12. Insulation:
a. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type I, for tubular materials and Type II, for sheet materials.
b. Thickness: 3/4 inch (19 mm) **OR** 1-1/2 inches (38 mm), **as directed**.
c. Factory-applied insulation over cold surfaces of water chiller components.
1) Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.
d. Apply protective coating to exposed surfaces of insulation.

13. Accessories:
a. Factory-furnished, chilled-water and condenser-water, **as directed**, flow switches for field installation.
b. Individual compressor suction and discharge pressure gages with shutoff valves for each refrigeration circuit.
c. Factory-furnished neoprene **OR** spring, **as directed**, isolators for field installation.

C. Packaged Refrigerant Recovery Units
1. Packaged portable unit shall consist of compressor, air-cooled condenser, recovery system, tank pressure gages, filter-dryer, and valving that allows for switching between liquid and vapor recovery mode. Refrigerant recovery unit shall be factory mounted on an ASME-constructed and -stamped refrigerant storage vessel that is sized to hold the full refrigerant charge of the largest water chiller.

D. Source Quality Control
1. Perform functional test of water chillers before shipping.
2. Factory performance test water chillers, **as directed**, before shipping, according to ARI 550/590, "Water Chilling Packages Using the Vapor Compression Cycle."
   a. Allow the Owner access to place where water chillers are being tested. Notify the Owner 14 days in advance of testing.
3. Factory test and inspect evaporator and water-cooled condenser, **as directed**, according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1. Stamp with ASME label.
4. For water chillers located indoors, rate sound power level according to ARI 575 procedure.
5. For water chillers located outdoors, rate sound power level according to ARI 370 procedure.

1.3 EXECUTION

A. Water Chiller Installation
1. Install water chillers on support structure indicated.
2. Equipment Mounting: Install water chiller on concrete bases using elastomeric pads **OR** elastomeric mounts **OR** restrained spring isolators, **as directed**. Comply with requirements in Division 03 Section "Cast-in-place Concrete". Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   a. Minimum Deflection: 1/4 inch (6 mm) **OR** 1 inch (25 mm), **as directed**.
   b. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   c. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   d. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   e. Install anchor bolts to elevations required for proper attachment to supported equipment.
3. Equipment Mounting: Install water chiller using elastomeric pads **OR** elastomeric mounts **OR** restrained spring isolators, **as directed**. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   a. Minimum Deflection: 1/4 inch (6 mm) **OR** 1 inch (25 mm), **as directed**.
4. Equipment Mounting: Install water chiller on vibration isolation inertia bases. Comply with requirements specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
5. Equipment Mounting: Install water chiller on concrete bases. Comply with requirements in Division 03 Section "Cast-in-place Concrete".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   d. Install anchor bolts to elevations required for proper attachment to supported equipment.
6. Maintain manufacturer's recommended clearances for service and maintenance.
7. Charge water chiller with refrigerant if not factory charged and fill with oil if not factory installed.
8. Install separate devices furnished by manufacturer and not factory installed.

B. Connections
1. Comply with requirements in Division 23 Section "Hydronic Piping". Drawings indicate general arrangement of piping, fittings, and specialties.
2. Comply with requirements in Division 23 Section "Refrigerant Piping". Drawings indicate general arrangement of piping, fittings, and specialties.
3. Install piping adjacent to chiller to allow service and maintenance.
4. Evaporator Fluid Connections: Connect to evaporator inlet with shutoff valve, strainer, **as directed**, flexible connector, **as directed**, thermometer, and plugged tee with pressure gage. Connect to evaporator outlet with shutoff valve, balancing valve, flexible connector, **as directed**, flow switch, thermometer, plugged tee with pressure gage, flow meter, **as directed**, and drain connection with valve. Make connections to water chiller with a union **OR** flange **OR** mechanical coupling, **as directed**.
5. Condenser Fluid Connections: Connect to condenser inlet with shutoff valve, strainer, **as directed**, flexible connector, **as directed**, thermometer, and plugged tee with pressure gage. Connect to condenser outlet with shutoff valve, balancing valve, flexible connector, **as directed**, flow switch, thermometer, plugged tee with pressure gage, flow meter, **as directed**, and drain connection with valve. Make connections to water chiller with a union **OR** flange **OR** mechanical coupling, **as directed**.
6. Refrigerant Pressure Relief Valve Connections: For water chillers installed indoors, extend vent piping to the outside without valves or restrictions. Comply with ASHRAE 15, **as directed**.
7. Connect each drain connection with a union and drain pipe and extend pipe, full size of connection, to floor drain. Provide a shutoff valve at each connection if required.

C. Startup Service
1. Perform startup service.
2. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assemblies, installations, and connections.
3. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
   a. Verify that refrigerant charge is sufficient and water chiller has been leak tested.
   b. Verify that pumps are installed and functional.
   c. Verify that thermometers and gages are installed.
   d. Operate water chiller for run-in period.
   e. Check bearing lubrication and oil levels.
   f. Verify that refrigerant pressure relief device for chillers installed indoors is vented outside.
   g. Verify proper motor rotation.
   h. Verify static deflection of vibration isolators, including deflection during water chiller startup and shutdown.
   i. Verify and record performance of chilled-water and condenser-water, **as directed**, flow and low-temperature interlocks.
   j. Verify and record performance of water chiller protection devices.
   k. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.
4. Prepare a written startup report that records results of tests and inspections.

END OF SECTION 23 64 23 00

Task	Specification	Specification Description
23 64 23 00	23 64 19 00	Reciprocating Water Chillers
23 64 26 00	23 61 16 00a	Rotary-Screw Water Chillers

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SECTION 23 65 00 00 - COOLING TOWERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for cooling towers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Closed-circuit, forced-draft, counterflow cooling towers.
b. Closed-circuit, induced-draft, combined-flow cooling towers.
c. Closed-circuit, induced-draft, counterflow cooling towers.
d. Open-circuit, forced-draft, counterflow cooling towers.
e. Open-circuit, induced-draft, counterflow cooling towers.
f. Open-circuit, induced-draft, crossflow cooling towers.

C. Definitions
1. BMS: Building management system.
2. FRP: Fiber-reinforced polyester.

D. Performance Requirements
1. Delegated Design: Design cooling tower support structure and seismic restraints, **as directed**, and wind restraints, **as directed**, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
2. Structural Performance: Cooling tower support structure shall withstand the effects of gravity loads and loads and stresses within limits and under conditions indicated according to SEI/ASCE 7.
3. Seismic Performance: Cooling towers shall withstand the effects of earthquake motions determined according to SEI/ASCE 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

E. Submittals
1. Product Data: For each type of product indicated. Include rated capacities, pressure drop, fan performance data, rating curves with selected points indicated, furnished specialties, and accessories.
a. Maximum flow rate.
b. Minimum flow rate.
c. Drift loss as percent of design flow rate.
d. Volume of water in suspension for purposes of sizing a remote storage tank.
e. Sound power levels in eight octave bands for operation with fans off, fans at minimum, and design speed.
f. Performance curves for the following:
1) Varying entering-water temperatures from design to minimum.
2) Varying ambient wet-bulb temperatures from design to minimum.
3) Varying water flow rates from design to minimum.
4) Varying fan operation (off, minimum, and design speed).
g. Fan airflow, brake horsepower, and drive losses.
h. Pump flow rate, head, brake horsepower, and efficiency.

i. Motor amperage, efficiency, and power factor at 100, 75, 50, and 25 percent of nameplate horsepower.
j. Electrical power requirements for each cooling tower component requiring power.

2. Shop Drawings: Complete set of manufacturer's prints of cooling tower assemblies, control panels, sections and elevations, and unit isolation. Include the following:
   a. Assembled unit dimensions.
   b. Weight and load distribution.
   c. Required clearances for maintenance and operation.
   d. Sizes and locations of piping and wiring connections.
   e. Wiring Diagrams: For power, signal, and control wiring.
3. Delegated-Design Submittal: For cooling tower support structure indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
   a. Detail fabrication and assembly of support structure.
   b. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
   c. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints, **as directed**, and wind restraints, **as directed**, and for designing vibration isolation bases.
   d. Coordination Drawings: Floor plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:
   e. Structural supports.
   f. Piping roughing-in requirements.
   g. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
   h. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.
4. Certificates: For certification required in "Quality Assurance" Article.
5. Seismic Qualification Certificates: For cooling towers, accessories, and components, from manufacturers.
   a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
   c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
6. Source quality-control reports.
7. Field quality-control reports.
8. Startup service reports.
9. Operation and Maintenance Data: For each cooling tower to include in emergency, operation, and maintenance manuals.
10. Warranty: Sample of special warranty.

F. Quality Assurance
1. Testing Agency Qualifications: Certified by CTI **OR** An NRTL, **as directed**.
2. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
3. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
4. ASME Compliance: Fabricate and label heat-exchanger coils to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
5. CTI Certification: Cooling tower thermal performance according to CTI STD 201, "Certification Standard for Commercial Water-Cooling Towers Thermal Performance."
6. FMG approval and listing in the latest edition of FMG's "Approval Guide."

G. Coordination
1. Coordinate sizes and locations of concrete bases with actual equipment provided.
2. Coordinate sizes, locations, and anchoring attachments of structural-steel support structures.
3. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

H. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace the following components of cooling towers that fail in materials or workmanship within specified warranty period:
   a. Fan assembly including fan, drive, and motor.
   b. All components of cooling tower.
   c. Warranty Period: Five years from date of Final Completion.

1.2 PRODUCTS

A. Closed-Circuit, Forced-Draft, Counterflow Cooling Towers
1. Fabricate cooling tower mounting base with reinforcement strong enough to resist cooling tower movement during a seismic event when cooling tower is anchored to field support structure.
2. Cooling tower designed to resist wind load of 30 lbf/sq. ft. (1.44 kPa) **OR as directed**.
3. Casing and Frame:
   a. Casing **OR** Casing and Frame, **as directed**, Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Polymer-coated galvanized steel **OR** Stainless steel, **as directed**.
   b. Frame Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Polymer-coated galvanized steel **OR** Stainless steel, **as directed**.
   c. Fasteners: Galvanized **OR** Stainless, **as directed**, steel.
   d. Joints and Seams: Sealed watertight.
   e. Welded Connections: Continuous and watertight.
4. Collection Basin: Configure tower for installation with a field-constructed collection basin.
   OR
   Collection Basin:
   a. Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Polymer-coated galvanized steel **OR** Stainless steel, **as directed**.
   b. Strainer: Removable stainless-steel, **as directed**, strainer with openings smaller than nozzle orifices.
   c. Overflow and drain connections.
   d. Makeup water connection.
   e. Basin Sweeper Distribution Piping and Nozzles:
      1) Pipe Material: PVC.
      2) Nozzle Material: Plastic.
      3) Configure piping and nozzles to minimize sediment from collecting in the collection basin.
5. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.
   OR
   Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:
   a. Enclosure: NEMA 250, Type 4 **OR** Type 4X, **as directed**.
   b. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide control of water makeup valve **OR** control of water makeup valve and low-level alarm **OR** control of water makeup valve and low- and high-level alarms **OR**

control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level, **as directed**.

c. Electrode Probes: Stainless steel.

d. Water Stilling Chamber: Corrosion-resistant material **OR** FRP **OR** Galvanized steel **OR** PVC pipe **OR** Stainless steel, **as directed**.

e. Solenoid Valve: Slow closing with stainless-steel body, **as directed**, controlled and powered through level controller in response to water-level set point.

f. Electrical Connection Requirements: 120 V, single phase, 60 Hz.

6. Electric Basin Heater:

a. Stainless-Steel Electric Immersion Heaters: Installed in a threaded coupling on the side of the collection basin.

b. Heater Control Panel: Mounted on the side of each cooling tower cell.

c. Enclosure: NEMA 250, Type 3R **OR** Type 4 **OR** Type 4X, **as directed**.

d. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.

e. Control-circuit transformer with primary and secondary side fuses.

f. Terminal blocks with numbered and color-coded wiring to match wiring diagram.

g. Single-point, field-power connection to a fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**, and heater branch circuiting complying with NFPA 70.

h. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.

OR

Hot-Water-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.

OR

Steam-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.

OR

Steam-Injector Basin Heater: Manufacturer's standard offering to provide capacity indicated.

7. Water Distribution Piping: Main header and lateral branch piping designed for even distribution over fill throughout the flow range without the need for balancing valves and for connecting individual, removable, nonclogging spray nozzles.

a. Pipe Material: Fiberglass **OR** PVC **OR** Galvanized steel, **as directed**.

b. Spray Nozzle Material: Plastic **OR** Polypropylene **OR** PVC, **as directed**.

c. Piping Supports: Corrosion-resistant hangers and supports designed to resist movement during operation and shipment.

8. Recirculating Piping: PVC, **as directed**, with connections for separately provided, remote spray pump, **as directed**.

9. Spray Pump: Close-coupled, end-suction, single-stage, bronze-fitted centrifugal pump; with suction strainer and flow balancing valve, and mechanical seal suitable for outdoor service.

a. General Requirements for Spray Pump Motor: Comply with NEMA designation and temperature-rating requirements specified in Division 15 Section "Common Motor Requirements for HVAC Equipment" and not indicated below.

b. Motor Enclosure: Totally enclosed **OR** Totally enclosed nonventilated (TENV) **OR** Totally enclosed fan cooled (TEFC), **as directed**, with epoxy or polyurethane finish, **as directed**.

c. Energy Efficiency: Comply with ASHRAE/IESNA 90.1 **OR** NEMA Premium Efficient, **as directed**.

d. Service Factor: 1.0 **OR** 1.15, **as directed**.

10. Heat-Exchanger Coils:

a. Tube and Tube Sheet Materials: Copper tube with stainless-steel sheet **OR** Stainless-steel tube and sheet **OR** Prime-coated steel tube and sheet with outer surface of tube and sheet hot-dip galvanized after fabrication, **as directed**.

b. Heat-Exchanger Arrangement: Serpentine tubes **OR** Serpentine tubes with removable cover plate on inlet and outlet headers **OR** Straight tubes with removable header cover

plate on both ends of heat exchanger for straight-through access to each tube, **as directed**; and sloped for complete drainage of fluid by gravity.

OR

ASME Compliance: Designed, manufactured, and tested according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, and bearing ASME "U" stamp; and sloped for complete drainage of fluid by gravity.

c. Field Piping Connections: Vent, supply, and return suitable for mating to ASME B16.5, Class 150 flange, **as directed**.

11. Removable, **as directed**, Drift Eliminator:
    a. Material: FRP **OR** PVC, **as directed**; with maximum flame-spread index of 5 **OR** 25, **as directed**, according to ASTM E 84.
    b. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
    c. Configuration: Multipass, designed and tested to reduce water carryover to achieve performance indicated.
12. Removable, **as directed**, Air-Intake Screens: Galvanized **OR** Polymer-coated, galvanized **OR** Stainless, **as directed**,-steel wire mesh.
13. Centrifugal Fan: Double-width, double-inlet, forward-curved blades, and statically and dynamically balanced at the factory after assembly.
    a. Number of Fans: Each cooling tower cell shall have a single fan or multiple fans connected to a common shaft.
    b. Fan Wheel and Housing Materials: Galvanized steel.
    c. Fan Shaft: Steel, coated to resist corrosion.
    d. Protective Enclosure: Removable, galvanized-steel, wire-mesh screens complying with OSHA regulations.
    e. Fan Shaft Bearings: Self-aligning, grease-lubricated ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between minus 20 and plus 300 deg F (minus 29 and plus 149 deg C). Bearings designed for an L-10 life of 40,000 **OR** 50,000, **as directed**, hours.
    f. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.
14. Belt Drive:
    a. Belt-Drive Service Factor: 1.5 based on motor nameplate horsepower.
    b. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
    c. Belt: Multiple V-belt design with a matched set of cogged, **as directed**, belts.

       OR

       Belt: One-piece, multigrooved, solid-back belt.
    d. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
    e. Belt-Drive Guard: Comply with OSHA regulations.
    f. Two-Motor, Single-Fan Drive:
       1) Two single-speed motors per fan, one sized for full speed and load, and the other sized for 67 percent of full-load speed.
       2) Belt Drives: Each motor shall have belt drive complying with requirements for belt drives and configured for operation when other motor fails.
       3) Motor controller and wiring same as two-speed, two-winding motor.
15. Fan Motor:
    a. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment" and not indicated below.
    b. Motor Enclosure: Totally enclosed **OR** Totally enclosed air over (TEAO) **OR** Totally enclosed fan cooled (TEFC), **as directed**, with epoxy or polyurethane finish, **as directed**.
    c. Energy Efficiency: Comply with ASHRAE/IESNA 90.1 **OR** NEMA Premium Efficient, **as directed**.
    d. Service Factor: 1.15.
    e. Insulation: Class F **OR** Class H, **as directed**.

f. Variable-Speed Motors: Inverter-duty rated per NEMA MG-1, Section IV, "Performance Standard Applying to All Machines," Part 31, "Definite-Purpose, Inverter-Fed, Polyphase Motors."
g. Severe-duty rating with the following features:
   1) Rotor and stator protected with corrosion-inhibiting epoxy resin.
   2) Double-shielded, vacuum-degassed bearings lubricated with premium moisture-resistant grease suitable for temperatures between minus 20 and plus 300 deg F (minus 29 and plus 149 deg C).
   3) Internal heater automatically energized when motor is de-energized.
h. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.

16. Discharge Hoods:
   a. Hood Configuration: Tapered **OR** Straight, **as directed**; totally surrounding drift eliminators and constructed of same material as casing; and having factory-installed insulation, **as directed**, and access doors.
   b. Discharge Dampers: Positive-closure, automatic, isolation dampers with electric actuators.
      1) Provide field power and controls to open dampers when pump is energized and close dampers when pump is de-energized.
17. Capacity-Control Dampers: Galvanized-steel **OR** Stainless-steel, **as directed**, dampers, with linkages, electric operator, controller, limit switches, transformer, and weatherproof enclosure.
18. Vibration Switch: For each fan drive.
   a. Enclosure: NEMA 250, Type 4 **OR** Type 4X, **as directed**.
   b. Vibration Detection: Sensor with a field-adjustable acceleration sensitivity set point in a range of 0 to 1 g and frequency range of 0 to 3000 cycles per minute. Cooling tower manufacturer shall recommend switch set point for proper operation and protection.
   c. Provide switch with manual-reset button, **as directed**, for field connection to a BMS and, **as directed**, hardwired connection to fan motor electrical circuit.
   d. Switch shall, on sensing excessive vibration, signal an alarm through the BMS and, **as directed**, shut down the fan.
19. Controls: Comply with requirements in Division 23 Section "Instrumentation And Control For Hvac".

   OR

   Control Package: Factory installed and wired, and functionally tested at factory before shipment.
   a. NEMA 250, Type 3R **OR** Type 4 **OR** Type 4X, **as directed**, enclosure with removable internally mount backplate.
   b. Control-circuit transformer with primary and secondary side fuses.
   c. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
   d. Microprocessor-based controller for automatic control of fan and spray pump, **as directed**, based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
   e. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
   f. Collection basin, electric/electronic level controller complying with requirements in "Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve" Paragraph.
   g. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.
   h. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
   i. Controls and wiring for "two-motor, single-fan drives" shall be same as two-speed, two-winding motor.
   j. Power and controls to open discharge hood dampers when pump is energized and close dampers when pump is de-energized.
   k. Single-point, field-power connection to a fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**, for each cooling tower cell, **as directed**.

1) Branch power circuit to each motor and electric basin heater and to controls with a disconnect switch or circuit breaker, **as directed**.
2) NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.

l. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.

m. Visual indication of status and alarm with momentary test push button, **as directed**, for each motor.

n. Audible alarm and silence switch.

o. Visual indication of elapsed run time, graduated in hours for each motor.

p. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:
1) Operational status of each motor.
2) Position of dampers.
3) Cooling tower leaving-fluid temperature.
4) Fan vibration alarm.
5) Collection basin high **OR** low **OR** high- and low, **as directed**,-water-level alarms.

20. Personnel Access Components:

a. Doors: Large enough for personnel to access cooling tower internal components from both, **as directed**, cooling tower end walls. Doors shall be operable from both sides of the door, **as directed**.

b. External Ladders with Safety Cages: Aluminum, galvanized- or stainless-steel, fixed ladders with ladder extensions to access external platforms and top of cooling tower from adjacent grade without the need for portable ladders. Comply with 29 CFR 1910.27.

c. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.

d. Handrail: Aluminum, galvanized steel, or stainless steel complete with kneerail and toeboard at platforms and around top of cooling tower. Comply with 29 CFR 1910.23.

e. Internal Platforms: Aluminum, FRP, or galvanized-steel bar grating.
1) Spanning the collection basin from one end of cooling tower to the other and positioned to form a path between the access doors. Platform shall be elevated so that all parts are above the high water level of the collection basin.

B. Closed-Circuit, Induced-Draft, Combined-Flow Cooling Towers

1. Fabricate cooling tower mounting base with reinforcement strong enough to resist cooling tower movement during a seismic event when cooling tower is anchored to field support structure.

2. Cooling tower designed to resist wind load of 30 lbf/sq. ft. (1.44 kPa) **OR as directed**.

3. Casing and Frame:

a. Casing and Frame, **as directed**, Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Polymer-coated galvanized steel **OR** Stainless steel, **as directed**.

b. Frame Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Polymer-coated galvanized steel **OR** Stainless steel, **as directed**.

c. Fasteners: Galvanized **OR** Stainless, **as directed**, steel.

d. Joints and Seams: Sealed watertight.

e. Welded Connections: Continuous and watertight.

4. Collection Basin: Configure tower for installation with a field-constructed collection basin.
OR
Collection Basin:

a. Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Polymer-coated galvanized steel **OR** Stainless steel, **as directed**.

b. Strainer: Removable stainless-steel, **as directed**, strainer with openings smaller than nozzle orifices.

c. Overflow and drain connections.

d. Makeup water connection.
e. Basin Sweeper Distribution Piping and Nozzles:
   1) Pipe Material: PVC, **as directed**.
   2) Nozzle Material: Plastic, **as directed**.
   3) Configure piping and nozzles to minimize sediment from collecting in the collection basin.

5. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.

OR

Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:
a. Enclosure: NEMA 250, Type 4 **OR** Type 4X, **as directed**.
b. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide control of water makeup valve **OR** control of water makeup valve and low-level alarm **OR** control of water makeup valve and low- and high-level alarms **OR** control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level, **as directed**.
c. Electrode Probes: Stainless steel.
d. Water Stilling Chamber: Corrosion-resistant material **OR** FRP **OR** Galvanized steel **OR** PVC pipe **OR** Stainless steel, **as directed**.
e. Solenoid Valve: Slow closing with stainless-steel body, **as directed**, controlled and powered through level controller in response to water-level set point.
f. Electrical Connection Requirements: 120 V, single phase, 60 Hz.

OR

Ultrasonic Collection Basin Water-Level Controller with Solenoid Valve:
a. Enclosure: NEMA 250, Type 4 **OR** Type 4X, **as directed**.
b. Controller: Ultrasonic level sensor/transmitter and relays factory wired to a terminal strip to control water makeup valve and signal a level alarm. Controller shall provide continuous level indication through a 4- to 20-mA signal for connection to BMS, **as directed**.
c. Water Stilling Chamber: Corrosion-resistant material **OR** FRP **OR** Galvanized steel **OR** PVC pipe **OR** Stainless steel, **as directed**.
d. Solenoid Valve: Slow closing with stainless-steel body, **as directed**, controlled and powered through level controller in response to water-level set point.
e. Electrical Connection Requirements: 120 V, single phase, 60 Hz.

6. Electric Basin Heater:
a. Stainless-Steel Electric Immersion Heaters: Installed in a threaded coupling on the side of the collection basin.
b. Heater Control Panel: Mounted on the side of each cooling tower cell.
c. Enclosure: NEMA 250, Type 3R **OR** Type 4 **OR** Type 4X, **as directed**.
d. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
e. Control-circuit transformer with primary and secondary side fuses.
f. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
g. Single-point, field-power connection to a fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**, and heater branch circuiting complying with NFPA 70.
h. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.

OR

Hot-Water-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.

OR

Steam-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.

OR

Steam-Injector Basin Heater: Manufacturer's standard offering to provide capacity indicated.

7. Gravity Water Distribution Basin: Nonpressurized design with head of water level in basin adequate to overcome spray nozzle losses and designed to evenly distribute water over fill throughout the flow range indicated.
   a. Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Polymer-coated galvanized steel **OR** Stainless steel, **as directed**.
   b. Location: Over each bank of fill with easily replaceable plastic, **as directed**, spray nozzles mounted in bottom of basin.
   c. Joints and Seams: Sealed watertight.
   d. Partitioning Dams: Same material as basin to distribute water over the fill to minimize icing while operating throughout the flow range indicated.
   e. Removable Panels: Same material as basin to completely cover top of basin. Secure panels to basin with removable corrosion-resistant **OR** stainless-steel, **as directed**, hardware.
   f. Valves: Manufacturer's standard valve installed at each inlet connection and arranged to balance or shut off flow to each gravity water distribution basin.
8. Pressurized Water Distribution Piping: Main header and lateral branch piping designed for even distribution over heat-exchanger coil or fill throughout the flow range without the need for balancing valves and for connecting individual, removable, nonclogging spray nozzles.
   a. Pipe Material: PVC **OR** Galvanized steel, **as directed**.
   b. Spray Nozzle Material: Plastic **OR** Polypropylene, **as directed**.
   c. Piping Supports: Corrosion-resistant hangers and supports to resist movement during operation and shipment.
9. Recirculating Piping: PVC, **as directed**, with connections for separately provided, remote spray pump, **as directed**.
10. Spray Pump: Close-coupled, end-suction, single-stage, bronze-fitted centrifugal pump; with suction strainer and flow balancing valve, and mechanical seal suitable for outdoor service.
    a. General Requirements for Spray Pump Motor: Comply with NEMA designation and temperature-rating requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment" and not indicated below.
    b. Motor Enclosure: Totally enclosed **OR** Totally enclosed nonventilated (TENV) **OR** Totally enclosed fan cooled (TEFC), **as directed**, with epoxy or polyurethane finish, **as directed**.
    c. Energy Efficiency: Comply with ASHRAE/IESNA 90.1 **OR** NEMA Premium Efficient, **as directed**.
    d. Service Factor: 1.0 **OR** 1.15, **as directed**.
11. Fill:
    a. Materials: PVC, **as directed**, with maximum flame-spread index of 5 **OR** 25, **as directed**, according to ASTM E 84.
    b. Minimum Thickness: 15 mils (0.4 mm) **OR** 20 mils (0.5 mm), **as directed**, before forming.
    c. Fabrication: Fill-type sheets fabricated, formed, and bonded together after forming into removable assemblies that are factory installed by manufacturer.
    d. Fill Material Operating Temperature: Suitable for entering-water temperatures up through 120 deg F (49 deg C).
12. Heat-Exchanger Coils:
    a. Tube and Tube Sheet Materials: Copper tube with stainless-steel sheet **OR** Stainless-steel tube and sheet **OR** Prime-coated steel tube and sheet with outer surface of tube and sheet hot-dip galvanized after fabrication, **as directed**.
    b. Heat-Exchanger Arrangement: Serpentine tubes **OR** Serpentine tubes with removable cover plate on inlet and outlet headers **OR** Straight tubes with removable header cover plate on both ends of heat exchanger for straight-through access to each tube, **as directed**; and sloped for complete drainage of fluid by gravity.

       OR

       ASME Compliance: Designed, manufactured, and tested according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1 and bearing ASME "U" stamp; and sloped for complete drainage of fluid by gravity.

c. Field Piping Connections: Vent, supply, and return suitable for mating to ASME B16.5, Class 150 flange, **as directed**.

13. Drift Eliminator:
    a. Material: FRP **OR** PVC, **as directed**; with maximum flame-spread index of 5 according to ASTM E 84.
    b. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
    c. Configuration: Multipass, designed and tested to reduce water carryover to achieve performance indicated.
    d. Fill Drift Eliminators: Integral to **OR** Separate and removable from, **as directed**, fill.
    e. Heat-Exchanger Coil Drift Eliminators: Located on discharge side and removable.
14. Air-Intake Louvers:
    a. Material: FRP **OR** PVC **OR** Matching casing, **as directed**.
    b. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
    c. Louver Blades: Arranged to uniformly direct air into cooling tower, to minimize air resistance, and to prevent water from splashing out of tower during all modes of operation including operation with fans off.
    d. Location: Integral to **OR** Separate from, **as directed**, fill.
15. Removable, **as directed**, Air-Intake Screens: Galvanized **OR** Polymer-coated, galvanized **OR** Stainless, **as directed**,-steel wire mesh.
16. Axial Fan: Balanced at the factory after assembly.
    a. Blade Material: Aluminum **OR** FRP, **as directed**.
    b. Hub Material: Aluminum **OR** FRP, **as directed**.
    c. Blade Pitch: Field adjustable.
    d. Protective Enclosure: Removable, galvanized-steel, wire-mesh screens complying with OSHA regulations.
    e. Fan Shaft Bearings: Self-aligning ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between minus 20 and plus 300 deg F (minus 29 and plus 149 deg C). Bearings designed for an L-10 life of 40,000 **OR** 50,000, **as directed**, hours.
    f. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.
17. Belt Drive:
    a. Service Factor: 1.5 based on motor nameplate horsepower.
    b. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
    c. Belt: Multiple V-belt design with a matched set of cogged, **as directed**, belts.
       OR
       Belt: One-piece, multigrooved, solid-back belt.
    d. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
    e. Belt-Drive Guard: Comply with OSHA regulations.
    f. Two-Motor, Single-Fan Drive:
       1) Two single-speed motors per fan, one sized for full speed and load and the other sized for 67 percent of full-load speed.
       2) Each motor with belt drive and configured for operation when other motor fails.
       3) Controls and wiring same as two-speed, two-winding motor.
18. Gear Drive: Right angle, reduced speed, and designed for cooling tower applications according to CTI STD 111. Motor and gear drive shall be aligned before shipment.
    a. Gear Drive and Coupling Service Factor: 2.0 based on motor nameplate horsepower.
    b. Housing: Cast iron, with epoxy or polyurethane finish, beveled high-strength steel gears continuously bathed in oil, and with lubrication to other internal parts at all operating speeds.
    c. Mounting: Directly mounted to fan hub and connected to motor so motor shaft is in horizontal position.
    d. Operation: Able to operate both forward and in reverse.

e. Drive-to-Motor Connection: Close coupled to motor using a flexible coupling **OR** Connected to motor located outside of cooling tower casing by a full-floating drive shaft, **as directed**.
f. Drive Shaft Material: Corrosion resistant **OR** Stainless steel, **as directed**, and fitted with flexible couplings on both ends. Provide exposed shaft and couplings with guards according to OSHA regulations.
g. Extend oil fill, drain, and vent to outside of cooling tower casing using galvanized-steel piping. Provide installation with oil-level sight glass.

19. Fan Motor:
    a. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment" and not indicated below.
    b. Motor Enclosure: Totally enclosed **OR** Totally enclosed air over (TEAO) **OR** Totally enclosed fan cooled (TEFC), **as directed**, with epoxy or polyurethane finish, **as directed**.
    c. Energy Efficiency: Comply with ASHRAE/IESNA 90.1 **OR** NEMA Premium Efficient, **as directed**.
    d. Service Factor: 1.15.
    e. Insulation: Class F **OR** Class H, **as directed**.
    f. Variable-Speed Motors: Inverter-duty rated per NEMA MG-1, Section IV, "Performance Standard Applying to All Machines," Part 31, "Definite-Purpose, Inverter-Fed, Polyphase Motors."
    g. Motor Location: Mounted outside of cooling tower casing and cooling tower discharge airstream.
    h. Severe-duty rating with the following features:
        1) Rotor and stator protected with corrosion-inhibiting epoxy resin.
        2) Double-shielded, vacuum-degassed bearings lubricated with premium, moisture-resistant grease suitable for temperatures between minus 20 and plus 300 deg F (minus 29 and plus 149 deg C).
        3) Internal heater automatically energized when motor is de-energized.
    i. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.
20. Fan Discharge Stack: Material shall match casing, manufacturer's standard **OR** velocity recovery, **as directed**, design.
    a. Stack Extension: Fabricated to extend above fan deck unless otherwise indicated.
    b. Stack Termination: Wire-mesh, galvanized-steel screens; complying with OSHA regulations.
21. Vibration Switch: For each fan drive.
    a. Enclosure: NEMA 250, Type 4 **OR** Type 4X, **as directed**.
    b. Vibration Detection: Sensor with a field-adjustable, acceleration-sensitivity set point in a range of 0 to 1 g and frequency range of 0 to 3000 cycles per minute. Cooling tower manufacturer shall recommend switch set point for proper operation and protection.
    c. Provide switch with manual-reset button, **as directed**, for field connection to a BMS, **as directed**, and hardwired connection to fan motor electrical circuit.
    d. Switch shall, on sensing excessive vibration, signal an alarm through the BMS, **as directed**, and shut down the fan.
22. Gear-Drive, Oil-Level Switch: Low-oil-level warning switch for connection to a BMS, **as directed**.
    a. Switch shall, on reaching a low-oil-level set point recommended by cooling tower manufacturer, signal an alarm through the BMS, **as directed**.
23. Controls: Comply with requirements in Division 23 Section "Instrumentation And Control For Hvac".

    OR

    Control Package: Factory installed and wired, and functionally tested at factory before shipment.
    a. NEMA 250, Type 3R **OR** Type 4 **OR** Type 4X, **as directed**, enclosure with removable internally mount backplate.
    b. Control-circuit transformer with primary and secondary side fuses.
    c. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.

d. Microprocessor-based controller for automatic control of fan and spray pump, **as directed**, based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
e. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
f. Collection basin level controller complying with requirements in "Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve" **OR** "Ultrasonic Collection Basin Water-Level Controller with Solenoid Valve", **as directed**, Paragraph.
g. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.
h. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
i. Oil-level switch for each fan with a gear drive, complying with requirement in "Gear-Drive, Oil-Level Switch" Paragraph.
j. Single-point, field-power connection to a fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**, for each cooling tower cell, **as directed**.
   1) Branch power circuit to each motor and electric basin heater and to controls with a disconnect switch or circuit breaker, **as directed**.
   2) NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.
k. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.
l. Visual indication of status and alarm with momentary test push button, **as directed**, for each motor.
m. Audible alarm and silence switch.
n. Visual indication of elapsed run time, graduated in hours for each motor.
o. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:
   1) Operational status of each motor.
   2) Position of dampers.
   3) Cooling tower leaving-fluid temperature.
   4) Fan vibration alarm.
   5) Oil-level alarm.
   6) Collection basin high **OR** low **OR** high- and low, **as directed**,-water-level alarms.

24. Personnel Access Components:
   a. Doors: Large enough for personnel to access cooling tower internal components from both cooling tower end walls. Doors shall be operable from both sides of the door.
   b. External Ladders with Safety Cages: Aluminum, galvanized- or stainless-steel, fixed ladders with ladder extensions to access external platforms and top of cooling tower from adjacent grade without the need for portable ladders. Comply with 29 CFR 1910.27.
   c. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.
   d. Handrail: Aluminum, galvanized steel, or stainless steel complete with kneerail and toeboard, around top of cooling tower. Comply with 29 CFR 1910.23.
   e. Internal Platforms: Aluminum, FRP, or galvanized-steel bar grating.
      1) Spanning the collection basin from one end of cooling tower to the other and positioned to form a path between the access doors. Platform shall be elevated so that all parts are above the high water level of the collection basin.
      2) Elevated internal platforms with handrails accessible from fixed vertical ladders to access the fan drive assembly when out of reach from collection basin platform.

C. Closed-Circuit, Induced-Draft, Counterflow Cooling Towers

1. Fabricate cooling tower mounting base with reinforcement strong enough to resist cooling tower movement during a seismic event when cooling tower is anchored to field support structure.
2. Cooling tower designed to resist wind load of 30 lbf/sq. ft. (1.44 kPa) **OR as directed**.
3. Casing and Frame:
   a. Casing and Frame, **as directed**, Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Stainless steel, **as directed**.
   b. Frame Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Polymer-coated galvanized steel **OR** Stainless steel, **as directed**.
   c. Fasteners: Galvanized **OR** Stainless, **as directed**, steel.
   d. Joints and Seams: Sealed watertight.
   e. Welded Connections: Continuous and watertight.
4. Collection Basin: Configure tower for installation with a field-constructed collection basin.
   OR
   Collection Basin:
   a. Material: Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Stainless steel, **as directed**.
   b. Overflow and drain connections.
   c. Makeup water connection.
5. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.
   OR
   Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:
   a. Enclosure: NEMA 250, Type 4 **OR** Type 4X, **as directed**.
   b. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide control of water makeup valve **OR** control of water makeup valve and low-level alarm **OR** control of water makeup valve and low- and high-level alarms **OR** control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level, **as directed**.
   c. Electrode Probes: Stainless steel.
   d. Water Stilling Chamber: Corrosion-resistant material **OR** FRP **OR** Galvanized steel **OR** PVC pipe **OR** Stainless steel, **as directed**.
   e. Solenoid Valve: Slow closing with stainless-steel body, **as directed**; controlled and powered through level controller in response to water-level set point.
   f. Electrical Connection Requirements: 120 V, single phase, 60 Hz.
6. Electric Basin Heater:
   a. Stainless-Steel Electric Immersion Heaters: Installed in a threaded coupling on the side of the collection basin.
   b. Heater Control Panel: Mounted on the side of each cooling tower cell.
   c. Enclosure: NEMA 250, Type 3R **OR** Type 4 **OR** Type 4X, **as directed**.
   d. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
   e. Control-circuit transformer with primary and secondary side fuses.
   f. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
   g. Single-point, field-power connection to a fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**, and heater branch circuiting complying with NFPA 70.
   h. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.

   OR
   Hot-Water-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.
   OR
   Steam-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.
   OR

Steam-Injector Basin Heater: Manufacturer's standard offering to provide capacity indicated.

7. Pressurized Water Distribution Piping: Main header and lateral branch piping designed for even distribution over heat-exchanger coil or fill throughout the flow range without the need for balancing valves and for connecting individual, removable, nonclogging spray nozzles.
   a. Pipe Material: Fiberglass **OR** PVC **OR** Galvanized steel, **as directed**.
   b. Spray Nozzle Material: Plastic **OR** Polypropylene **OR** PVC, **as directed**.
   c. Piping Supports: Corrosion-resistant hangers and supports to resist movement during operation and shipment.
8. Recirculating Piping: PVC, **as directed**, with connections for separately provided, remote spray pump, **as directed**.
9. Spray Pump: Close-coupled, end-suction, single-stage, bronze-fitted centrifugal pump; with suction strainer and flow balancing valve, and mechanical seal suitable for outdoor service.
10. General Requirements for Spray Pump Motor: Comply with NEMA designation and temperature-rating requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment" and not indicated below.
    a. Motor Enclosure: Totally enclosed **OR** Totally enclosed nonventilated (TENV) **OR** Totally enclosed fan cooled (TEFC), **as directed**, with epoxy or polyurethane finish, **as directed**.
    b. Energy Efficiency: Comply with ASHRAE/IESNA 90.1 **OR** NEMA Premium Efficient, **as directed**.
    c. Service Factor: 1.0 **OR** 1.15, **as directed**.
11. Heat-Exchanger Coils:
    a. Tube and Tube Sheet Materials: Copper tube with stainless-steel sheet **OR** Stainless-steel tube and sheet **OR** Prime-coated steel tube and sheet with outer surface of tube and sheet hot-dip galvanized after fabrication, **as directed**.
    b. Heat-Exchanger Arrangement: Serpentine tubes **OR** Serpentine tubes with removable cover plate on inlet and outlet headers **OR** Straight tubes with removable header cover plate on both ends of heat exchanger for straight-through access to each tube, **as directed**; and sloped for complete drainage of fluid by gravity.
       OR
       ASME Compliance: Designed, manufactured, and tested according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1 and bearing ASME "U" stamp; and sloped for complete drainage of fluid by gravity.
    c. Field Piping Connections: Vent, supply, and return suitable for mating to ASME B16.5, Class 150 flange, **as directed**.
12. Removable, **as directed**, Drift Eliminator:
    a. Material: FRP **OR** PVC, **as directed**; with maximum flame-spread index of 5 **OR** 25, **as directed**, according to ASTM E 84.
    b. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
    c. Configuration: Multipass, designed and tested to reduce water carryover to achieve performance indicated.
13. Air-Intake Louvers:
    a. Material: FRP **OR** PVC **OR** Matching casing, **as directed**.
    b. UV Treatment: Treat louvers with inhibitors to protect against damage caused by UV radiation.
    c. Louver Blades: Arranged to uniformly direct air into cooling tower, to minimize air resistance, and to prevent water from splashing out during all modes of operation including operation with fans off.
14. Axial Fan: Balanced at the factory after assembly.
    a. Blade Material: Aluminum **OR** FRP **OR** Galvanized steel, **as directed**.
    b. Hub Material: Aluminum **OR** FRP **OR** Galvanized steel, **as directed**.
    c. Blade Pitch: Field adjustable.
    d. Protective Enclosure: Removable, galvanized-steel, wire-mesh screens complying with OSHA regulations.
    e. Fan Shaft Bearings: Self-aligning ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between minus 20 and plus

300 deg F (minus 29 and plus 149 deg C). Bearings designed for an L-10 life of 40,000 **OR** 50,000, **as directed**, hours.

f. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.

15. Belt Drive:
    a. Service Factor: 1.5 based on motor nameplate horsepower.
    b. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
    c. Belt: Multiple V-belt design with a matched set of cogged, **as directed**, belts.
       OR
       Belt: One-piece, multigrooved, solid-back belt.
    d. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
    e. Belt-Drive Guard: Comply with OSHA regulations.
    f. Two-Motor, Single-Fan Drive:
       1) Two single-speed motors per fan, one sized for full speed and load and the other sized for 67 percent of full-load speed.
       2) Each motor with belt drive and configured for operation when other motor fails.
       3) Controls and wiring same as two-speed, two-winding motor.
16. Fan Motor:
    a. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment" and not indicated below.
    b. Motor Enclosure: Totally enclosed **OR** Totally enclosed air over (TEAO) **OR** Totally enclosed fan cooled (TEFC), **as directed**, with epoxy or polyurethane finish, **as directed**.
    c. Energy Efficiency: Comply with ASHRAE/IESNA 90.1 **OR** NEMA Premium Efficient, **as directed**.
    d. Service Factor: 1.15.
    e. Insulation: Class F **OR** Class H, **as directed**.
    f. Variable-Speed Motors: Inverter-duty rated per NEMA MG-1, Section IV, "Performance Standard Applying to All Machines," Part 31, "Definite-Purpose, Inverter-Fed, Polyphase Motors."
    g. Severe-duty rating with the following features:
       1) Rotor and stator protected with corrosion-inhibiting epoxy resin.
       2) Double-shielded, vacuum-degassed bearings lubricated with premium, moisture-resistant grease suitable for temperatures between minus 20 and plus 300 deg F (minus 29 and plus 149 deg C).
       3) Internal heater automatically energized when motor is de-energized.
    h. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.
17. Fan Discharge Stack: Material shall match casing, manufacturer's standard **OR** velocity recovery, **as directed**, design.
    a. Stack Extension: Fabricated to extend above fan deck unless otherwise indicated.
    b. Stack Termination: Wire-mesh, galvanized-steel screens; complying with OSHA regulations.
18. Vibration Switch: For each fan drive.
    a. Enclosure: NEMA 250, Type 4 **OR** Type 4X, **as directed**.
    b. Vibration Detection: Sensor with a field-adjustable, acceleration-sensitivity set point in a range of 0 to 1 g and frequency range of 0 to 3000 cycles per minute. Cooling tower manufacturer shall recommend switch set point for proper operation and protection.
    c. Provide switch with manual-reset button, **as directed**, for field connection to a BMS, **as directed**, and hardwired connection to fan motor electrical circuit.
    d. Switch shall, on sensing excessive vibration, signal an alarm through the BMS, **as directed**, and shut down the fan.
19. Controls: Comply with requirements in Division 23 Section "Instrumentation And Control For Hvac".
    OR
    Control Package: Factory installed and wired, and functionally tested at factory before shipment.

a. NEMA 250, Type 3R **OR** Type 4 **OR** Type 4X, **as directed**, enclosure with removable internally mount backplate.
b. Control-circuit transformer with primary and secondary side fuses.
c. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
d. Microprocessor-based controller for automatic control of fan and spray pump, **as directed**, based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
e. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
f. Collection basin electric/electronic level controller complying with requirements in "Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve" Paragraph.
g. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.
h. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
i. Single-point, field-power connection to a fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker **OR** for each cooling tower cell, **as directed**.
   1) Branch power circuit to each motor and electric basin heater and to controls with a disconnect switch or circuit breaker, **as directed**.
   2) NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.
j. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.
k. Visual indication of status and alarm with momentary test push button, **as directed**, for each motor.
l. Audible alarm and silence switch.
m. Visual indication of elapsed run time, graduated in hours for each motor.
n. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:
   1) Operational status of each motor.
   2) Cooling tower leaving-fluid temperature.
   3) Fan vibration alarm.
   4) Collection basin high **OR** low **OR** high- and low, **as directed**,-water-level alarms.

20. Personnel Access Components:
   a. Doors: Large enough for personnel to access cooling tower internal components from both cooling tower end walls. Doors shall be operable from both sides of the door.
   b. External Ladders with Safety Cages: Aluminum, galvanized- or stainless-steel, fixed ladders with ladder extensions to access external platforms and top of cooling tower from adjacent grade without the need for portable ladders. Comply with 29 CFR 1910.27.
   c. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.
   d. Handrail: Aluminum, galvanized steel, or stainless steel complete with kneerail and toeboard, around top of cooling tower. Comply with 29 CFR 1910.23.
   e. Internal Platforms: Aluminum, FRP, or galvanized-steel bar grating.
      1) Spanning the collection basin from one end of cooling tower to the other and positioned to form a path between the access doors. Platform shall be elevated so that all parts are above the high water level of the collection basin.
      2) Elevated internal platforms with handrails accessible from fixed vertical ladders to access the fan drive assembly when out of reach from collection basin platform.

D. Open-Circuit, Forced-Draft, Counterflow Cooling Towers

1. Fabricate cooling tower mounting base with reinforcement strong enough to resist cooling tower movement during a seismic event when cooling tower is anchored to field support structure.
2. Cooling tower designed to resist wind load of 30 lbf/sq. ft. (1.44 kPa) **OR as directed**.
3. Casing and Frame:
   a. Casing and Frame, **as directed**, Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Polymer-coated galvanized steel **OR** Stainless steel, **as directed**.
   b. Frame Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Polymer-coated galvanized steel **OR** Stainless steel, **as directed**.
   c. Fasteners: Galvanized **OR** Stainless, **as directed**, steel.
   d. Joints and Seams: Sealed watertight.
   e. Welded Connections: Continuous and watertight.
4. Collection Basin: Configure tower for installation with a field-constructed collection basin.
   OR
   Collection Basin:
   a. Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Polymer-coated galvanized steel **OR** Stainless steel, **as directed**.
   b. Strainer: Removable stainless-steel, **as directed**, strainer with openings smaller than nozzle orifices.
   c. Overflow and drain connections.
   d. Makeup water connection.
   e. Basin Sweeper Distribution Piping and Nozzles:
      1) Pipe Material: PVC, **as directed**.
      2) Nozzle Material: Plastic, **as directed**.
      3) Configure piping and nozzles to minimize sediment from collecting in the collection basin.
5. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.
6. Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:
   a. Enclosure: NEMA 250, Type 4 **OR** Type 4X, **as directed**.
   b. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide control of water makeup valve **OR** control of water makeup valve and low-level alarm **OR** control of water makeup valve and low- and high-level alarms **OR** control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level, **as directed**.
   c. Electrode Probes: Stainless steel.
   d. Water Stilling Chamber: Corrosion-resistant material **OR** FRP **OR** Galvanized steel **OR** PVC pipe **OR** Stainless steel, **as directed**.
   e. Solenoid Valve: Slow closing with stainless-steel body, **as directed**, controlled and powered through level controller in response to water-level set point.
   f. Electrical Connection Requirements: 120 V, single phase, 60 Hz.
7. Electric Basin Heater:
   a. Stainless-Steel Electric Immersion Heaters: Installed in a threaded coupling on the side of the collection basin.
   b. Heater Control Panel: Mounted on the side of each cooling tower cell.
   c. Enclosure: NEMA 250, Type 3R **OR** Type 4 **OR** Type 4X, **as directed**.
   d. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
   e. Control-circuit transformer with primary and secondary side fuses.
   f. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
   g. Single-point, field-power connection to a fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**, and heater branch circuiting complying with NFPA 70.

h. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.

i. Hot-Water-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.

OR

Steam-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.

OR

Steam-Injector Basin Heater: Manufacturer's standard offering to provide capacity indicated.

8. Pressurized Water Distribution Piping: Main header and lateral branch piping designed for even distribution over heat-exchanger coil or fill throughout the flow range without the need for balancing valves and for connecting individual, removable, nonclogging spray nozzles.
   a. Pipe Material: Fiberglass **OR** PVC **OR** Galvanized steel, **as directed**.
   b. Spray Nozzle Material: Plastic **OR** Polypropylene **OR** PVC, **as directed**.
   c. Piping Supports: Corrosion-resistant hangers and supports to resist movement during operation and shipment.
9. Fill:
   a. Materials: PVC, **as directed**, with maximum flame-spread index of 5 according to ASTM E 84.
   b. Minimum Thickness: 15 mils (0.4 mm) **OR** 20 mils (0.5 mm), **as directed**, before forming.
   c. Fabrication: Fill-type sheets, fabricated, formed, and bonded together after forming into removable assemblies that are factory installed by manufacturer.
   d. Fill Material Operating Temperature: Suitable for entering-water temperatures up through 120 deg F (49 deg C).
10. Removable, **as directed**, Drift Eliminator:
   a. Material: FRP **OR** PVC, **as directed**; with maximum flame-spread index of 5 **OR** 25, **as directed**, according to ASTM E 84.
   b. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
   c. Configuration: Multipass, designed and tested to reduce water carryover to achieve performance indicated.
11. Removable, **as directed**, Air-Intake Screens: Galvanized **OR** Polymer-coated, galvanized **OR** Stainless, **as directed**,-steel wire mesh.
12. Centrifugal Fan: Double-width, double-inlet, forward-curved blades, and statically and dynamically balanced at the factory after assembly.
   a. Number of Fans: Each cooling tower cell shall have a single fan or multiple fans connected to a common shaft.
   b. Fan Wheel and Housing Materials: Galvanized steel.
   c. Fan Shaft: Steel, coated to resist corrosion.
   d. Protective Enclosure: Removable, galvanized-steel, wire-mesh screens complying with OSHA regulations.
   e. Fan Shaft Bearings: Self-aligning, grease-lubricated ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between minus 20 and plus 300 deg F (minus 29 and plus 149 deg C). Bearings designed for an L-10 life of 40,000 **OR** 50,000, **as directed**, hours.
   f. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.
13. Axial Fan: Balanced at the factory after assembly.
   a. Blade Material: FRP, **as directed**.
   b. Hub Material: Aluminum **OR** FRP, **as directed**.
   c. Blade Pitch: Field adjustable.
   d. Protective Enclosure: Removable, galvanized-steel, wire-mesh screens complying with OSHA regulations.
   e. Fan Shaft Bearings: Self-aligning ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between minus 20 and plus 300 deg F (minus 29 and plus 149 deg C). Bearings designed for an L-10 life of 40,000 **OR** 50,000, **as directed**, hours.
   f. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.

14. Belt Drive:
    a. Service Factor: 1.5 based on motor nameplate horsepower.
    b. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
    c. Belt: Multiple V-belt design with a matched set of cogged, **as directed**, belts.
       OR
       Belt: One-piece, multigrooved, solid-back belt.
    d. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
    e. Belt-Drive Guard: Comply with OSHA regulations.
    f. Two-Motor, Single-Fan Drive:
       1) Two single-speed motors per fan, one sized for full speed and load and the other sized for 67 percent of full-load speed.
       2) Each motor with belt drive and configured for operation when other motor fails.
       3) Controls and wiring same as two-speed, two-winding motor.
15. Direct Drive: Fan hub directly connected, and properly secured, to motor shaft.
16. Fan Motor:
    a. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Division 15 Section "Common Motor Requirements for HVAC Equipment" and not indicated below.
    b. Motor Enclosure: Totally enclosed **OR** Totally enclosed air over (TEAO) **OR** Totally enclosed fan cooled (TEFC), **as directed**, with epoxy or polyurethane finish, **as directed**.
    c. Energy Efficiency: Comply with ASHRAE/IESNA 90.1 **OR** NEMA Premium Efficient, **as directed**.
    d. Service Factor: 1.15.
    e. Insulation: Class F **OR** Class H, **as directed**.
    f. Variable-Speed Motors: Inverter-duty rated per NEMA MG-1, Section IV, "Performance Standard Applying to All Machines," Part 31, "Definite-Purpose, Inverter-Fed, Polyphase Motors."
    g. Severe-duty rating with the following features:
       1) Rotor and stator protected with corrosion-inhibiting epoxy resin.
       2) Double-shielded, vacuum-degassed bearings lubricated with premium, moisture-resistant grease suitable for temperatures between minus 20 and 300 deg F (minus 29 and 149 deg C).
       3) Internal heater automatically energized when motor is de-energized.
    h. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.
17. Discharge Hoods:
    a. Hood Configuration: Tapered **OR** Straight, **as directed**; totally surrounding drift eliminators and constructed of same material as casing; and having factory-installed insulation, **as directed**, and access doors.
    b. Discharge Dampers: Positive-closure, automatic, isolation dampers with electric actuators.
       1) Provide field power and controls to open dampers when pump is energized and close dampers when pump is de-energized.
18. Capacity-Control Dampers: Galvanized-steel **OR** Stainless-steel, **as directed**, dampers, with linkages, electric operator, controller, limit switches, transformer, and weatherproof enclosure.
19. Vibration Switch: For each fan drive.
    a. Enclosure: NEMA 250, Type 4 **OR** Type 4X, **as directed**.
    b. Vibration Detection: Sensor with a field-adjustable, acceleration-sensitivity set point in a range of 0 to 1 g and frequency range of 0 to 3000 cycles per minute. Cooling tower manufacturer shall recommend switch set point for proper operation and protection.
    c. Provide switch with manual-reset button, **as directed**, for field connection to a BMS, **as directed**, and hardwired connection to fan motor electrical circuit.
    d. Switch shall, on sensing excessive vibration, signal an alarm through the BMS, **as directed**, and shut down the fan.
20. Controls: Comply with requirements in Division 23 Section "Instrumentation And Control For Hvac".

OR

Control Package: Factory installed and wired, and functionally tested at factory before shipment.

a. NEMA 250, Type 3R **OR** Type 4 **OR** Type 4X, **as directed**, enclosure with removable internally mount backplate.

b. Control-circuit transformer with primary and secondary side fuses.

c. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.

d. Microprocessor-based controller for automatic control of fan based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.

e. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.

f. Factory-installed and -wired, collection basin electric/electronic level controller.

g. Collection basin electric/electronic level controller complying with requirements in "Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve" Paragraph.

h. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.

i. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.

j. Controls and wiring for "two-motor, single-fan drives" shall be same as two-speed, two-winding motor.

k. Single-point, field-power connection to a fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**, for each cooling tower cell, **as directed**.

   1) Branch power circuit to each motor and electric basin heater and to controls with a disconnect switch or circuit breaker, **as directed**.

   2) NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.

l. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.

m. Visual indication of status and alarm with momentary test push button, **as directed**, for each motor.

n. Audible alarm and silence switch.

o. Visual indication of elapsed run time, graduated in hours for each motor.

p. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:

   1) Operational status of each motor.

   2) Position of dampers.

   3) Cooling tower leaving-fluid temperature.

   4) Fan vibration alarm.

   5) Collection basin high **OR** low **OR** high- and low, **as directed**,-water-level alarms.

21. Personnel Access Components:

a. Doors: Large enough for personnel to access cooling tower internal components from both cooling tower end walls. Doors shall be operable from both sides of the door.

b. External Ladders with Safety Cages: Aluminum, galvanized- or stainless-steel, fixed ladders with ladder extensions to access external platforms and top of cooling tower from adjacent grade without the need for portable ladders. Comply with 29 CFR 1910.27.

c. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.

d. Handrail: Aluminum, galvanized steel, or stainless steel complete with kneerail and toeboard, around top of cooling tower. Comply with 29 CFR 1910.23.

e. Internal Platforms: Aluminum, FRP, or galvanized-steel bar grating.

1) Spanning the collection basin from one end of cooling tower to the other and positioned to form a path between the access doors. Platform shall be elevated so that all parts are above the high water level of the collection basin.
2) Elevated internal platforms with handrails accessible from fixed vertical ladders to access the fan drive assembly when out of reach from collection basin platform.

E. Open-Circuit, Induced-Draft, Counterflow Cooling Towers
1. Fabricate cooling tower mounting base with reinforcement strong enough to resist cooling tower movement during a seismic event when cooling tower is anchored to field support structure.
2. Cooling tower designed to resist wind load of 30 lbf/sq. ft. (1.44 kPa) **OR as directed**.
3. Casing and Frame:
   a. Casing and Frame, **as directed**, Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Stainless steel, **as directed**.
   b. Frame Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Stainless steel, **as directed**.
   c. Fasteners: Galvanized **OR** Stainless, **as directed**, steel.
   d. Joints and Seams: Sealed watertight.
   e. Welded Connections: Continuous and watertight.
4. Collection Basin: Configure tower for installation with a field-constructed collection basin.
   OR
   Collection Basin:
   a. Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G210 (Z600) coating **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Polymer-coated galvanized steel **OR** Stainless steel, **as directed**.
   b. Strainer: Removable stainless-steel, **as directed**, strainer with openings smaller than nozzle orifices.
   c. Overflow and drain connections.
   d. Makeup water connection.
   e. Outlet Connection: ASME B16.5, Class 150 flange.
   f. Removable equalization flume plate between adjacent cells of multiple-cell towers.
   g. Equalizer connection for field-installed equalizer piping.
   h. Basin Sweeper Distribution Piping and Nozzles:
      1) Pipe Material: PVC, **as directed**.
      2) Nozzle Material: Plastic, **as directed**.
      3) Configure piping and nozzles to minimize sediment from collecting in the collection basin.
5. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.
   OR
   Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:
   a. Enclosure: NEMA 250, Type 4 **OR** Type 4X, **as directed**.
   b. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide control of water makeup valve **OR** control of water makeup valve and low-level alarm **OR** control of water makeup valve and low- and high-level alarms **OR** control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level, **as directed**.
   c. Electrode Probes: Stainless steel.
   d. Water Stilling Chamber: Corrosion-resistant material **OR** FRP **OR** Galvanized steel **OR** PVC pipe **OR** Stainless steel, **as directed**.
   e. Solenoid Valve: Slow closing with stainless-steel body, **as directed**; controlled and powered through level controller in response to water-level set point.
   f. Electrical Connection Requirements: 120 V, single phase, 60 Hz.
   OR
   Ultrasonic Collection Basin Water-Level Controller with Solenoid Valve:

a. Enclosure: NEMA 250, Type 4 **OR** Type 4X, **as directed**.
b. Controller: Ultrasonic level sensor/transmitter and relays factory wired to a terminal strip to control water makeup valve and signal a level alarm. Controller shall provide continuous level indication through a 4- to 20-mA signal for connection to BMS, **as directed**.
c. Water Stilling Chamber: Corrosion-resistant material **OR** FRP **OR** Galvanized steel **OR** PVC pipe **OR** Stainless steel, **as directed**.
d. Solenoid Valve: Slow closing with stainless-steel body, **as directed**; controlled and powered through level controller in response to water-level set point.
e. Electrical Connection Requirements: 120 V, single phase, 60 Hz.

6. Electric Basin Heater:
   a. Stainless-Steel Electric Immersion Heaters: Installed in a threaded coupling on the side of the collection basin.
   b. Heater Control Panel: Mounted on the side of each cooling tower cell.
   c. Enclosure: NEMA 250, Type 3R **OR** Type 4 **OR** Type 4X, **as directed**.
   d. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
   e. Control-circuit transformer with primary and secondary side fuses.
   f. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
   g. Single-point, field-power connection to a fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**, and heater branch circuiting complying with NFPA 70.
   h. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.

   OR

   Hot-Water-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.

   OR

   Steam-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.

   OR

   Steam-Injector Basin Heater: Manufacturer's standard offering to provide capacity indicated.
7. Pressurized Water Distribution Piping: Main header and lateral branch piping designed for even distribution over heat-exchanger coil or fill throughout the flow range without the need for balancing valves and for connecting individual, removable, nonclogging spray nozzles.
   a. Pipe Material: Fiberglass **OR** PVC **OR** Galvanized steel, **as directed**.
   b. Spray Nozzle Material: Plastic **OR** Polypropylene **OR** PVC, **as directed**.
   c. Piping Supports: Corrosion-resistant hangers and supports to resist movement during operation and shipment.
8. Fill:
   a. Materials: CPVC **OR** PVC, **as directed**, resistant to rot, decay, and biological attack; with maximum flame-spread index of 5 **OR** 25, **as directed**, according to ASTM E 84.
   b. Minimum Thickness: 15 mils (0.4 mm) **OR** 20 mils (0.5 mm), **as directed**, before forming.
   c. Fabrication: Fill-type sheets, fabricated, formed, and bonded together after forming into removable assemblies that are factory installed by manufacturer.
   d. Fill Material Operating Temperature: Suitable for entering-water temperatures up through 120 deg F (49 deg C).
9. Removable, **as directed**, Drift Eliminator:
   a. Material: FRP **OR** PVC, **as directed**; resistant to rot, decay, and biological attack; with maximum flame-spread index of 5 **OR** 25, **as directed**, according to ASTM E 84.
   b. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
   c. Configuration: Multipass, designed and tested to reduce water carryover to achieve performance indicated.
10. Air-Intake Louvers:
   a. Material: FRP **OR** PVC **OR** Matching casing, **as directed**.
   b. UV Treatment: Inhibitors to protect against damage caused by UV radiation.

c. Louver Blades: Arranged to uniformly direct air into cooling tower, to minimize air resistance, and to prevent water from splashing out of tower during all modes of operation including operation with fans off.

11. Removable, **as directed**, Air-Intake Screens: Galvanized **OR** Polymer-coated, galvanized **OR** Stainless, **as directed**,-steel wire mesh.
12. Axial Fan: Balanced at the factory after assembly.
    a. Blade Material: Aluminum **OR** FRP **OR** Galvanized steel, **as directed**.
    b. Hub Material: Aluminum **OR** FRP **OR** Galvanized steel, **as directed**.
    c. Blade Pitch: Field adjustable.
    d. Protective Enclosure: Removable, galvanized-steel, wire-mesh screens, complying with OSHA regulations.
    e. Fan Shaft Bearings: Self-aligning ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between minus 20 and plus 300 deg F (minus 29 and plus 149 deg C). Bearings designed for an L-10 life of 40,000 **OR** 50,000, **as directed**, hours.
    f. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.
13. Belt Drive:
    a. Service Factor: 1.5 based on motor nameplate horsepower.
    b. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
    c. Belt: Multiple V-belt design with a matched set of cogged, **as directed**, belts.
       OR
       Belt: One-piece, multigrooved, solid-back belt.
    d. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
    e. Belt-Drive Guard: Comply with OSHA regulations.
14. Direct Drive: Fan hub directly connected, and properly secured, to motor shaft.
15. Gear Drive: Right angle, reduced speed, and designed for cooling tower applications according to CTI STD 111. Motor and gear drive shall be aligned before shipment.
    a. Gear Drive and Coupling Service Factor: 2.0 based on motor nameplate horsepower.
    b. Housing: Cast iron, with epoxy or polyurethane finish, beveled high-strength steel gears continuously bathed in oil, and with lubrication to other internal parts at all operating speeds.
    c. Mounting: Directly mounted to fan hub and connected to motor so motor shaft is in horizontal position.
    d. Operation: Able to operate both forward and in reverse.
    e. Drive-to-Motor Connection: Close coupled to motor using a flexible coupling **OR** Connected to motor located outside of cooling tower casing by a full-floating drive shaft, **as directed**.
    f. Drive Shaft Material: Corrosion resistant **OR** Stainless steel, **as directed**, and fitted with flexible couplings on both ends. Provide exposed shaft and couplings with guards according to OSHA regulations.
    g. Extend oil fill, drain, and vent to outside of cooling tower casing using galvanized-steel piping. Provide installation with oil-level sight glass.
16. Fan Motor:
    a. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Division 15 Section "Common Motor Requirements for HVAC Equipment" and not indicated below.
    b. Motor Enclosure: Totally enclosed **OR** Totally enclosed air over (TEAO) **OR** Totally enclosed fan cooled (TEFC), **as directed**, with epoxy or polyurethane finish, **as directed**.
    c. Energy Efficiency: Comply with ASHRAE/IESNA 90.1 **OR** NEMA Premium Efficient, **as directed**.
    d. Service Factor: 1.15.
    e. Insulation: Class F **OR** Class H, **as directed**.

f. Variable-Speed Motors: Inverter-duty rated per NEMA MG-1, Section IV, "Performance Standard Applying to All Machines," Part 31, "Definite-Purpose, Inverter-Fed, Polyphase Motors."
g. Motor Location: Mounted outside of cooling tower casing and cooling tower discharge airstream.
h. Severe-duty rating with the following features:
   1) Rotor and stator protected with corrosion-inhibiting epoxy resin.
   2) Double-shielded, vacuum-degassed bearings lubricated with premium, moisture-resistant grease suitable for temperatures between minus 20 and plus 300 deg F (minus 29 and plus 149 deg C).
   3) Internal heater automatically energized when motor is de-energized.
i. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.

17. Fan Discharge Stack: Material shall match casing, manufacturer's standard **OR** velocity recovery, **as directed**, design.
    a. Stack Extension: Fabricated to extend above fan deck unless otherwise indicated.
    b. Stack Termination: Wire-mesh, galvanized-steel screens; complying with OSHA regulations.
18. Vibration Switch: For each fan drive.
    a. Enclosure: NEMA 250, Type 4 **OR** Type 4X, **as directed**.
    b. Vibration Detection: Sensor with a field-adjustable, acceleration-sensitivity set point in a range of 0 to 1 g and frequency range of 0 to 3000 cycles per minute. Cooling tower manufacturer shall recommend switch set point for proper operation and protection.
    c. Provide switch with manual-reset button, **as directed**, for field connection to a BMS, **as directed**, and hardwired connection to fan motor electrical circuit.
    d. Switch shall, on sensing excessive vibration, signal an alarm through the BMS, **as directed**, and shut down the fan.
19. Gear-Drive, Oil-Level Switch: Low-oil-level warning switch for connection to a BMS, **as directed**.
    a. Switch shall, on reaching a low-oil-level set point recommended by cooling tower manufacturer, signal an alarm through the BMS, **as directed**.
20. Controls: Comply with requirements in Division 23 Section "Instrumentation And Control For Hvac".

    OR

    Control Package: Factory installed and wired, and functionally tested at factory before shipment.
    a. NEMA 250, Type 3R **OR** Type 4 **OR** Type 4X, **as directed**, enclosure with removable internally mount backplate.
    b. Control-circuit transformer with primary and secondary side fuses.
    c. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
    d. Microprocessor-based controller for automatic control of fan based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
    e. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
    f. Collection basin level controller complying with requirements in "Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve" **OR** "Ultrasonic Collection Basin Water-Level Controller with Solenoid Valve", **as directed**, Paragraph.
    g. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.
    h. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
    i. Oil-level switch for each fan with a gear drive, complying with requirement in "Gear-Drive, Oil-Level Switch" Paragraph.
    j. Single-point, field-power connection to a fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**, for each cooling tower cell, **as directed**.
       1) Branch power circuit to each motor and electric basin heater and to controls with a disconnect switch or circuit breaker, **as directed**.

2) NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.

k. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.

l. Visual indication of status and alarm with momentary test push button, **as directed**, for each motor.

m. Audible alarm and silence switch.

n. Visual indication of elapsed run time, graduated in hours for each motor.

o. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:

1) Operational status of each motor.

2) Position of dampers.

3) Cooling tower leaving-fluid temperature.

4) Fan vibration alarm.

5) Oil-level alarm.

6) Collection basin high **OR** low **OR** high- and low, **as directed**,-water-level alarms.

21. Personnel Access Components:

a. Doors: Large enough for personnel to access cooling tower internal components from both cooling tower end walls. Doors shall be operable from both sides of the door.

b. External Ladders with Safety Cages: Aluminum, galvanized- or stainless-steel, fixed ladders with ladder extensions to access external platforms and top of cooling tower from adjacent grade without the need for portable ladders. Comply with 29 CFR 1910.27.

c. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.

d. Handrail: Aluminum, galvanized steel, or stainless steel complete with kneerail and toeboard, around top of cooling tower. Comply with 29 CFR 1910.23.

e. Internal Platforms: Aluminum, FRP, or galvanized-steel bar grating.

1) Spanning the collection basin from one end of cooling tower to the other and positioned to form a path between the access doors. Platform shall be elevated so that all parts are above the high water level of the collection basin.

2) Elevated internal platforms with handrails accessible from fixed vertical ladders to access the fan drive assembly when out of reach from collection basin platform.

F. Open-Circuit, Induced-Draft, Crossflow Cooling Towers

1. Fabricate cooling tower mounting base with reinforcement strong enough to resist cooling tower movement during a seismic event when cooling tower is anchored to field support structure.

2. Cooling tower designed to resist wind load of 30 lbf/sq. ft. (1.44 kPa), **as directed**.

3. Casing and Frame:

a. Casing and Frame, **as directed**, Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Polymer-coated galvanized steel **OR** Stainless steel, **as directed**.

b. Frame Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Polymer-coated galvanized steel **OR** Stainless steel, **as directed**.

c. Fasteners: Galvanized **OR** Stainless, **as directed**, steel.

d. Joints and Seams: Sealed watertight.

e. Welded Connections: Continuous and watertight.

4. Collection Basin: Configure tower for installation with a field-constructed collection basin.

OR

Collection Basin:

a. Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Polymer-coated galvanized steel **OR** Stainless steel, **as directed**.

b. Removable stainless-steel, **as directed**, strainer with openings smaller than nozzle orifices.

c. Overflow and drain connections.

d. Makeup water connection.
e. Outlet Connection: ASME B16.5, Class 150 flange.
f. Removable equalization flume plate between adjacent cells of multiple-cell towers.
g. Equalizer connection for field-installed equalizer piping.
h. Basin Sweeper Distribution Piping and Nozzles:
   1) Pipe Material: PVC, **as directed**.
   2) Nozzle Material: Plastic, **as directed**.
   3) Configure piping and nozzles to minimize sediment from collecting in the collection basin.

5. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve.

OR

Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve:
a. Enclosures: NEMA 250, Type 4 **OR** Type 4X, **as directed**.
b. Sensor: Solid-state controls with multiple electrode probes and relays factory wired to a terminal strip to provide control of water makeup valve **OR** control of water makeup valve and low-level alarm **OR** control of water makeup valve and low- and high-level alarms **OR** control of water makeup valve, low- and high-level alarms, and output for shutoff of pump on low level, **as directed**.
c. Electrode Probes: Stainless steel.
d. Water Stilling Chamber: Corrosion-resistant material **OR** FRP **OR** Galvanized steel **OR** PVC pipe **OR** Stainless steel, **as directed**.
e. Solenoid Valve: Slow closing with stainless-steel body, **as directed**, controlled and powered through level controller in response to water-level set point.
f. Electrical Connection Requirements: 120 V, single phase, 60 Hz.

OR

Ultrasonic Collection Basin Water-Level Controller with Solenoid Valve:
a. Enclosure: NEMA 250, Type 4 **OR** Type 4X, **as directed**.
b. Controller: Ultrasonic level sensor/transmitter and relays factory wired to a terminal strip to control water makeup valve and signal a level alarm. Controller shall provide continuous level indication through a 4- to 20-mA signal for connection to BMS, **as directed**.
c. Water Stilling Chamber: Corrosion-resistant material **OR** FRP **OR** Galvanized steel **OR** PVC pipe **OR** Stainless steel, **as directed**.
d. Solenoid Valve: Slow closing with stainless-steel body, **as directed**; controlled and powered through level controller in response to water-level set point.
e. Electrical Connection Requirements: 120 V, single phase, 60 Hz.

6. Electric Basin Heater:
a. Stainless-Steel Electric Immersion Heaters: Installed in a threaded coupling on the side of the collection basin.
b. Heater Control Panel: Mounted on the side of each cooling tower cell.
c. Enclosure: NEMA 250, Type 3R **OR** Type 4 **OR** Type 4X, **as directed**.
d. Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
e. Control-circuit transformer with primary and secondary side fuses.
f. Terminal blocks with numbered and color-coded wiring to match wiring diagram.
g. Single-point, field-power connection to a fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**, and heater branch circuiting complying with NFPA 70.
h. Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.

OR

Hot-Water-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.

OR

Steam-Coil Basin Heater: Manufacturer's standard offering to provide capacity indicated.

OR
Steam-Injector Basin Heater: Manufacturer's standard offering to provide capacity indicated.

7. Gravity Water Distribution Basin: Nonpressurized design with head of water level in basin adequate to overcome spray nozzle losses and designed to evenly distribute water over fill throughout the flow range indicated.
   a. Material: FRP with UV inhibitors **OR** Galvanized steel, ASTM A 653/A 653M, G235 (Z700) coating **OR** Polymer-coated galvanized steel **OR** Stainless steel, **as directed**.
   b. Location: Over each bank of fill with easily replaceable plastic, **as directed**, spray nozzles mounted in bottom of basin.
   c. Inlet Connection: ASME B16.5, Class 150 flange.
   d. Joints and Seams: Sealed watertight.
   e. Partitioning Dams: Same material as basin to distribute water over the fill to minimize icing while operating throughout the flow range indicated.
   f. Removable Panels: Same material as basin to completely cover top of basin. Secure panels to basin with removable corrosion-resistant **OR** stainless-steel, **as directed**, hardware.
   g. Valves: Manufacturer's standard valve installed at each inlet connection and arranged to balance or shut off flow to each gravity distribution basin.
   h. Single-Inlet, Field Pipe Connection: Galvanized-steel **OR** PVC, **as directed**, pipe arranged to provide balancing of flow within cooling tower cell without the need for additional balancing valves. Pipe each cooling tower cell internally to a single, field connection suitable for mating to ASME B16.5, Class 150 flange and located on the bottom **OR** side, **as directed**, unless otherwise indicated.
8. Fill:
   a. Materials: PVC, with maximum flame-spread index of 5 **OR** 25, **as directed**, according to ASTM E 84.
   b. Minimum Thickness: 15 mils (0.4 mm) **OR** 20 mils (0.5 mm), **as directed**, before forming.
   c. Fabrication: Fill-type sheets, fabricated, formed, and bonded together after forming into removable assemblies that are factory installed by manufacturer.
   d. Fill Material Operating Temperature: Suitable for entering-water temperatures up through 120 deg F (49 deg C).
9. Drift Eliminator:
   a. Material: FRP **OR** PVC, **as directed**; with maximum flame-spread index of 5 **OR** 25, **as directed**, according to ASTM E 84.
   b. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
   c. Configuration: Multipass, designed and tested to reduce water carryover to achieve performance indicated.
   d. Location: Integral to **OR** Separate and removable from, **as directed**, fill.
10. Air-Intake Louvers:
   a. Material: FRP **OR** PVC **OR** Matching casing, **as directed**.
   b. UV Treatment: Inhibitors to protect against damage caused by UV radiation.
   c. Louver Blades: Arranged to uniformly direct air into cooling tower, to minimize air resistance, and to prevent water from splashing out of tower during all modes of operation including operation with fans off.
   d. Location: Integral to **OR** Separate from, **as directed**, fill.
11. Removable, **as directed**, Air-Intake Screens: Galvanized **OR** Polymer-coated, galvanized **OR** Stainless, **as directed**,-steel wire mesh.
12. Axial Fan: Balanced at the factory after assembly.
   a. Blade Material: Aluminum **OR** FRP **OR** Galvanized steel, **as directed**.
   b. Hub Material: Aluminum **OR** FRP **OR** Galvanized steel, **as directed**.
   c. Blade Pitch: Field adjustable.
   d. Protective Enclosure: Removable, galvanized-steel, wire-mesh screens complying with OSHA regulations.
   e. Fan Shaft Bearings: Self-aligning ball or roller bearings with moisture-proof seals and premium, moisture-resistant grease suitable for temperatures between minus 20 and plus

300 deg F (minus 29 and plus 149 deg C). Bearings designed for an L-10 life of 40,000 **OR** 50,000, **as directed**, hours.

f. Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.

13. Belt Drive:
    a. Service Factor: 1.5 based on motor nameplate horsepower.
    b. Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
    c. Belt: Multiple V-belt design with a matched set of cogged, **as directed**, belts.
       OR
       Belt: One-piece, multigrooved, solid-back belt.
    d. Belt Material: Oil resistant, nonstatic conducting, and constructed of neoprene polyester cord.
    e. Belt-Drive Guard: Comply with OSHA regulations.
    f. Two-Motor, Single-Fan Drive:
       1) Two single-speed motors per fan, one sized for full speed and load and the other sized for 67 percent of full-load speed.
       2) Each motor with belt drive and configured for operation when other motor fails.
       3) Controls and wiring same as two-speed, two-winding motor.
14. Gear Drive: Right angle, reduced speed, and designed for cooling tower applications according to CTI STD 111. Motor and gear drive shall be aligned before shipment.
    a. Gear Drive and Coupling Service Factor: 2.0 based on motor nameplate horsepower.
    b. Housing: Cast iron, with epoxy or polyurethane finish, beveled high-strength steel gears continuously bathed in oil, and with lubrication to other internal parts at all operating speeds.
    c. Mounting: Directly mounted to fan hub and connected to motor so motor shaft is in horizontal position.
    d. Operation: Able to operate both forward and in reverse.
    e. Drive-to-Motor Connection: Close coupled to motor using a flexible coupling **OR** Connected to motor located outside of cooling tower casing by a full-floating drive shaft, **as directed**.
    f. Drive Shaft Material: Corrosion resistant **OR** Stainless steel, **as directed**, and fitted with flexible couplings on both ends. Provide exposed shaft and couplings with guards according to OSHA regulations.
    g. Extend oil fill, drain, and vent to outside of cooling tower casing using galvanized-steel piping. Provide installation with oil-level sight glass.
15. Fan Motor:
    a. General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Division 23 Section "Common Motor Requirements For Hvac Equipment" and not indicated below.
    b. Motor Enclosure: Totally enclosed **OR** Totally enclosed air over (TEAO) **OR** Totally enclosed fan cooled (TEFC), **as directed**, with epoxy or polyurethane finish, **as directed**.
    c. Energy Efficiency: Comply with ASHRAE/IESNA 90.1 **OR** NEMA Premium Efficient, **as directed**.
    d. Service Factor: 1.15.
    e. Insulation: Class F **OR** Class H, **as directed**.
    f. Variable-Speed Motors: Inverter-duty rated per NEMA MG-1, Section IV, "Performance Standard Applying to All Machines," Part 31, "Definite-Purpose, Inverter-Fed, Polyphase Motors."
    g. Motor Location: Mounted outside of cooling tower casing and cooling tower discharge airstream.
    h. Severe-duty rating with the following features:
       1) Rotor and stator protected with corrosion-inhibiting epoxy resin.
       2) Double-shielded, vacuum-degassed bearings lubricated with premium, moisture-resistant grease suitable for temperatures between minus 20 and plus 300 deg F (minus 29 and plus 149 deg C).

3) Internal heater automatically energized when motor is de-energized.

i. Motor Base: Adjustable, or other suitable provision for adjusting belt tension.

16. Fan Discharge Stack: Material shall match casing, manufacturer's standard **OR** velocity recovery, **as directed**, design.
    a. Stack Extension: Fabricated to extend above fan deck unless otherwise indicated.
    b. Stack Termination: Wire-mesh, galvanized-steel screens; complying with OSHA regulations.
17. Vibration Switch: For each fan drive.
    a. Enclosure: NEMA 250, Type 4 **OR** Type 4X, **as directed**.
    b. Vibration Detection: Sensor with a field-adjustable, acceleration-sensitivity set point in a range of 0 to 1 g and frequency range of 0 to 3000 cycles per minute. Cooling tower manufacturer shall recommend switch set point for proper operation and protection.
    c. Provide switch with manual-reset button, **as directed**, for field connection to a BMS, **as directed**, and hardwired connection to fan motor electrical circuit.
    d. Switch shall, on sensing excessive vibration, signal an alarm through the BMS, **as directed**, and shut down the fan.
18. Gear-Drive, Oil-Level Switch: Low-oil-level warning switch for connection to a BMS, **as directed**.
    a. Switch shall, on reaching a low-oil-level set point recommended by cooling tower manufacturer, signal an alarm through the BMS, **as directed**.
19. Capacity-Control Dampers: Galvanized-steel **OR** Stainless-steel, **as directed**, dampers, with linkages, electric operator, controller, limit switches, transformer, and weatherproof enclosure.
20. Controls: Comply with requirements in Division 23 Section "Instrumentation And Control For Hvac".

    OR

    Control Package: Factory installed and wired, and functionally tested at factory before shipment.
    a. NEMA 250, Type 3R **OR** Type 4 **OR** Type 4X, **as directed**, enclosure with removable internally mount backplate.
    b. Control-circuit transformer with primary and secondary side fuses.
    c. Terminal blocks with numbered and color-coded wiring to match wiring diagram. Spare wiring terminal block for connection to external controls or equipment.
    d. Microprocessor-based controller for automatic control of fan based on cooling tower leaving-water temperature with control features to improve operating efficiency based on outdoor ambient wet-bulb temperature by using adaptive logic.
    e. Fan motor sequencer for multiple-cell and two-speed applications with automatic lead stage rotation.
    f. Collection basin level controller complying with requirements in "Electric/Electronic, Collection Basin Water-Level Controller with Solenoid Valve" **OR** "Ultrasonic Collection Basin Water-Level Controller with Solenoid Valve", **as directed**, Paragraph.
    g. Electric basin heaters with temperature control and low-water-level safety switch for each cell, complying with requirements in "Electric Basin Heater" Paragraph.
    h. Vibration switch for each fan, complying with requirements in "Vibration Switch" Paragraph.
    i. Oil-level switch for each fan with a gear drive, complying with requirement in "Gear-Drive, Oil-Level Switch" Paragraph.
    j. Single-point, field-power connection to a fused disconnect switch **OR** nonfused disconnect switch **OR** circuit breaker, **as directed**, for each cooling tower cell, **as directed**.
        1) Branch power circuit to each motor and electric basin heater and to controls with a disconnect switch or circuit breaker, **as directed**.
        2) NEMA-rated motor controller, hand-off-auto switch, and overcurrent protection for each motor. Provide variable frequency controller with manual bypass and line reactors for each variable-speed motor indicated.
    k. Factory-installed wiring outside of enclosures shall be in metal raceway, except make connections to each motor and electric basin heater with liquidtight conduit.
    l. Visual indication of status and alarm with momentary test push button, **as directed**, for each motor.
    m. Audible alarm and silence switch.
    n. Visual indication of elapsed run time, graduated in hours for each motor.

o. Cooling tower shall have hardware to enable BMS to remotely monitor and display the following:
   1) Operational status of each motor.
   2) Position of dampers.
   3) Cooling tower leaving-fluid temperature.
   4) Fan vibration alarm.
   5) Oil-level alarm.
   6) Collection basin high **OR** low **OR** high- and low, **as directed**,-water-level alarms.

21. Personnel Access Components:
   a. Doors: Large enough for personnel to access cooling tower internal components from both cooling tower end walls. Doors shall be operable from both sides of the door.
   b. External Ladders with Safety Cages: Aluminum, galvanized- or stainless-steel, fixed ladders with ladder extensions to access external platforms and top of cooling tower from adjacent grade without the need for portable ladders. Comply with 29 CFR 1910.27.
   c. External Platforms with Handrails: Aluminum, FRP, or galvanized-steel bar grating at cooling tower access doors when cooling towers are elevated and not accessible from grade.
   d. Handrail: Aluminum, galvanized steel, or stainless steel complete with kneerail and toeboard, around top of cooling tower. Comply with 29 CFR 1910.23.
   e. Internal Platforms: Aluminum, FRP, or galvanized-steel bar grating.
      1) Spanning the collection basin from one end of cooling tower to the other and positioned to form a path between the access doors. Platform shall be elevated so that all parts are above the high water level of the collection basin.
      2) Elevated internal platforms with handrails accessible from fixed vertical ladders to access the fan drive assembly when out of reach from collection basin platform.

G. Source Quality Control
   1. Verification of Performance: Test and certify cooling tower performance according to CTI STD 201, "Certification Standard for Commercial Water-Cooling Towers Thermal Performance."
   2. Factory pressure test heat exchangers after fabrication and prove to be free of leaks.

1.3 EXECUTION

A. Examination
   1. Before cooling tower installation, examine roughing-in for tower support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting tower performance, maintenance, and operation.
      a. Cooling tower locations indicated on Drawings are approximate. Determine exact locations before roughing-in for piping and electrical connections.
   2. Proceed with installation only after unsatisfactory conditions have been corrected.

B. Installation
   1. Install cooling towers on support structure indicated.
   2. Equipment Mounting: Install cooling tower on concrete bases using elastomeric pads **OR** elastomeric mounts **OR** restrained spring isolators, **as directed**. Comply with requirements in Division 03 Section "Cast-in-place Concrete". Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
      a. Minimum Deflection: 1/2 inch (13 mm) **OR** 1 inch (25 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**.
      b. Provide galvanized **OR** stainless, **as directed**,-steel plate to equally distribute weight over elastomeric pad.

c. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
d. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
e. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

3. Equipment Mounting: Install cooling tower using elastomeric pads **OR** elastomeric mounts **OR** restrained spring isolators, **as directed**. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   a. Minimum Deflection: 1/2 inch (13 mm) **OR** 1 inch (25 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**.
   b. Provide galvanized **OR** stainless, **as directed**,-steel plate to equally distribute weight over elastomeric pad.
4. Equipment Mounting: Install cooling tower on concrete bases. Comply with requirements in Division 03 Section "Cast-in-place Concrete".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
5. Install anchor bolts to elevations required for proper attachment to supported equipment.
6. Maintain manufacturer's recommended clearances for service and maintenance.
7. Loose Components: Install electrical components, devices, and accessories that are not factory mounted.

C. Connections
1. Piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
2. Install piping adjacent to cooling towers to allow service and maintenance.
3. Install flexible pipe connectors at pipe connections of cooling towers mounted on vibration isolators.
4. Provide drain piping with valve at cooling tower drain connections and at low points in piping.
5. Connect cooling tower overflows and drains, and piping drains to sanitary sewage system.
6. Domestic Water Piping: Comply with applicable requirements in Division 22 Section "Domestic Water Piping". Connect to water-level control with shutoff valve and union, flange, or mechanical coupling at each connection.
7. Supply and Return Piping: Comply with applicable requirements in Division 23 Section "Hydronic Piping". Connect to entering cooling tower connections with shutoff valve, balancing valve, thermometer, plugged tee with pressure gage, flow meter, **as directed**, and drain connection with valve. Connect to leaving cooling tower connection with shutoff valve. Make connections to cooling tower with a union **OR** flange **OR** mechanical coupling, **as directed**.
8. Equalizer Piping: Piping requirements to match supply and return piping. Connect an equalizer pipe, full size of cooling tower connection, between tower cells. Connect to cooling tower with shutoff valve.
9. Hot-Water Piping: Comply with applicable requirements in Division 23 Section "Hydronic Piping". Connect to supply and return basin heater with shutoff valve, strainer, control valve, and union or flange on supply connection and union or flange and balancing valve on return connection. Provide supply and return piping with pressure gage and thermometer.
10. Steam and Condensate Piping: Comply with applicable requirements in Division 23 Section "Steam And Condensate Heating Piping". Connect steam supply to basin heater with shutoff valve, strainer, control valve, and union or flange and condensate piping with union or flange, shutoff valve, strainer, and an appropriate steam trap.

D. Field Quality Control

1. Perform tests and inspections.
2. Tests and Inspections: Comply with ASME PTC 23, "ASME Performance Test Codes - Code on Atmospheric Water Cooling Equipment **OR** CTI ATC 105, "Acceptance Test Code for Water Cooling Towers", **as directed**.
3. Cooling towers will be considered defective if they do not pass tests and inspections.
4. Prepare test and inspection reports.

E. Startup Service
1. Perform startup service.
2. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assemblies, installations, and connections.
3. Obtain performance data from manufacturer.
   a. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
      1) Clean entire unit including basins.
      2) Verify that accessories are properly installed.
      3) Verify clearances for airflow and for cooling tower servicing.
      4) Check for vibration isolation and structural support.
      5) Lubricate bearings.
      6) Verify fan rotation for correct direction and for vibration or binding and correct problems.
      7) Adjust belts to proper alignment and tension.
      8) Verify proper oil level in gear-drive housing. Fill with oil to proper level.
      9) Operate variable-speed fans through entire operating range and check for harmonic vibration imbalance. Set motor controller to skip speeds resulting in abnormal vibration.
      10) Check vibration switch setting. Verify operation.
      11) Verify water level in tower basin. Fill to proper startup level. Check makeup water-level control and valve.
      12) Verify operation of basin heater and control.
      13) Verify that cooling tower air discharge is not recirculating air into tower or HVAC air intakes. Recommend corrective action.
      14) Replace defective and malfunctioning units.
4. Start cooling tower and associated water pumps. Follow manufacturer's written starting procedures.
5. Prepare a written startup report that records the results of tests and inspections.

F. Adjusting
1. Set and balance water flow to each tower inlet.
2. Adjust water-level control for proper operating level.

G. Demonstration
1. Train Owner's maintenance personnel to adjust, operate, and maintain cooling towers.

END OF SECTION 23 65 00 00

SECTION 23 72 16 00 - AIR-TO-AIR ENERGY RECOVERY UNITS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for air-to-air energy recovery equipment. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Heat wheels.
b. Heat-pipe heat exchangers.
c. Fixed-plate sensible heat exchangers.
d. Fixed-plate total heat exchangers.
e. Packaged energy recovery units.

C. Performance Requirements
1. Delegated Design: Design vibration isolation and seismic-restraint details, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
2. Seismic Performance: Air-to-air energy recovery equipment shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

D. Submittals
1. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, furnished specialties, and accessories.
2. LEED Submittals:
a. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.
b. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
3. Shop Drawings: For air-to-air energy recovery equipment. Include plans, elevations, sections, details, and attachments to other work.
a. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
b. Wiring Diagrams: For power, signal, and control wiring.
4. Delegated-Design Submittal: For air-to-air energy recovery equipment indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
a. Detail fabrication and assembly of air-to-air energy recovery equipment.
b. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
c. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
5. Coordination Drawings: Plans, elevations, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:
a. Suspended ceiling components.

b. Structural members to which equipment or suspension systems will be attached.

6. Seismic Qualification Certificates: For air-to-air energy recovery equipment, accessories, and components, from manufacturer.
   a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
   c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
7. Field quality-control reports.
8. Operation and Maintenance Data: For air-to-air energy recovery equipment to include in maintenance manuals.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. ARI Compliance:
   a. Capacity ratings for air-to-air energy recovery equipment shall comply with ARI 1060, "Performance Rating of Air-to-Air Heat Exchangers for Energy Recovery Ventilation Equipment."
   b. Capacity ratings for air coils shall comply with ARI 410, "Forced-Circulation Air- Cooling and Air-Heating Coils."
3. ASHRAE Compliance:
   a. Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
   b. Capacity ratings for air-to-air energy recovery equipment shall comply with ASHRAE 84, "Method of Testing Air-to-Air Heat Exchangers."
4. NRCA Compliance: Roof curbs for roof-mounted equipment shall be constructed according to recommendations of NRCA.
5. UL Compliance:
   a. Packaged heat recovery ventilators shall comply with requirements in UL 1812, "Ducted Heat Recovery Ventilators"; or UL 1815, "Nonducted Heat Recovery Ventilators."
   b. Electric coils shall comply with requirements in UL 1995, "Heating and Cooling Equipment."

F. Coordination
1. Coordinate layout and installation of air-to-air energy recovery equipment and suspension system with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, fire-suppression system, and partition assemblies.
2. Coordinate sizes and locations of concrete bases with actual equipment provided.
3. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

G. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of air-to-air energy recovery equipment that fail in materials or workmanship within specified warranty period.
   a. Warranty Period for Packaged Energy Recovery Units: Two years.
   b. Warranty Period for Fixed-Plate Total Heat Exchangers: 10 years.

1.2 PRODUCTS

A. Heat Wheels
1. Casing:
   a. Steel with standard factory-painted finish.

b. Integral purge section limiting carryover of exhaust air to between 0.05 percent at 1.6-inch wg and 0.20 percent at 4-inch wg (0.05 percent at 400-Pa and 0.20 percent at 1000-Pa) differential pressure.
c. Casing seals on periphery of rotor and on duct divider and purge section.
d. Support vertical rotors on grease-lubricated ball bearings having extended grease fittings or permanently lubricated bearings. Support horizontal rotors on tapered roller bearing.

2. Rotor: Aluminum segmented wheel strengthened with radial spokes, with nontoxic, noncorrosive, silica-gel desiccant coating, **as directed**.
   a. Maximum Solid Size for Media to Pass: 500 **OR** 800 **OR** 1200, **as directed**, micrometer.
3. Rotor: Glass-fiber **OR** Polymer, **as directed**, segmented wheel strengthened with radial spokes impregnated with nonmigrating, water-selective, molecular-sieve desiccant coating.
   a. Maximum Solid Size for Media to Pass: 800 **OR** 1200, **as directed**, micrometer.
4. Drive: Fractional horsepower motor and gear reducer, with speed changed by variable frequency controller, **as directed**, and self-adjusting multilink belt around outside of rotor.
   a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   b. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
5. Controls:
   a. Starting relay, factory mounted and wired, and manual motor starter for field wiring.
   b. Variable frequency controller, factory mounted and wired, permitting input of field connected 4-20 mA or 1-10-V control signal.
      OR
      Variable frequency controller, factory mounted and wired, with exhaust-air sensor to vary rotor speed and maintain exhaust temperature above freezing.
      OR
      Variable frequency controller, factory mounted and wired, with exhaust- and outdoor-air sensors, automatic changeover thermostat and set-point adjuster, to vary rotor speed and maintain exhaust temperature above freezing and, **as directed**, air differential temperature above set point. Rotor speed shall increase to maximum when exhaust-air temperature is less than outdoor-air temperature.
   c. Pilot-Light Indicator: Display rotor rotation and speed.
   d. Speed Settings: Adjustable settings for maximum and minimum rotor speed limits.
6. Disposable Panel Filters:
   a. Comply with NFPA 90A.
   b. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
   c. Factory-fabricated, viscous-coated, flat-panel type.
   d. Thickness: 1 inch (25 mm) **OR** 2 inches (50 mm), **as directed**.
   e. Minimum Arrestance: 80, according to ASHRAE 52.1.
   f. Minimum Merv: 5, according to ASHRAE 52.2.
   g. Media: Interlaced glass fibers sprayed with nonflammable adhesive and antimicrobial agent, **as directed**.
   h. Frame: Galvanized steel with metal grid on outlet side, steel rod grid on inlet side, hinged, and with pull and retaining handles.
7. Extended-Surface, Disposable Panel Filters:
   a. Comply with NFPA 90A.
   b. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
   c. Factory-fabricated, dry, extended-surface type.
   d. Thickness: 1 inch (25 mm) **OR** 2 inches (50 mm) **OR** 4 inches (100 mm), **as directed**.
   e. Minimum Arrestance: 90, according to ASHRAE 52.1.
   f. Minimum Merv: 7, according to ASHRAE 52.2.

g. Media: Fibrous material formed into deep-V-shaped pleats with antimicrobial agent, **as directed**, and held by self-supporting wire grid.
h. Media-Grid Frame: Nonflammable cardboard **OR** Galvanized steel **OR** Fire-retardant, 3/4-inch (20-mm) particleboard with gaskets, **as directed**.
i. Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks.

8. Extended-Surface, Nonsupported-Media Filters:
   a. Comply with NFPA 90A.
   b. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
   c. Factory-fabricated, dry, extended-surface, self-supporting type.
   d. Minimum Arrestance: 95, according to ASHRAE 52.1.
   e. Minimum Merv: 13, according to ASHRAE 52.2.
   f. Media: Fibrous material constructed so individual pleats are maintained in tapered form by flexible internal supports under rated-airflow conditions and antimicrobial agent, **as directed**.
   g. Filter-Media Frame: Galvanized steel **OR** Hard polyurethane foam, **as directed**.
   h. Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks with space for prefilter, **as directed**.

B. Heat-Pipe Heat Exchangers
1. Casing: Galvanized-steel flanged casing, with airtight partition between airstreams.
2. Refrigerant: ASHRAE 15, Group 1..
3. Tubes: 5/8-inch- (16-mm-) **OR** 1-inch- (25-mm-), **as directed**, diameter, aluminum **OR** copper, **as directed**.
4. Fins: Aluminum **OR** Integral aluminum **OR** Copper, **as directed**.
   a. Fin Spacing: 0.125 inch (3.18 mm) **OR** 0.091 inch (2.31 mm) **OR** 0.071 inch (1.80 mm) **OR** 0.067 inch (1.70 mm) **OR** 0.056 inch (1.42 mm) **OR** 0.0075 inch (0.19 mm), **as directed**.
   b. Fin and Tube Joint: Mechanical bond **OR** Silver brazed, **as directed**.
5. Coating: Thermoplastic vinyl **OR** Epoxy **OR** Synthetic resin **OR** Phenolic **OR** Polytetrafluoroethylene **OR** Vinyl ester, **as directed**; apply to supply and exhaust.
6. Control: Integral plenum containing heat-pipe coil and gasketed, face-and-bypass, opposed-blade dampers with rods extended outside casing for damper operator and linkage.
   OR
   Control: Pivot center of bottom of heat-pipe coil on shaft and bearings to tilt coil. Include tilt controls with electronic controller, electric actuator and linkage, thermostats, sensors, and polyester fabric with PVC-coated flexible connector for automatic supply temperature regulation, summer/winter changeover, and frost protection.

C. Fixed-Plate Sensible Heat Exchangers
1. Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
2. Casing: Aluminum **OR** Galvanized steel **OR** Enameled steel, with galvanized-steel liner **OR** Enameled steel, **as directed**, with duct collars.
3. Casing Insulation: 1/2-inch- (13-mm-) thick, foil-faced glass fiber **OR** 1-inch- (25-mm-) thick, foil-faced glass fiber **OR** 1 inch (25 mm) thick, ASTM C 1071 with coated surface **OR** 1 inch (25 mm) thick, fiber free, **as directed**.
4. Drain Pan: Same material as casing, with drain connections on exhaust and supply side **OR** Molded ABS covering bottom of case, with drain connections on exhaust and supply side, ,**as directed**.
   a. Comply with requirements in ASHRAE 62.1.
5. Plates: Evenly spaced and sealed and arranged for counter airflow.
   a. Plate Material: Embossed aluminum **OR** Stainless steel **OR** Polypropylene copolymer (high-density plastic), **as directed**.
   b. Plate Coating: Epoxy **OR** Air-dried phenolic, **as directed**.

6. Bypass Plenum: Within casing, with gasketed face-and-bypass dampers having operating rods extended outside casing.
7. Water Wash: Automatic system, with spray manifold to individual spray tubes or traversing type with stainless-steel-screw operating mechanism and electric motor drive; activated by time clock, with detergent injection, **as directed**.
8. Disposable Panel Filters:
   a. Comply with NFPA 90A.
   b. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
   c. Factory-fabricated, viscous-coated, flat-panel type.
   d. Thickness: 1 inch (25 mm) **OR** 2 inches (50 mm), **as directed**.
   e. Minimum Arrestance: 80, according to ASHRAE 52.1.
   f. Minimum Merv: 5, according to ASHRAE 52.2.
   g. Media: Interlaced glass fibers sprayed with nonflammable adhesive and antimicrobial agent, **as directed**.
   h. Frame: Galvanized steel with metal grid on outlet side, steel rod grid on inlet side, hinged, and with pull and retaining handles.
9. Extended-Surface, Disposable Panel Filters:
   a. Comply with NFPA 90A.
   b. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
   c. Factory-fabricated, dry, extended-surface type.
   d. Thickness: 1 inch (25 mm) **OR** 2 inches (50 mm) **OR** 4 inches (100 mm), **as directed**.
   e. Minimum Arrestance: 90, according to ASHRAE 52.1.
   f. Minimum Merv: 7, according to ASHRAE 52.2.
   g. Media: Fibrous material formed into deep-V-shaped pleats with antimicrobial agent, **as directed**, and held by self-supporting wire grid.
   h. Media-Grid Frame: Nonflammable cardboard **OR** Galvanized steel **OR** Fire-retardant, 3/4-inch (20-mm) particleboard with gaskets, **as directed**.
   i. Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks.
10. Extended-Surface, Nonsupported-Media Filters:
   a. Comply with NFPA 90A.
   b. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
   c. Factory-fabricated, dry, extended-surface, self-supporting type.
   d. Minimum Arrestance: 95, according to ASHRAE 52.1.
   e. Minimum Merv: 13, according to ASHRAE 52.2.
   f. Media: Fibrous material constructed so individual pleats are maintained in tapered form by flexible internal supports under rated-airflow conditions and antimicrobial agent, **as directed**.
   g. Filter-Media Frame: Galvanized steel **OR** Hard polyurethane foam, **as directed**.
   h. Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks with space for prefilter, **as directed**.

D. Fixed-Plate Total Heat Exchangers
1. Casing: Galvanized steel.
2. Plates: Evenly spaced and sealed and arranged for counter airflow.
   a. Plate Material: Chemically treated paper with selective hydroscopicity and moisture permeability, and gas barrier properties.
3. Bypass Plenum: Within casing, with gasketed face-and-bypass dampers having operating rods extended outside casing.
4. Disposable Panel Filters:
   a. Comply with NFPA 90A.
   b. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.

c. Factory-fabricated, viscous-coated, flat-panel type.
d. Thickness: 1 inch (25 mm) **OR** 2 inches (50 mm), **as directed**.
e. Minimum Arrestance: 80, according to ASHRAE 52.1.
f. Minimum Merv: 5, according to ASHRAE 52.2.
g. Media: Interlaced glass fibers sprayed with nonflammable adhesive and antimicrobial agent, **as directed**.
h. Frame: Galvanized steel with metal grid on outlet side, steel rod grid on inlet side, hinged, and with pull and retaining handles.

5. Extended-Surface, Disposable Panel Filters:
   a. Comply with NFPA 90A.
   b. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
   c. Factory-fabricated, dry, extended-surface type.
   d. Thickness: 1 inch (25 mm) **OR** 2 inches (50 mm) **OR** 4 inches (100 mm), **as directed**.
   e. Minimum Arrestance: 90, according to ASHRAE 52.1.
   f. Minimum Merv: 7, according to ASHRAE 52.2.
   g. Media: Fibrous material formed into deep-V-shaped pleats with antimicrobial agent, **as directed**, and held by self-supporting wire grid.
   h. Media-Grid Frame: Nonflammable cardboard **OR** Galvanized steel **OR** Fire-retardant, 3/4-inch (20-mm) particleboard with gaskets, **as directed**.
   i. Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks.

E. Packaged Energy Recovery Units
1. Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
2. Housing: Manufacturer's standard construction with corrosion-protection coating and exterior finish, gasketed and calked weathertight, **as directed**, hinged access doors **OR** removable panels, **as directed**, with neoprene gaskets for inspection and access to internal parts, minimum 1-inch- (25-mm-) **OR** 2-inch- (50-mm-), **as directed**, thick thermal insulation, knockouts for electrical and piping connections, exterior drain connection, and lifting lugs.
   a. Inlet: Weatherproof hood **OR** louver, **as directed**, with damper for exhaust and supply.
      1) Exhaust: Gravity backdraft damper **OR** Spring-return, two-position, motor-operated damper, **as directed**.
      2) Supply: Gravity backdraft damper **OR** Spring-return, two-position, motor-operated damper, **as directed**.
   b. Roof Curb: Refer to Division 07 Section "Roof Accessories" for roof curbs and equipment supports.
3. Heat Recovery Device: Heat wheel **OR** Heat-pipe heat exchanger **OR** Fixed-plate heat exchanger, **as directed**.
4. Supply and Exhaust Fans: Forward-curved, centrifugal **OR** Propeller **OR** Backward-inclined, SWSI centrifugal **OR** Backward-inclined, plenum centrifugal, **as directed**, fan with spring isolators **OR** restrained, spring isolators **OR** spring hangers **OR** spring hangers with vertical-limit stops, **as directed**, and insulated, **as directed**, flexible duct connections.
   a. Motor and Drive: Direct driven **OR** Belt driven with adjustable sheaves, motor mounted on adjustable base **OR** Drive type indicated on Drawings, **as directed**.
   b. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   c. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
   d. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 22.
   e. Spring isolators on each fan having 1-inch (25-mm) static deflection.
5. Disposable Panel Filters:
   a. Comply with NFPA 90A.

b. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
c. Factory-fabricated, viscous-coated, flat-panel type.
d. Thickness: 1 inch (25 mm) **OR** 2 inches (50 mm), **as directed**.
e. Minimum Arrestance: 80, according to ASHRAE 52.1.
f. Minimum Merv: 5, according to ASHRAE 52.2.
g. Media: Interlaced glass fibers sprayed with nonflammable adhesive and antimicrobial agent, **as directed**.
h. Frame: Galvanized steel with metal grid on outlet side, steel rod grid on inlet side, hinged, and with pull and retaining handles.

6. Extended-Surface, Disposable Panel Filters:
   a. Comply with NFPA 90A.
   b. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
   c. Factory-fabricated, dry, extended-surface type.
   d. Thickness: 1 inch (25 mm) **OR** 2 inches (50 mm) **OR** 4 inches (100 mm), **as directed**.
   e. Minimum Arrestance: 90, according to ASHRAE 52.1.
   f. Minimum Merv: 7, according to ASHRAE 52.2.
   g. Media: Fibrous material formed into deep-V-shaped pleats with antimicrobial agent, **as directed**, and held by self-supporting wire grid.
   h. Media-Grid Frame: Nonflammable cardboard **OR** Galvanized steel **OR** Fire-retardant, 3/4-inch (20-mm) particleboard with gaskets, **as directed**.
   i. Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks.
7. Extended-Surface, Nonsupported-Media Filters:
   a. Comply with NFPA 90A.
   b. Filter Holding Frames: Arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lift out from access plenum.
   c. Factory-fabricated, dry, extended-surface, self-supporting type.
   d. Minimum Arrestance: 95, according to ASHRAE 52.1.
   e. Minimum Merv: 13, according to ASHRAE 52.2.
   f. Media: Fibrous material constructed so individual pleats are maintained in tapered form by flexible internal supports under rated-airflow conditions and antimicrobial agent, **as directed**.
   g. Filter-Media Frame: Galvanized steel **OR** Hard polyurethane foam, **as directed**.
   h. Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks with space for prefilter, **as directed**.
8. Cooling Coils: Rated according to ARI 410 and ASHRAE 33, and bearing the ARI label, **as directed**.
   a. Access: Fabricate coil section to allow removal and replacement of coil and to allow in-place access for service and maintenance of coil(s).
   b. Casing: Manufacturer's standard material **OR** Aluminum **OR** Galvanized steel **OR** Stainless steel, **as directed**.
   c. Tubes: Copper.
   d. Tube Headers: Manufacturer's standard material **OR** Copper **OR** Carbon steel **OR** Red brass, **as directed**.
   e. Fins: Aluminum **OR** Copper, **as directed**.
   f. Fin and Tube Joint: Mechanical bond.
   g. Leak Test: Coils shall be leak tested with air under water.
   h. Refrigerant Coils:
      1) Capacity Reduction: Circuit coils for face **OR** row **OR** interleaved, **as directed**, control.
      2) Suction and Distributor: Seamless copper tube with brazed joints.
   i. Coating: Phenolic epoxy corrosion-protection coating after assembly.
9. Cooling-Coil Condensate Drain Pans:

a. Fabricated from galvanized steel **OR** stainless-steel, **as directed**, sheet and sloped in multiple planes to collect and drain condensate from cooling coils, coil piping connections, coil headers, and return bends.
b. Complying with requirements in ASHRAE 62.1.
c. Drain Connections: At low point of pan with minimum <**Insert size**> threaded nipple.
d. Units with stacked coils shall have an intermediate drain pan to collect and drain condensate from top coil.

10. Hot-Water Coils: Rated according to ARI 410 and ASHRAE 33, and bearing the ARI label, **as directed**.
    a. Access: Fabricate coil section to allow removal and replacement of coil and to allow in-place access for service and maintenance of coil(s).
    b. Casing: Manufacturer's standard material **OR** Aluminum **OR** Galvanized steel **OR** Stainless steel, **as directed**.
    c. Tubes: Copper.
    d. Tube Headers: Manufacturer's standard material **OR** Copper **OR** Carbon steel **OR** Red brass, **as directed**.
    e. Fins: Aluminum **OR** Copper, **as directed**.
    f. Fin and Tube Joint: Mechanical bond.
    g. Leak Test: Coils shall be leak tested with air under water.
    h. Coating: Phenolic epoxy corrosion-protection coating after assembly.
11. Nonfreeze Type, **as directed**, Steam Coils: Rated according to ARI 410 and ASHRAE 33, and bearing the ARI label, **as directed**.
    a. Access: Fabricate coil section to allow removal and replacement of coil and to allow in-place access for service and maintenance of coil(s).
    b. Casing: Manufacturer's standard material **OR** Aluminum **OR** Galvanized steel **OR** Stainless steel, **as directed**.
    c. Tubes: Copper.
    d. Tube Headers: Manufacturer's standard material **OR** Copper **OR** Carbon steel **OR** Red brass, **as directed**.
    e. Fins: Aluminum **OR** Copper, **as directed**.
    f. Fin and Tube Joint: Mechanical bond.
    g. Leak Test: Coils shall be leak tested with air under water.
    h. Coating: Phenolic epoxy corrosion-protection coating after assembly.
12. Electrical Coils, Controls, and Accessories: Comply with UL 1995.
    a. Casing Assembly: Slip-in **OR** Flanged, **as directed**, type with galvanized-steel frame.
    b. Access: Fabricate coil section to allow removal and replacement of coil and to allow in-place access for service.
    c. Sheathed Heating Elements: Coiled resistance wire of 80 percent nickel and 20 percent chromium surrounded by compacted magnesium-oxide powder in tubular-steel sheath; with spiral-wound, copper-plated, steel fins continuously brazed to sheath.
       OR
       Open Heating Elements: Resistance wire of 80 percent nickel and 20 percent chromium supported and insulated by floating ceramic bushings recessed into casing openings, fastened to supporting brackets, and mounted in galvanized-steel frame.
    d. Overtemperature Protection: Disk-type, automatically resetting, thermal-cutout, safety device; serviceable through terminal box without removing heater from coil section.
    e. Secondary Protection: Load-carrying, manually resetting or manually replaceable, thermal cutouts; factory wired in series with each heater stage.
    f. Control Panel: Unit **OR** Remote, **as directed**, mounted with disconnecting means and overcurrent protection.
       1) Magnetic **OR** Mercury, **as directed**, contactor.
       2) Solid-state, stepless pulse controller.
       3) Toggle switches, one per step.
       4) Step controller.
       5) Time-delay relay.

6) Pilot lights, one per step.
7) Airflow proving switch.

13. Indirect-Fired Gas Furnaces:
    a. Description: Factory assembled, piped, and wired; complying with NFPA 54, "National Fuel Gas Code," and ANSI Z21.47, "Gas-Fired Central Furnaces."
        1) AGA Approval: Furnace shall bear label of AGA.
    b. Burners: Aluminized steel with stainless-steel inserts **OR** Stainless steel, **as directed**.
        1) Ignition: Electronically controlled electric spark with flame sensor.
        2) High-Altitude Model **OR** Kit, **as directed**: For Project at elevations more than 2000 feet (610 m) above sea level.
    c. Heat-Exchanger Drain Pan: Stainless steel.
    d. Venting: Gravity vented.
       OR
       Power Vent: Integral, motorized centrifugal fan interlocked with gas valve.
    e. Gas Control Valve: Single stage **OR** Two stage **OR** Electronic modulating, **as directed**.
    f. Gas Train: Single-body, regulated, redundant, 24-V ac gas valve assembly containing pilot solenoid valve, pilot filter, pressure regulator, pilot shutoff, and manual shutoff. Control devices and control sequence shall comply with requirements of FMG **OR** IRI, **as directed**.
    g. Access: Fabricate section to allow removal and replacement of furnace and to allow in-place access for service.
14. Piping and Wiring: Fabricate units with space within housing for piping and electrical conduits. Wire motors and controls so only external connections are required during installation.
    a. Indoor Enclosure: NEMA 250, Type 12 enclosure contains relays, starters, and terminal strip.
    b. Outdoor Enclosure: NEMA 250, Type 3R enclosure contains relays, starters, and terminal strip.
    c. Include fused **OR** nonfused, **as directed**, disconnect switches.
    d. Variable-speed controller to vary fan capacity from 100 to approximately 50 percent.
15. Accessories:
    a. Roof Curb: Steel **OR** Galvanized steel **OR** Aluminum, **as directed**, with gasketing, and factory-installed wood nailer; complying with NRCA standards; minimum height of 14 inches (350 mm) **OR** 24 inches (600 mm), **as directed**.
    b. Intake weather hood with 2-inch- (50-mm-) thick filters.
    c. Louvered intake weather hood with 2-inch- (50-mm-) thick filters in V-bank configuration.
    d. Exhaust weather hood with birdscreen.
    e. Low-Leakage, Isolation Dampers: Double-skin, airfoil-blade, galvanized-steel **OR** aluminum **OR** extruded-aluminum, **as directed**, dampers with compressible jamb seals and extruded-vinyl blade edge seals, in opposed-blade **OR** parallel-blade, **as directed**, arrangement with steel **OR** cadmium-plated steel, **as directed**, operating rods rotating in stainless-steel sleeve **OR** sintered bronze or nylon, **as directed**, bearings mounted in a single galvanized-steel **OR** aluminum **OR** extruded-aluminum, **as directed**, frame, with operating rods connected with a common linkage, and electric damper operator factory wired. Leakage rate shall not exceed 5 cfm/sq. ft. (0.22 L/s per sq. m) at 1-inch wg (250 Pa) and 9 cfm/sq. ft. (0.4 L/s per sq. m) at 4-inch wg (1.0 MPa).
       OR
       Isolation Dampers: Opposed-blade, galvanized-steel **OR** aluminum **OR** extruded-aluminum, **as directed**, dampers with steel **OR** cadmium-plated steel, **as directed**, operating rods rotating in sintered bronze or nylon bearings mounted in a single galvanized-steel **OR** aluminum **OR** extruded-aluminum, **as directed**, frame with operating rods connected with a common linkage, and electric damper operator factory wired. Blades shall have gaskets and edge seals, and shall be mechanically fastened to operating rod.
    f. Duct flanges.
    g. Rubber-in-shear isolators for ceiling-mounted units.
    h. Hinged access doors with quarter-turn latches.
    i. Drain pans for condensate removal complying with ASHRAE 62.1, **as directed**.

j. Automatic, in-place, spray-wash system.
k. Weatherproofing for tilt-control system.

F. Controls
1. Time Clock: Solid-state, programmable, microprocessor-based unit for wall mounting **OR** mounting in outdoor NEMA 250, Type 3R enclosure, **as directed**, with up to eight on/off cycles per day and battery backup protection of program settings against power failure to energize unit.
2. Motion (Occupancy) Sensor: Passive infrared sensor for wall **OR** ceiling, **as directed**, mounting with adjustable time-off delay of up to 30 minutes to energize unit.
3. Carbon Monoxide Sensor: Adjustable control from 600 to 2000 ppm for wall **OR** duct, **as directed**, mounting with digital display and computer/building management system interface to energize unit.
4. Humidistat: Adjustable, wall-mounted instrument to energize unit when space relative humidity exceeds 50 percent.
5. Chilled-Water-Cooling-Coils Controls:
   a. For chilled-water cooling coils with discharge-air temperature control: Factory-mounted sensor in unit discharge **OR** Remote-mounted sensor for field installation in supply-air duct, **as directed**, with sensor adjustment located in control panel to modulate factory-mounted **OR** furnished, **as directed**, coil-control valve to maintain temperature.
   b. For chilled-water cooling coils with remote temperature control: Wall-mounted, space-temperature sensor with temperature adjustment **OR** unit-mounted temperature adjustment **OR** adjustment on remote-control panel, **as directed**, to modulate factory-mounted **OR** furnished, **as directed**, coil-control valve to maintain temperature.
6. Refrigerant-Cooling-Coils Controls:
   a. For refrigerant cooling coils with discharge-air temperature control: Factory-mounted sensor in unit discharge **OR** Remote-mounted sensor for field installation in supply-air duct, **as directed**, with sensor adjustment located in control panel to control remote condensing unit to maintain temperature.
   b. For refrigerant cooling coils coils with remote temperature control: Wall-mounted, space-temperature sensor with temperature adjustment **OR** unit-mounted temperature adjustment **OR** adjustment on remote-control panel, **as directed**, controls remote condensing unit to maintain temperature.
   c. Cooling Capacity Control: On/off **OR** Multiple steps, **as directed**.
7. Hot-Water- and Steam-Coils Controls:
   a. For hot-water or steam coils with discharge-air temperature control: Factory-mounted sensor in unit discharge **OR** Remote-mounted sensor for field installation in supply-air duct, **as directed**, with sensor adjustment located in control panel to modulate factory-mounted **OR** furnished, **as directed**, coil-control valve to maintain temperature.
   b. For hot-water or steam coils with remote temperature control: Wall-mounted, space-temperature sensor with temperature adjustment **OR** unit-mounted temperature adjustment **OR** adjustment on remote-control panel, **as directed**, to modulate factory-mounted **OR** furnished, **as directed**, coil-control valve to maintain temperature.
8. Electric-Coils Controls:
   a. For electric coils with discharge-air temperature control: Factory-mounted sensor in unit discharge **OR** Remote-mounted sensor for field installation in supply-air duct, **as directed**, with sensor adjustment located in control panel to control electric coil to maintain temperature.
   b. For electric coils with remote temperature control: Wall-mounted, space-temperature sensor with temperature adjustment **OR** unit-mounted temperature adjustment **OR** adjustment on remote-control panel, **as directed**, to control electric coil to maintain temperature.
   c. Coil Controls: On/off **OR** Multiple steps **OR** Modulating SCR, **as directed**.
9. Indirect-Fired-Gas-Furnaces Controls:
   a. For indirect-fired gas furnaces with discharge-air temperature control: Factory-mounted sensor in unit discharge **OR** Remote-mounted sensor for field installation in supply-air duct,

as directed, with sensor adjustment located in control panel to control gas furnace burner to maintain temperature.

b. For indirect-fired gas furnaces with remote temperature control: Wall-mounted, space-temperature sensor with temperature adjustment **OR** unit-mounted temperature adjustment **OR** adjustment on remote-control panel, **as directed**, to control gas furnace burner to maintain temperature.

c. Burner Controls: On/off **OR** Multiple steps **OR** Modulating, **as directed**.

1.3 EXECUTION

A. Examination

1. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
2. Examine casing insulation materials and filter media before air-to-air energy recovery equipment installation. Reject insulation materials and filter media that are wet, moisture damaged, or mold damaged.
3. Examine roughing-in for electrical services to verify actual locations of connections before installation.
4. Proceed with installation only after unsatisfactory conditions have been corrected.

B. Installation

1. Install heat wheels so supply and exhaust airstreams flow in opposite directions and rotation is away from exhaust side to purge section to supply side.
   a. Install access doors in both supply and exhaust ducts, both upstream and downstream, for access to wheel surfaces, drive motor, and seals.
   b. Install removable panels or access doors between supply and exhaust ducts on building side for bypass during startup.
   c. Access doors and panels are specified in Division 23 Section "Air Duct Accessories".
2. Install heat-pipe heat exchangers so supply and exhaust airstreams flow in opposite directions. Install flexible connectors on ducts to enable tilt control; make connections airtight and with slack to compensate for full tilt.
   a. Install heat exchanger with clearance space for heat-pipe coil removal.
   b. Install duct access doors in both supply and exhaust ducts, both upstream and downstream, for access to both sides of heat-pipe coil. Access doors and panels are specified in Division 23 Section "Air Duct Accessories".
   c. Install tilt-control components, including electronic controller, electric actuator and linkage, thermostats, and sensors.
3. Install fixed-plate heat exchangers so supply and exhaust airstreams flow in opposite directions.
   a. Install duct access doors in both supply and exhaust ducts, both upstream and downstream, for access to heat exchanger. Access doors and panels are specified in Division 23 Section "Air Duct Accessories".
4. Install gas-fired furnaces according to NFPA 54, "National Fuel Gas Code."
5. Install floor-mounted units on 4-inch- (100-mm-) high concrete base designed to withstand, without damage to equipment, seismic force required by code, **as directed**.
6. Equipment Mounting (for equipment supported on a concrete base on grade without vibration isolation devices): Install air-to-air energy recovery equipment on concrete bases. Comply with requirements for concrete bases specified in Division 03 Section "Cast-in-place Concrete".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
7. Roof Curb: Install on roof structure or concrete base, level and secure, according to The NRCA "Roofing and Waterproofing Manual - Volume 4: Construction Details - Low-Slope Roofing,"

Illustration "Raised Curb Detail for Rooftop Air Handling Units and Ducts" **OR** ARI Guideline B, **as directed**. Install air-to-air energy recovery equipment on curbs and coordinate roof penetrations and flashing with roof construction specified in Division 07 Section "Roof Accessories". Secure air-to-air energy recovery equipment to upper curb rail, and secure curb base to roof framing or concrete base with anchor bolts.

8. Unit Support: Install unit level on structural curbs **OR** pilings, **as directed**. Coordinate wall penetrations and flashing with wall construction. Secure air-to-air energy recovery equipment to structural support with anchor bolts.
9. Install wind and seismic restraints according to manufacturers' written instructions. Wind and seismically restrained vibration isolation roof-curb rails are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
10. Suspended Units: Suspend and brace, **as directed**, units from structural-steel support frame using threaded steel rods and spring hangers. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
11. Install units with clearances for service and maintenance.
12. Install new filters at completion of equipment installation and before testing, adjusting, and balancing.
13. Pipe drains from units and drain pans to nearest floor drain; use ASTM B 88, Type L (ASTM B 88M, Type B), drawn-temper copper water tubing with soldered joints **OR** ASTM D 1785, Schedule 40 PVC pipe and solvent-welded fittings, **as directed**, same size as condensate drain connection.
    a. Requirements for Low-Emitting Materials:
        1) Use PVC solvent cement that has a VOC content of 510 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).
        2) Use adhesive primer that has a VOC content of 550 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24).

C. Connections
1. Comply with requirements for piping specified in Division 23 Section "Hydronic Piping". Drawings indicate general arrangement of piping, fittings, and specialties.
2. Install piping adjacent to unit to allow service and maintenance.
3. Connect piping to units mounted on vibration isolators with flexible connectors.
4. Connect cooling condensate drain pans with air seal trap at connection to drain pan and install cleanouts at changes in pipe direction.
5. Chilled and Hot Water Piping: Comply with applicable requirements in Division 23 Section "Hydronic Piping". Install shutoff valve and union or flange at each coil supply connection. Install balancing valve and union or flange at each coil return connection.
6. Steam and Condensate Piping: Comply with applicable requirements in Division 23 Section "Steam And Condensate Heating Piping". Install shutoff valve at steam coil connections, float and thermostatic trap, and union or flange at each coil return connection.
7. Refrigerant Piping: Comply with applicable requirements in Division 23 Section "Refrigerant Piping".
8. Gas Piping: Comply with requirements in Division 23 Section(s) "Facility Natural-gas Piping" OR "Facility Liquefied-petroleum Gas Piping", **as directed**. Connect gas piping with shutoff valve and union and with sufficient clearance for burner removal and service. Make connection with AGA-approved flexible connectors.
9. Comply with requirements for ductwork specified in Division 23 Section "Metal Ducts".
10. Indirect-Fired Furnace Vent Connections: Comply with Division 23 Section "Breechings, Chimneys, And Stacks".
11. Electrical Connections: Comply with applicable requirements in Division 22.
    a. Install electrical devices furnished with units but not factory mounted.

D. Field Quality Control
1. Perform tests and inspections.

2. Tests and Inspections:
   a. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   b. Adjust seals and purge.
   c. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
   d. Set initial temperature and humidity set points.
   e. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
3. Air-to-air energy recovery equipment will be considered defective if it does not pass tests and inspections.
4. Prepare test and inspection reports.

E. Demonstration
1. Train Owner's maintenance personnel to adjust, operate, and maintain air-to-air energy recovery units.

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SECTION 23 73 13 00 - MODULAR INDOOR CENTRAL-STATION AIR-HANDLING UNITS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for modular indoor central-station air-handling units. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Constant-air-volume, single-zone air-handling units.
b. Constant-air-volume, multizone air-handling units.
c. Constant-air-volume, dual-duct air-handling units.
d. Variable-air-volume, single-zone air-handling units.
e. Variable-air-volume, dual-duct air-handling units.

C. Performance Requirements
1. Delegated Design: Design vibration isolation and seismic-restraint details, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
2. Structural Performance: Casing panels shall be self-supporting and capable of withstanding 133 percent of internal static pressures indicated, without panel joints exceeding a deflection of L/200 **OR** L/100, **as directed**, where "L" is the unsupported span length within completed casings.
3. Seismic Performance: Air-handling units shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

D. Submittals
1. Product Data: For each air-handling unit indicated.
a. Unit dimensions and weight.
b. Cabinet material, metal thickness, finishes, insulation, and accessories.
c. Fans:
1) Certified fan-performance curves with system operating conditions indicated.
2) Certified fan-sound power ratings.
3) Fan construction and accessories.
4) Motor ratings, electrical characteristics, and motor accessories.
d. Certified coil-performance ratings with system operating conditions indicated.
e. Dampers, including housings, linkages, and operators.
f. Filters with performance characteristics.
2. LEED Submittal:
a. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
3. Delegated-Design Submittal: For vibration isolation and seismic restraints, **as directed**, indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
a. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
b. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints, **as directed**, and for designing vibration isolation bases.

4. Seismic Qualification Certificates: For air-handling units, accessories, and components, from manufacturer.
   a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
   c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
5. Source quality-control reports.
6. Field quality-control reports.
7. Operation and maintenance data

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components.
3. ARI Certification: Air-handling units and their components shall be factory tested according to ARI 430, "Central-Station Air-Handling Units," and shall be listed and labeled by ARI.
4. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
5. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
6. Comply with NFPA 70.

1.2 PRODUCTS

A. Unit Casings
1. General Fabrication Requirements for Casings:
   a. Forming: Form walls, roofs, and floors with at least two breaks at each joint.
   b. Casing Joints: Sheet metal screws or pop rivets.
   c. Sealing: Seal all joints with water-resistant sealant.
   d. Factory Finish for Steel and Galvanized-Steel Casings: Apply manufacturer's standard primer immediately after cleaning and pretreating.
      OR
      Factory Finish for Steel and Galvanized-Steel Casings: Immediately after cleaning and pretreating, apply manufacturer's standard two-coat, baked-on enamel finish, consisting of prime coat and thermosetting topcoat.
      OR
      Casing Coating: Thermoplastic vinyl **OR** Epoxy **OR** Zinc **OR** Synthetic resin **OR** Phenolic **OR** Polytetrafluoroethylene **OR** Vinyl ester **OR** Hot-dip galvanized **OR** Powder-baked enamel, **as directed**.
   e. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
2. Casing Insulation and Adhesive:
   a. Materials: ASTM C 1071, Type I **OR** Type II, **as directed**.
   b. Location and Application: Factory applied with adhesive and mechanical fasteners to the internal surface of section panels downstream from, and including, the cooling-coil section.
      1) Liner Adhesive: Comply with ASTM C 916, Type I.
      2) Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, mechanical attachment, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in cabinet.

3) Liner materials applied in this location shall have air-stream surface coated with a temperature-resistant coating or faced with a plain or coated fibrous mat or fabric depending on service-air velocity.

OR

Location and Application: Encased between outside and inside casing.

3. Inspection and Access Panels and Access Doors:
   a. Panel and Door Fabrication: Formed and reinforced, single- or double-wall and insulated panels of same materials and thicknesses as casing.
   b. Inspection and Access Panels:
      1) Fasteners: Two or more camlock type for panel lift-out operation. Arrangement shall allow panels to be opened against air-pressure differential.
      2) Gasket: Neoprene, applied around entire perimeters of panel frames.
      3) Size: Large enough to allow inspection and maintenance of air-handling unit's internal components.
   c. Access Doors:
      1) Hinges: A minimum of two ball-bearing hinges or stainless-steel piano hinge and two wedge-lever-type latches, operable from inside and outside. Arrange doors to be opened against air-pressure differential.
      2) Gasket: Neoprene, applied around entire perimeters of panel frames.
      3) Fabricate windows in fan section doors of double-glazed, wire-reinforced safety glass with an air space between panes and sealed with interior and exterior rubber seals.
      4) Size: At least 18 inches (450 mm) **OR** 24 inches (600 mm), **as directed**, wide by full height of unit casing up to a maximum height of 60 inches (1500 mm) **OR** 72 inches (1800 mm), **as directed**.
   d. Locations and Applications:
      1) Fan Section: Inspection and access panels **OR** Doors **OR** Doors and inspection and access panels, **as directed**.
      2) Access Section: Doors.
      3) Coil Section: Inspection and access panel.
      4) Damper Section: Inspection and access panels **OR** Doors, **as directed**.
      5) Filter Section: Inspection and access panels **OR** Doors, **as directed**, large enough to allow periodic removal and installation of filters.
      6) Mixing Section: Doors.
      7) Humidifier Section: Doors.
   e. Service Light: 100-W vaporproof fixture with switched junction box located outside **OR** inside, **as directed**, adjacent to door.
      1) Locations: Each section accessed with door **OR** Fan section, **as directed**.
4. Condensate Drain Pans:
   a. Fabricated with one **OR** two, **as directed**, percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and from humidifiers and to direct water toward drain connection.
      1) Length: Extend drain pan downstream from leaving face to comply with ASHRAE 62.1.
      2) Depth: A minimum of 2 inches (50 mm) deep.
   b. Formed sections **OR** Integral part of floor plating, **as directed**.
   c. Single-wall, galvanized-steel **OR** stainless-steel, **as directed**, sheet.

      OR

      Double-wall, galvanized-steel **OR** stainless-steel, **as directed**, sheet with space between walls filled with foam insulation and moisture-tight seal.
   d. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on one end **OR** both ends, **as directed**, of pan.
      1) Minimum Connection Size: NPS 1 (DN 25) **OR** NPS 2 (DN 50), **as directed**.
   e. Pan-Top Surface Coating: Asphaltic waterproofing compound, for galvanized-steel drain pans.

f. Units with stacked coils shall have an intermediate drain pan to collect condensate from top coil.

5. Service Platform: Steel **OR** Galvanized steel **OR** Aluminum, **as directed**, 42 inches (1070 mm) wide running entire length of unit and located on service access side, with angle side rails, 4-inch (100-mm) kick plates, and expanded metal floor. Provide platform with a fixed ladder that extends from the top of the side rail to the floor.

6. Air-Handling-Unit Mounting Frame: Formed galvanized-steel channel or structural channel supports, designed for low deflection, welded with integral lifting lugs.

a. Seismic Fabrication Requirements: Fabricate mounting base and attachment to air-handling unit sections, accessories, and components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" when air-handling unit frame is anchored to building structure.

B. Fan, Drive, And Motor Section

1. Fan and Drive Assemblies: Statically and dynamically balanced and designed for continuous operation at maximum-rated fan speed and motor horsepower.

a. Shafts: Designed for continuous operation at maximum-rated fan speed and motor horsepower, and with field-adjustable alignment.

1) Turned, ground, and polished hot-rolled steel with keyway. Ship with a protective coating of lubricating oil.

2) Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

2. Centrifugal Fan Housings: Formed- and reinforced-steel panels to form curved scroll housings with shaped cutoff and spun-metal inlet bell.

a. Bracing: Steel angle or channel supports for mounting and supporting fan scroll, wheel, motor, and accessories.

b. Horizontal-Flanged, Split Housing: Bolted construction.

c. Housing for Supply Fan: Attach housing to fan-section casing with metal-edged flexible duct connector.

d. Flexible Connector: Factory fabricated with a fabric strip 3-1/2 inches (89 mm) **OR** 5-3/4 inches (146 mm), **as directed**, wide attached to 2 strips of 2-3/4-inch- (70-mm-) wide, 0.028-inch- (0.7-mm-) thick, galvanized-steel sheet or 0.032-inch- (0.8-mm-) thick aluminum sheets; select metal compatible with casing.

1) Flexible Connector Fabric: Glass fabric, double coated with neoprene. Fabrics, coatings, and adhesives shall comply with UL 181, Class 1.

a) Fabric Minimum Weight: 26 oz./sq. yd. (880 g/sq. m).

b) Fabric Tensile Strength: 480 lbf/inch (84 N/mm) in the warp and 360 lbf/inch (63 N/mm) in the filling.

c) Fabric Service Temperature: Minus 40 to plus 200 deg F (Minus 40 to plus 93 deg C).

3. Plenum Fan Housings: Steel frame and panel; fabricated without fan scroll and volute housing.

4. Backward-Inclined, Centrifugal Fan Wheels: Single-width-single-inlet and double-width-double-inlet construction with curved inlet flange, backplate, backward-inclined blades welded or riveted to flange and backplate; cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.

OR

Forward-Curved, Centrifugal Fan Wheels: Inlet flange, backplate, and shallow blades with inlet and tip curved forward in direction of airflow and mechanically fastened to flange and backplate; cast-steel hub swaged to backplate and fastened to shaft with set screws.

OR

Airfoil, Centrifugal Fan Wheels: Smooth-curved inlet flange, backplate, and hollow die-formed airfoil-shaped blades continuously welded at tip flange and backplate; cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.

OR

Axial Fans: Fan wheel and housing, straightening-vane section, factory-mounted motor with belt drive or direct drive, an inlet cone section, and accessories.

a. Variable-Pitch Fans: Internally mounted pneumatic **OR** electric **OR** electronic, **as directed**, actuator, externally mounted positive positioner, and mechanical-blade-pitch indicator.

b. Housings: Steel **OR** Galvanized steel **OR** Aluminum, **as directed**.

1) Inlet and Outlet Connections: Flanges.

2) Guide Vane Section: Integral guide vanes downstream from fan wheel designed to straighten airflow.

5. Fan Shaft Bearings:

a. Prelubricated and Sealed, Ball Bearings: Self-aligning, pillow-block type with a rated life of 50,000 **OR** 120,000, **as directed**, hours according to ABMA 9.

OR

Grease-Lubricated, Tapered-Roller Bearings: Self-aligning, pillow-block type with double-locking collars and 2-piece, cast-iron housing with grease lines extended to outside unit, **as directed**, and a rated life of 50,000 **OR** 120,000, **as directed**, hours according to ABMA 11.

OR

Grease-Lubricated Bearings: Self-aligning, pillow-block-type, ball or roller bearings with adapter mount and two-piece, cast-iron housing with grease lines extended to outside unit, **as directed**.

6. Belt Drives: Factory mounted, with adjustable alignment and belt tensioning, and with 1.5 **OR** 1.4 **OR** 1.3 **OR** 1.2, **as directed**, service factor based on fan motor.

a. Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.

b. Motor Pulleys: Adjustable pitch for use with 5-hp motors and smaller; fixed pitch for use with motors larger than 5 hp. Select pulley size so pitch adjustment is at the middle of adjustment range at fan design conditions.

c. Belts: Oil resistant, nonsparking, and nonstatic; in matched sets for multiple-belt drives.

d. Belt Guards: Comply with requirements specified by OSHA and fabricate according to SMACNA's "HVAC Duct Construction Standards"; 0.1046-inch- (2.7-mm-) thick, 3/4-inch (20-mm) diamond-mesh wire screen, welded to steel angle frame; prime coated.

7. Variable-Inlet Vanes: Steel, with blades supported at both ends with permanently lubricated bearings. Variable mechanism terminating in single lever for connection to control actuator with connecting shaft for second set of variable inlet vanes on double-width fans.

OR

Discharge Dampers: Heavy-duty steel assembly with channel frame and sealed ball bearings, and opposed **OR** parallel, **as directed**, blades constructed of two plates formed around and welded to shaft, with blades linked out of air stream to single control lever.

8. Internal Vibration Isolation and Seismic Control, **as directed**: Fans shall be factory mounted with manufacturer's standard restrained, **as directed**, vibration isolation mounting devices having a minimum static deflection of 1 inch (25 mm) **OR** 2 inches (50 mm), **as directed**.

a. Seismic Fabrication Requirements: Fabricate fan section, internal mounting frame and attachment to fans, fan housings, motors, casings, accessories, and other fan section components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" when fan-mounting frame and air-handling-unit mounting frame are anchored to building structure.

9. Motor: Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".

a. Enclosure Type: Totally enclosed, fan cooled.

b. NEMA Premium (TM) efficient motors as defined in NEMA MG 1.

c. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.

d. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 21.
e. Mount unit-mounted disconnect switches on exterior **OR** interior, **as directed**, of unit.

10. Variable Frequency Controllers:
    a. Description: NEMA ICS 2, IGBT, PWM, VFC; listed and labeled as a complete unit and arranged to provide variable speed of an NEMA MG 1, Design B, 3-phase induction motor by adjusting output voltage and frequency.
    b. Output Rating: 3-phase; 6 to 60 Hz, with voltage proportional to frequency throughout voltage range **OR** 66 Hz, with torque constant as speed changes **OR** 120 Hz, with horsepower constant throughout speed range, **as directed**.
    c. Unit Operating Requirements:
        1) Input ac voltage tolerance of 208 V, plus or minus 5 **OR** 380 to 500 V, plus or minus 10 **OR** 525 to 575 V, plus or minus 10, **as directed**, percent.
        2) Input frequency tolerance of 50/60 Hz, plus or minus 6 percent.
        3) Minimum Efficiency: 96 percent at 60 Hz, full load.
        4) Minimum Displacement Primary-Side Power Factor: 96 percent.
        5) Overload Capability: 1.1 times the base load current for 60 seconds; 2.0 times the base load current for 3 seconds.
        6) Starting Torque: 100 percent of rated torque or as indicated.
        7) Speed Regulation: Plus or minus 1 percent.
    d. Isolated control interface to allow controller to follow control signal over an 11:1 speed range.
    e. Internal Adjustability Capabilities:
        1) Minimum Speed: 5 to 25 percent of maximum rpm.
        2) Maximum Speed: 80 to 100 percent of maximum rpm.
        3) Acceleration: 2 to a minimum of 22 seconds.
        4) Deceleration: 2 to a minimum of 22 seconds.
        5) Current Limit: 50 to a minimum of 110 percent of maximum rating.
    f. Self-Protection and Reliability Features:
        1) Input transient protection by means of surge suppressors.
        2) Undervoltage and overvoltage trips; inverter overtemperature, overload, and overcurrent trips.
        3) Adjustable motor overload relays capable of NEMA ICS 2, Class 10 **OR** Class 20 **OR** Class 30, **as directed**, performance.
        4) Notch filter to prevent operation of the controller-motor-load combination at a natural frequency of the combination.
        5) Instantaneous line-to-line and line-to-ground overcurrent trips.
        6) Loss-of-phase protection.
        7) Reverse-phase protection.
        8) Short-circuit protection.
        9) Motor overtemperature fault.
    g. Automatic Reset/Restart: Attempts three restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Bidirectional autospeed search shall be capable of starting into rotating loads spinning in either direction and returning motor to set speed in proper direction, without damage to controller, motor, or load.
    h. Power-Interruption Protection: To prevent motor from re-energizing after a power interruption until motor has stopped.
    i. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.
    j. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.
    k. Door-mounted LED status lights shall indicate the following conditions:
        1) Power on.

2) Run.
3) Overvoltage.
4) Line fault.
5) Overcurrent.
6) External fault.

l. Panel-Mounted Operator Station: Start-stop and auto-manual selector switches with manual-speed-control potentiometer and elapsed time meter.

m. Meters or digital readout devices and selector switch, mounted flush in controller door and connected to indicate the following controller parameters:
1) Output frequency (Hertz).
2) Motor speed (rpm).
3) Motor status (running, stop, fault).
4) Motor current (amperes).
5) Motor torque (percent).
6) Fault or alarming status (code).
7) Proportional-integral-derivative (PID) feedback signal (percent).
8) DC-link voltage (volts direct current).
9) Set-point frequency (Hertz).
10) Motor output voltage (volts).

n. Control Signal Interface:
1) Electric Input Signal Interface: A minimum of 2 analog inputs (0 to 10 V or 0/4-20 mA) and 6 programmable digital inputs.
2) Remote signal inputs capable of accepting any of the following speed-setting input signals from the control system:
a) 0 to 10-V dc.
b) 0-20 or 4-20 mA.
c) Potentiometer using up/down digital inputs.
d) Fixed frequencies using digital inputs.
e) RS485.
f) Keypad display for local hand operation.
3) Output signal interface with a minimum of 1 analog output signal (0/4-20 mA), which can be programmed to any of the following:
a) Output frequency (Hertz).
b) Output current (load).
c) DC-link voltage (volts direct current).
d) Motor torque (percent).
e) Motor speed (rpm).
f) Set-point frequency (Hertz).
4) Remote indication interface with a minimum of 2 dry circuit relay outputs (120-V ac, 1 A) for remote indication of the following:
a) Motor running.
b) Set-point speed reached.
c) Fault and warning indication (overtemperature or overcurrent).
d) High- or low-speed limits reached.

o. Communications: RS485 interface allows VFC to be used with an external system within a multidrop LAN configuration. Interface shall allow all parameter settings of VFC to be programmed via BMS control. Provide capability for VFC to retain these settings within the nonvolatile memory.

p. Integral Disconnecting Means: NEMA AB 1, instantaneous-trip circuit breaker **OR** NEMA AB 1, molded-case switch **OR** NEMA KS 1, nonfusible switch **OR** NEMA KS 1, fusible switch, **as directed**, with lockable handle.

q. Accessories:
1) Devices shall be factory installed in controller enclosure unless otherwise indicated.
2) Push-Button Stations, Pilot Lights, and Selector Switches: NEMA ICS 2, heavy-duty type.
3) Standard Displays:

a) Output frequency (Hertz).
b) Set-point frequency (Hertz).
c) Motor current (amperes).
d) DC-link voltage (volts direct current).
e) Motor torque (percent).
f) Motor speed (rpm).
g) Motor output voltage (volts).

C. Coil Section
1. General Requirements for Coil Section:
a. Comply with ARI 410.
b. Fabricate coil section to allow removal and replacement of coil for maintenance and to allow in-place access for service and maintenance of coil(s).
c. For multizone units, provide air deflectors and air baffles to balance airflow across coils.
d. Coils shall not act as structural component of unit.
e. Seismic Fabrication Requirements: Fabricate coil section, internal mounting frame and attachment to coils, and other coil section components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" when coil-mounting frame and air-handling-unit mounting frame are anchored to building structure.
2. Electrical Heating Coils, Controls, and Accessories: Comply with UL 1995.
a. Casing Assembly: Slip-in **OR** Flanged, **as directed**, type with galvanized-steel frame.
b. Sheathed Heating Elements: Coiled resistance wire of 80 percent nickel and 20 percent chromium surrounded by compacted magnesium-oxide powder in tubular-steel sheath; with spiral-wound, copper-plated, steel fins continuously brazed to sheath.
OR
Open Heating Elements: Resistance wire of 80 percent nickel and 20 percent chromium supported and insulated by floating ceramic bushings recessed into casing openings, fastened to supporting brackets, and mounted in galvanized-steel frame.
c. Overtemperature Protection: Disk-type, automatically resetting, thermal-cutout, safety device; serviceable through terminal box without removing heater from coil section.
d. Secondary Protection: Load-carrying, manually resetting or manually replaceable, thermal cutouts; factory wired in series with each heater stage.
e. Control Panel: Unit **OR** Remote, **as directed**, mounted with disconnecting means and overcurrent protection.
1) Magnetic **OR** Mercury, **as directed**, contactor.
2) Solid-state, stepless pulse controller.
3) Toggle switches, one per step.
4) Step controller.
5) Time-delay relay.
6) Pilot lights, one per step.
7) Airflow proving switch.

D. Air Filtration Section
1. General Requirements for Air Filtration Section:
a. Comply with NFPA 90A.
b. Provide minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.
c. Provide filter holding frames arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side or lifted out from access plenum.
2. Disposable Panel Filters:
a. Factory-fabricated, viscous-coated, flat-panel type.
b. Thickness: 1 inch (25 mm) **OR** 2 inches (50 mm), **as directed**.
c. Dust-Holding Capacity: as directed by the Owner.

d. Initial Resistance: as directed by the Owner.
e. Recommended Final Resistance: as directed by the Owner.
f. Arrestance (ASHRAE 52.1): 80.
g. Merv (ASHRAE 52.2): 5.
h. Media: Interlaced glass fibers sprayed with nonflammable adhesive and antimicrobial agent, **as directed**.
i. Frame: Galvanized steel, with metal grid on outlet side, steel rod grid on inlet side, hinged, and with pull and retaining handles.

3. Extended-Surface, Disposable Panel Filters:
   a. Factory-fabricated, dry, extended-surface type.
   b. Thickness: 1 inch (25 mm) **OR** 2 inches (50 mm) **OR** 4 inches (100 mm), **as directed**.
   c. Dust-Holding Capacity: as directed by the Owner.
   d. Initial Resistance: as directed by the Owner.
   e. Recommended Final Resistance: as directed by the Owner.
   f. Arrestance (ASHRAE 52.1): 90.
   g. Merv (ASHRAE 52.2): 7.
   h. Media: Fibrous material formed into deep-V-shaped pleats with antimicrobial agent, **as directed**, and held by self-supporting wire grid.
   i. Media-Grid Frame: Nonflammable cardboard **OR** Galvanized steel **OR** Fire-retardant, 3/4-inch (20-mm) particleboard with gaskets, **as directed**.
   j. Mounting Frames: Welded, galvanized steel, with gaskets and fasteners, suitable for bolting together into built-up filter banks.
4. Extended-Surface, Nonsupported-Media Filters:
   a. Factory-fabricated, dry, extended-surface, self-supporting type.
   b. Dust-Holding Capacity: as directed by the Owner.
   c. Initial Resistance: as directed by the Owner.
   d. Recommended Final Resistance: as directed by the Owner.
   e. Arrestance (ASHRAE 52.1): 95.
   f. Merv (ASHRAE 52.2): 13.
   g. Media: Fibrous material with antimicrobial agent, **as directed**, constructed so individual pleats are maintained in tapered form by flexible internal supports under rated-airflow conditions.
   h. Filter-Media Frame: Galvanized steel **OR** Hard polyurethane foam, **as directed**.
   i. Mounting Frames: Welded, galvanized steel, with gaskets and fasteners, suitable for bolting together into built-up filter banks with space for prefilter, **as directed**.
5. Automatic Roll Filters:
   a. Factory-fabricated, automatic, motor-driven, roll type.
   b. Arrangement: Horizontal **OR** Vertical, **as directed**.
   c. Dust-Holding Capacity: as directed by the Owner.
   d. Initial Resistance: as directed by the Owner.
   e. Recommended Final Resistance: as directed by the Owner.
   f. Arrestance (ASHRAE 52.1): 80.
   g. Merv (ASHRAE 52.2): 5.
   h. Media: Compressed and rolled, fibrous-glass material viscous coated, and with antimicrobial agent, **as directed**.
   i. Holding Frame: Galvanized steel, with enclosed, clean media roll arranged to allow upstream replacement of filter media.
   j. Auxiliary Frame: Locate on downstream side of unit with downstream **OR** side, **as directed**, access.
   k. Final Filter: Extended-surface, retained-media **OR** nonsupported-media **OR** HEPA, **as directed**, filters.
   l. Control and Drive:
      1) Mechanism: Electric, gear-reducer, motor-driven, feed control equipped with manual media advance and runout switches for stopping media movement of filter bank and operating remote warning signal lights.

2) Manual Control: Manual switch to advance media and wired to override automatic controls.
3) Automatic Control: Prewired control package to advance media when filter resistance exceeds adjustable high limit **OR** after adjustable operating time, **as directed**.

6. Activated-Carbon Panel Filters:
   a. Factory-fabricated unit with activated-carbon media.
   b. Flat-Panel Media: Multilayer filter with inlet layer of polyester fibers, layer of activated-carbon granules bonded to fibers, layer of polyurethane foam, and housed in cardboard frame.
   c. Pleated Media: Multilayer filter with inlet layer of cotton and synthetic fibers and layer of activated-carbon granules bonded to synthetic fibers, formed into deep-V-shaped pleats and held by self-wire grid, and housed in nonflammable cardboard frame.
   d. Mounting Frames: Welded galvanized steel, with polyurethane gaskets and fasteners, capable of holding media and media frame in place and suitable for bolting together into built-up filter banks.
7. Activated-Carbon Filters:
   a. Factory-fabricated unit in deep-V arrangement with disposable panel prefilter.
   b. Media: Activated carbon mounted in removable carbon-cell trays of epoxy-coated steel.
   c. Activated-Carbon Capacity: 12 lb (5.4 kg) of activated carbon per 500 cfm (236 L/s) **OR** 8.8 lb (4.0 kg) of activated carbon per 2000 cfm (944 L/s), **as directed**, of airflow.
   d. Housing: 0.064-inch- (1.6-mm-) thick, galvanized steel, for side servicing through gasketed access doors on both sides. Equip housings with metal slide channel tracks to hold activated-carbon trays.
8. HEPA Filters:
   a. Factory-fabricated unit.
   b. Dust-Holding Capacity: as directed by the Owner.
   c. Initial Resistance: as directed by the Owner.
   d. Recommended Final Resistance: as directed by the Owner.
   e. Arrestance (ASHRAE 52.1): 95 percent on 0.3-micrometer D.O.P. particles **OR** 99.97 percent on 0.3-micrometer D.O.P. particles **OR** 99.9995 percent on 0.1- and 0.2-micrometer D.O.P. particles **OR** 99.99995 percent on 0.1- and 0.2-micrometer D.O.P. particles, **as directed**.
   f. Media: UL 586, fibrous glass, constructed of continuous sheets with closely spaced pleats with aluminum separators **OR** vinyl-coated aluminum separators **OR** separators of ribbons of filter media, **as directed**.
   g. Frame Material: 3/4-inch- (19-mm-) thick, fire-retardant plywood **OR** 3/4-inch- (19-mm-) thick, fire-retardant particleboard **OR** 3/4-inch- (19-mm-) thick plywood **OR** 3/4-inch- (19-mm-) thick particleboard **OR** Galvanized steel **OR** Aluminized steel **OR** Cadmium-plated steel **OR** Stainless steel **OR** Aluminum, **as directed**.
   h. Media to Frame Side Bond: Polyurethane foam **OR** Silicone **OR** Neoprene adhesive **OR** Fiberglass-mat packing **OR** Thermosetting sealant **OR** Knife edge in fluid-filled channel, **as directed**.
   i. Face Gasket: Neoprene expanded rubber **OR** Ceramic fiber **OR** Silicone, **as directed**.
   j. Mounting Frames: Downstream corners of holding device shall have cushion pads to protect media. Bolted filter-sealing mechanism shall mount and continuously seal each individual filter.
9. Filter Gage:
   a. 3-1/2-inch- (90-mm-) **OR** 2-inch- (50-mm-), **as directed**, diameter, diaphragm-actuated dial in metal case.
   b. Vent valves.
   c. Black figures on white background.
   d. Front recalibration adjustment.
   e. 2 **OR** 3, **as directed**, percent of full-scale accuracy.

f. Range: 0- to 0.5-inch wg (0 to 125 Pa) **OR** 0- to 1.0-inch wg (0 to 250 Pa) **OR** 0- to 2.0-inch wg (0 to 500 Pa) **OR** 0- to 3.0-inch wg (0 to 750 Pa) **OR** 0- to 4.0-inch wg (0 to 1000 Pa), **as directed**.

g. Accessories: Static-pressure tips with integral compression fittings, 1/4-inch (6-mm) aluminum **OR** plastic, **as directed**, tubing, and 2- or 3-way vent valves.

E. Dampers

1. General Requirements for Dampers: Leakage rate, according to AMCA 500, "Laboratory Methods for Testing Dampers for Rating," shall not exceed 2 percent of air quantity at 2000-fpm (10-m/s) face velocity through damper and 4-inch wg (1000-Pa) pressure differential.
2. Damper Operators: Comply with requirements in Division 23 Section "Instrumentation And Control For Hvac".

   OR

   Electronic Damper Operators:

   a. Direct-coupled type designed for minimum 60,000 full-stroke cycles at rated torque.
   b. Electronic damper position indicator shall have visual scale indicating percent of travel and 2- to 10-V dc, feedback signal.
   c. Operator Motors:
      1) Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Work Results For Hvac".
      2) Size to operate with sufficient reserve power to provide smooth modulating action or two-position action.
      3) Permanent Split-Capacitor or Shaded-Pole Type: Gear trains completely oil immersed and sealed. Equip spring-return motors with integral spiral-spring mechanism in housings designed for easy removal for service or adjustment of limit switches, auxiliary switches, or feedback potentiometer.
   d. Nonspring-Return Motors for Dampers Larger Than 25 Sq. Ft. (2.3 sq. m): Size for running torque of 150 in. x lbf (16.9 N x m) and breakaway torque of 300 in. x lbf (33.9 N x m).
   e. Spring-Return Motors for Dampers Larger Than 25 Sq. Ft. (2.3 sq. m): Size for running and breakaway torque of 150 in. x lbf (16.9 N x m).
   f. Size dampers for running torque calculated as follows:
      1) Parallel-Blade Damper with Edge Seals: 7 inch-lb/sq. ft. (86.8 kg-cm/sq. m) of damper.
      2) Opposed-Blade Damper with Edge Seals: 5 inch-lb/sq. ft. (62 kg-cm/sq. m) of damper.
      3) Parallel-Blade Damper without Edge Seals: 4 inch-lb/sq. ft (49.6 kg-cm/sq. m) of damper.
      4) Opposed-Blade Damper without Edge Seals: 3 inch-lb/sq. ft. (37.2 kg-cm/sq. m) of damper.
      5) Dampers with 2- to 3-Inch wg (500 to 750 Pa) of Pressure Drop or Face Velocities of 1000 to 2500 fpm (5 to 13 m/s): Increase running torque by 1.5.
      6) Dampers with 3- to 4-Inch wg (750 to 1000 Pa) of Pressure Drop or Face Velocities of 2500 to 3000 fpm (13 to 15 m/s): Increase running torque by 2.0.
   g. Coupling: V-bolt and V-shaped, toothed cradle.
   h. Overload Protection: Electronic overload or digital rotation-sensing circuitry.
   i. Fail-Safe Operation: Mechanical, spring-return mechanism with external, manual gear release on nonspring-return actuators.
   j. Power Requirements (Two-Position Spring Return): 24 **OR** 120 **OR** 230, **as directed**,-V ac.
   k. Power Requirements (Modulating): Maximum 10 VA at 24-V ac or 8 W at 24-V dc.
   l. Proportional Signal: 2- to 10-V dc or 4 to 20 mA, and 2- to 10-V dc position feedback signal.
   m. Temperature Rating: Minus 22 to plus 122 deg F (Minus 30 to plus 50 deg C) **OR** 40 to 104 deg F (5 to 40 deg C), **as directed**.

n. Run Time: 12 seconds open, 5 seconds closed **OR** 30 seconds **OR** 60 seconds **OR** 120 seconds, **as directed**.

OR

Pneumatic Damper Operators:

a. Rolling-diaphragm piston type with adjustable stops and spring return, sized to operate with sufficient reserve power to provide smooth modulating action or two-position action. Where actuators operate in sequence, provide pilot positioners.

b. Pneumatic Damper Position Indicator: Potentiometer mounted in enclosure with adjustable crank-arm assembly connected to damper to transmit 0 to 100 percent valve/damper travel.

c. Pilot Positioners:

1) Start Point: Adjustable from 2 to 12 psig (14 to 83 kPa).
2) Operating Span: Adjustable from 5 to 13 psig (35 to 90 kPa).
3) Linearity: Plus or minus 10 percent of output signal span.
4) Hysteresis: 3 percent of span.
5) Response: 0.25-psig (1723-Pa) input change.
6) Maximum Pilot Signal Pressure: 20 psig (140 kPa).
7) Maximum Control Air-Supply Pressure: 60 psig (410 kPa).

d. Actuator Housing: Molded or die-cast zinc or aluminum. Terminal unit actuators may be high-impact plastic with ambient temperature rating of 50 to 140 deg F (10 to 60 deg C) unless located in return-air plenums, **as directed**.

e. Inlet-Vane Operators: High pressure, with pilot positioners.

3. Zone Dampers: Two single-blade, galvanized-steel **OR** aluminum **OR** extruded-aluminum, **as directed**, dampers offset 90 degrees from each other on cadmium-plated, **as directed,** steel operating rod rotating in sintered bronze or nylon bearings mounted in a single galvanized-steel **OR** aluminum **OR** extruded-aluminum, **as directed**, frame. Provide blade gaskets and edge seals, and mechanically fasten blades to operating rod.

4. Face-and-Bypass Dampers: Opposed-blade, galvanized-steel **OR** aluminum **OR** extruded-aluminum, **as directed**, dampers with cadmium-plated, **as directed**, steel operating rods rotating in sintered bronze or nylon bearings mounted in a single galvanized-steel **OR** aluminum **OR** extruded-aluminum, **as directed**, frame and with operating rods connected with a common linkage. Provide blade gaskets and edge seals, and mechanically fasten blades to operating rod.

5. Outdoor- and Return-Air Mixing Dampers: Parallel-blade, galvanized-steel **OR** aluminum **OR** extruded-aluminum, **as directed**, dampers mechanically fastened to cadmium-plated, **as directed**, steel operating rod in reinforced cabinet. Connect operating rods with common linkage and interconnect linkages so dampers operate simultaneously.

6. Outdoor- and Return-Air Dampers: Low-leakage, double-skin, airfoil-blade, galvanized-steel **OR** aluminum **OR** extruded-aluminum, **as directed**, dampers with compressible jamb seals and extruded-vinyl blade edge seals in opposed-blade **OR** parallel-blade, **as directed**, arrangement with cadmium-plated, **as directed**, steel operating rods rotating in stainless-steel sleeve **OR** sintered bronze or nylon, **as directed**, bearings mounted in a single galvanized-steel **OR** aluminum **OR** extruded-aluminum, **as directed**, frame, and with operating rods connected with a common linkage. Leakage rate shall not exceed 5 cfm/sq. ft. (0.22 L/s per sq. m) at 1-inch wg (250 Pa) and 9 cfm/sq. ft. (0.4 L/s per sq. m) at 4-inch wg (1.0 MPa).

7. Mixing Section: Multiple-blade, air-mixer assembly located immediately downstream of mixing section.

8. Combination Filter and Mixing Section:

a. Cabinet support members shall hold 2-inch- (50-mm-) thick, pleated, flat, permanent or throwaway filters.

b. Multiple-blade, air-mixer assembly shall mix air to prevent stratification, located immediately downstream of mixing box.

F. Humidifiers

1. Steam Grid Humidifier:

a. Manifold:

1) ASTM A 666, Type 304 stainless steel.
2) Steam jacketed.
3) Insulated with 1/2-inch (13-mm) fiberglass and stainless-steel jacket.
4) Manifold shall extend the full width of unit with mounting brackets at ends.

b. Steam Separator: Cast iron, **OR** ASTM A 666, Type 304 stainless steel, **as directed**, with separate, **as directed**, humidifier control valve.

c. Humidifier Control Valve: Actuator: Pneumatic **OR** Electric, **as directed**, modulating with spring return.
OR
Humidifier Control Valve: Actuator: As specified in Division 23 Section "Instrumentation And Control For Hvac".

d. Steam Trap: Inverted-bucket type, sized for a minimum of three times the maximum rated condensate flow of humidifier at 1/2-psig (3.4-kPa) inlet pressure.

e. Aquastat: For separate mounting on steam condensate, return piping to prevent cold operation of humidifier.

f. Strainer: In-line type.

g. Airflow Switch: To prevent humidifier operation in the absence of airflow.

2. Wet Glass Cell Washer Section:

a. 3-inch- (75-mm-) deep cells with random packed, glass-fiber media in galvanized-steel **OR** stainless-steel, **as directed**, frames.

b. Access Door: Watertight with brass fittings, wire glass window, **as directed**, and locking handles.

c. Spray Tree Assembly: Brass **OR** Stainless-steel, **as directed**, nozzles and galvanized-steel **OR** stainless-steel, **as directed**, piping.

d. Eliminator: Galvanized-steel **OR** Stainless-steel, **as directed**, plates.

e. Tank:

1) Welded steel **OR** stainless steel, **as directed**, with interior and exterior surfaces blasted and painted with zinc-chromate paint, **as directed**.
2) Copper suction screen.
3) Drain, overflow, and suction connections.
4) Makeup connection with brass, **as directed**, float valve, and with quick-fill connection.

f. Insulate exterior with duct insulation and mount on 2-inch (-(50-mm-)) thick, rigid insulation board.

3. Evaporative Humidifier Section:

a. Access Door: Watertight cast iron, **as directed**, with brass fittings, wire glass window, and locking handles.

b. Spray Tree Assembly: Brass nozzles and galvanized piping, galvanized eliminator plates with flooding nozzles and header, and galvanized antisplash baffles **OR** cross-fluted cellulose media, **as directed**.

c. Tank:

1) Welded steel tank with interior and exterior surfaces blasted and painted with zinc-chromate paint.
2) Copper suction screen, drain, overflow, and suction connections.
3) Makeup connection with brass, **as directed**, float valve, and with quick-fill connection.

d. Insulation: Insulate with duct insulation on exterior and mount on 2-inch (-50-mm-) thick, rigid insulation board.

G. Air-To-Air Energy Recovery

1. Heat Wheels:

a. Casing:

1) Steel, with manufacturer's standard paint coating.
2) Integral purge section limiting carryover of exhaust air to between 0.05 percent at 1.6-inch wg and 0.20 percent at 4-inch wg (0.05 percent at 400-Pa and 0.20 percent at 1000-Pa) differential pressure.

3) Casing seals on periphery of rotor, on duct divider, and on purge section.
4) Support rotor on grease-lubricated ball bearings with extended grease fittings. Mount horizontal wheels on tapered roller bearing.

b. Rotor: Aluminum, segmented wheel, strengthened with radial spokes, with nontoxic, noncorrosive, silica-gel desiccant coating, **as directed**. Construct media for passing maximum 500 **OR** 800 **OR** 1200, **as directed**,-micrometer solids.
OR
Rotor: Glass-fiber **OR** Polymer, **as directed**, segmented wheel, strengthened with radial spokes impregnated with nonmigrating, water-selective, molecular-sieve desiccant coating. Construct media for passing maximum 800 **OR** 1200, **as directed**,-micrometer solids.

c. Drive: Fractional horsepower motor and gear reducer, with speed changed by variable frequency controller, **as directed**, and self-adjusting multilink belt around outside of rotor.

d. Controls:
1) Starting relay, factory mounted and wired, and manual motor starter for field wiring.
2) Variable frequency controller, factory mounted and wired, permitting input of field connected 4-20 mA or 1-10-V control signal.
OR
Variable frequency controller, factory mounted and wired, with exhaust-air sensor to vary rotor speed and maintain exhaust temperature above freezing.
OR
Variable frequency controller, factory mounted and wired, with exhaust- and outdoor-air sensors, automatic changeover thermostat and set-point adjuster, to vary rotor speed and maintain exhaust temperature above freezing, **as directed**, and air differential temperature above set point. Provide maximum rotor speed when exhaust-air temperature is less than outdoor-air temperature.
3) Pilot-Light Indicator: Display rotor rotation and speed.
4) Speed Settings: Adjustable settings for maximum and minimum rotor speed limits.

2. Fixed-Plate Sensible Heat Exchangers:

a. Casing: Aluminum **OR** Galvanized steel **OR** Enameled steel, with galvanized-steel liner **OR** Enameled steel, **as directed**.

b. Plates: Evenly spaced and sealed and arranged for counter airflow.

c. Plate Material: Embossed aluminum **OR** Stainless steel **OR** Polypropylene copolymer (high-density plastic), **as directed**.
1) Plate Coating: Epoxy **OR** Air-dried phenolic, **as directed**.

d. Bypass: Plenum within casing, with gasketed face-and-bypass dampers that have operating rods extended outside casing.

e. Water Wash: Automatic system, with spray manifold to individual spray tubes or traversing type with stainless-steel-screw operating mechanism and electric motor drive; activated by time clock, with detergent injection, **as directed**.

f. Heat-Exchanger Prefilters: 1 inch (25 mm) thick, disposable **OR** 2 inches (50 mm) thick, disposable **OR** Medium efficiency **OR** Electrostatic, **as directed**.

H. Source Quality Control

1. Fan Sound-Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Fans shall bear AMCA-certified sound ratings seal.
2. Fan Performance Rating: Factory test fan performance for airflow, pressure, power, air density, rotation speed, and efficiency. Rate performance according to AMCA 210, "Laboratory Methods of Testing Fans for Aerodynamic Performance Rating."
3. Water Coils: Factory tested to 300 psig (2070 kPa) according to ARI 410 and ASHRAE 33.
4. Steam Coils: Factory tested to 300 psig (2070 kPa) and to 200 psig (1380 kPa) underwater according to ARI 410 and ASHRAE 33.
5. Refrigerant Coils: Factory tested to 450 psig (3105 kPa) according to ARI 410 and ASHRAE 33.

1.3 EXECUTION

A. Installation

1. Equipment Mounting: Install air-handling units on concrete bases using elastomeric pads **OR** using elastomeric mounts **OR** using restrained spring isolators **OR** without vibration isolation devices, **as directed**. Secure units to anchor bolts installed in concrete bases. Comply with requirements for concrete bases specified in Division 03 Section "Cast-in-place Concrete". Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   a. Minimum Deflection: 1/2 inch (13 mm) **OR** 1 inch (25 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**.
   b. Install galvanized-steel **OR** stainless-steel, **as directed**, plate to equally distribute weight over elastomeric pad.
   c. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   d. Install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   e. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   f. Install anchor bolts to elevations required for proper attachment to supported equipment.

   OR

   Equipment Mounting: Install air-handling unit using elastomeric pads **OR** using elastomeric mounts **OR** using restrained spring isolators **OR** without vibration isolation devices, **as directed**. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   g. Minimum Deflection: 1/4 inch (6 mm) **OR** 1/2 inch (13 mm) **OR** 1 inch (25 mm) **OR** 2 inches (50 mm) **OR** 3 inches (75 mm), **as directed**.
   h. Install galvanized-steel **OR** stainless-steel, **as directed**, plate to equally distribute weight over elastomeric pad.
2. Suspended Units: Suspend and brace, **as directed**, units from structural-steel support frame using threaded steel rods and spring hangers. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
3. Arrange installation of units to provide access space around air-handling units for service and maintenance.
4. Do not operate fan system until filters (temporary or permanent) are in place. Replace temporary filters used during construction and testing, with new, clean filters.
5. Install filter-gage, static-pressure taps upstream and downstream of filters. Mount filter gages on outside of filter housing or filter plenum in accessible position. Provide filter gages on filter banks, installed with separate static-pressure taps upstream and downstream of filters.

B. Connections

1. Comply with requirements for piping specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
2. Install piping adjacent to air-handling unit to allow service and maintenance.
3. Connect piping to air-handling units mounted on vibration isolators with flexible connectors.
4. Connect condensate drain pans using NPS 1-1/4 (DN 32), ASTM B 88, Type M (ASTM B 88M, Type C) copper tubing. Extend to nearest equipment or floor drain. Construct deep trap at connection to drain pan and install cleanouts at changes in direction.
5. Hot- and Chilled-Water Piping: Comply with applicable requirements in Division 23 Section "Hydronic Piping". Install shutoff valve and union or flange at each coil supply connection. Install balancing valve and union or flange at each coil return connection.
6. Steam and Condensate Piping: Comply with applicable requirements in Division 23 Section "Steam And Condensate Heating Piping". Install shutoff valve at steam supply connections, float and thermostatic trap, and union or flange at each coil return connection. Install gate valve and

inlet strainer at supply connection of dry steam humidifiers, and inverted bucket steam trap to condensate return connection.

7. Refrigerant Piping: Comply with applicable requirements in Division 23 Section "Refrigerant Piping". Install shutoff valve and union or flange at each supply and return connection.
8. Connect duct to air-handling units with flexible connections. Comply with requirements in Division 23 Section "Air Duct Accessories".

C. Field Quality Control
1. Perform tests and inspections.
2. Tests and Inspections:
   a. Leak Test: After installation, fill water and steam coils with water, and test coils and connections for leaks.
   b. Charge refrigerant coils with refrigerant and test for leaks.
   c. Fan Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   d. Automatic-Roll-Filter Operational Test: Operate filters to demonstrate compliance with requirements. Test for leakage of unfiltered air while system is operating.
   e. HEPA-Filter Operational Test: Pressurize housing to a minimum of 3-inch wg (750 Pa) or to designed operating pressure, whichever is higher; test housing joints, door seals, and sealing edges of filter with soapy water to check for air leaks.
   f. HEPA-Filter Operational Test: Pressurize housing to a minimum of 3-inch wg (750 Pa) or to designed operating pressure, whichever is higher; test housing joints, door seals, and sealing edges of filter for air leaks according to ASME N510, pressure-decay method.
   g. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
3. Air-handling unit or components will be considered defective if unit or components do not pass tests and inspections.
4. Prepare test and inspection reports.

D. Startup Service
1. Perform startup service.
   a. Complete installation and startup checks according to manufacturer's written instructions.
   b. Verify that shipping, blocking, and bracing are removed.
   c. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, controllers, and switches.
   d. Verify proper motor rotation direction, free fan wheel rotation, and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
   e. Verify that bearings, pulleys, belts, and other moving parts are lubricated with factory-recommended lubricants.
   f. Verify that zone dampers fully open and close for each zone.
   g. Verify that face-and-bypass dampers provide full face flow.
   h. Verify that outdoor- and return-air mixing dampers open and close, and maintain minimum outdoor-air setting.
   i. Comb coil fins for parallel orientation.
   j. Verify that proper thermal-overload protection is installed for electric coils.
   k. Install new, clean filters.
   l. Verify that manual and automatic volume control and fire and smoke dampers in connected duct systems are in fully open position.
2. Starting procedures for air-handling units include the following:
   a. Energize motor; verify proper operation of motor, drive system, and fan wheel. Adjust fan to indicated rpm. Replace fan and motor pulleys as required to achieve design conditions, **as directed**.
   b. Measure and record motor electrical values for voltage and amperage.

c. Manually operate dampers from fully closed to fully open position and record fan performance.

E. Adjusting
1. Adjust damper linkages for proper damper operation.
2. Comply with requirements in Division 23 Section "Testing, Adjusting, And Balancing For Hvac" for air-handling system testing, adjusting, and balancing.

F. Cleaning
1. After completing system installation and testing, adjusting, and balancing air-handling unit and air-distribution systems and after completing startup service, clean air-handling units internally to remove foreign material and construction dirt and dust. Clean fan wheels, cabinets, dampers, coils, and filter housings, and install new, clean filters.

G. Demonstration
1. Train Owner's maintenance personnel to adjust, operate, and maintain air-handling units.

END OF SECTION 23 73 13 00

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Task	Specification	Specification Description
23 73 13 00	07 72 23 00	Roof Accessories

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SECTION 23 74 13 00 - SELF-CONTAINED AIR-CONDITIONERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for self-contained air-conditioners. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes packaged air **OR** water-cooled air-conditioning units, **as directed,** with refrigerant compressors and controls, intended for indoor installations.

C. Submittals
1. Product Data: For each unit indicated. Include rated capacities, operating characteristics, and furnished specialties and accessories.
2. LEED Submittals:
   a. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.
   b. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
3. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
   a. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   b. Wiring Diagrams: For power, signal, and control wiring.
4. Samples for Initial Selection: For units with factory-applied color finishes.
5. Operation and Maintenance Data: For self-contained air conditioners to include in emergency, operation, and maintenance manuals.
6. Warranty: Sample of special warranty.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a testing agency and marked for intended locations and application.
2. ARI Compliance:
   a. Applicable requirements in ARI 210/240.
   b. Applicable requirements in ARI 340/360.
   c. Applicable requirements in ARI 390.
3. ASHRAE Compliance:
   a. Fabricate and label refrigeration system to comply with ASHRAE 15, "Safety Standard for Refrigeration Systems."
   b. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality," Section 5 - "Systems and Equipment," Section 6 - "Ventilation Rate Procedures," and Section 7 - "Construction and Startup."
4. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1.

E. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of self-contained air conditioners that fail in materials or workmanship within specified warranty period.
   a. Warranty Period:
      1) For Compressor: One **OR** Five year(s), **as directed,** from date of Final Completion.
      2) For Parts: One **OR** Five year(s), **as directed,** from date of Final Completion.
      3) For Labor: One **OR** Five year(s), **as directed,** from date of Final Completion.

1.2 PRODUCTS

A. Packaged Units
1. Description: Factory-assembled, wired, and tested, and fully charged with refrigerant and oil.
2. Configuration: Horizontal, ceiling-plenum mounted.
3. Configuration: Vertical, floor mounted; vertical and horizontal discharge.
4. Configuration: Horizontal, ceiling mounted and vertical, floor mounted; vertical and horizontal discharge.
5. Disconnect Switch: Factory mounted in control panel **OR** on equipment, **as directed**.

B. Cabinet
1. Frame and Panels: Structural-steel frame with galvanized-steel panels and access doors or panels.
   a. Exterior-Surface Finish: Factory painted in color selected by Architect.
   b. Interior-Surface Finish: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
2. Insulation: Minimum 1-inch- (25-mm-), thick, glass-fiber duct liner complying with ASTM C 1091 and having a microbial coating on cabinet interior and control panel. 1/2-inch- (13-mm-) thick liner is acceptable for units smaller than 15 tons (50 kW).
3. Return-Air Opening: Rear, open **OR** flange for duct connection**, as directed**.
4. Corrosion-Resistant Treatment: Phenolic coating on unit interior and exterior.

C. Supply-Air Fan
1. Fan Material: Galvanized steel.
2. Configuration: Double-width, double-inlet, forward-curved **OR** airfoil, **as directed**, centrifugal fan; statically and dynamically balanced. Vertical **OR** Horizontal discharge, **as directed**, with flexible discharge collar.
3. Drive: Belt, with fan mounted on permanently lubricated bearings **OR** Direct, with fan and motor resiliently mounted, **as directed**.
4. Fan Sheaves: Variable pitch, dynamically balanced, bored to fit shafts and keyed for initial startup.
5. Motor Sheave: Variable and adjustable pitch dynamically balanced, and selected to achieve specified rpm when set at midposition.
6. Belt Rating: As recommended by the manufacturer or a minimum of one and one-half times nameplate rating of motor.
7. Bearings: Grease lubricated with grease lines extended to exterior of unit with L-50 life at 200,000 hours.
8. Variable Air Volume: Variable-frequency motor controller with bypass.
9. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   a. Special Motor Features: Premium efficiency, as defined in Division 23 Section "Common Motor Requirements For Hvac Equipment".
10. Isolation: Mount fan and motor on common subbase and mount assembly on spring isolators with minimum static deflection of **1 inch (25 mm).**
11. Outdoor-Air-Intake Accessories:
   a. Barometric Outdoor-Air Damper: Adjustable-blade damper allowing induction of up to 25 percent outdoor air when evaporator fan is running.
   b. Motorized Outdoor-Air Damper: Motorized, two-position blade damper allowing induction of up to 25 percent outdoor air; with spring-return, low-voltage damper motor.
   c. Energy-Recovery Ventilator: Assembly of desiccant-coated, heat-recovery wheels and centrifugal exhaust fans to transfer approximately 67 percent of the difference between the sensible and latent heat of outdoor and exhaust air.

d. Air-Side Economizer: Damper assembly allowing induction of up to 100 percent outdoor air to maintain a selected mixed-air temperature; and exhaust damper and spring-return, low-voltage, modulating damper motor with minimum position adjustment.

D. Refrigeration System
1. Compressor: Scroll type, hermetically sealed, 3600 rpm maximum, and resiliently mounted with positive lubrication and internal motor protection.
2. Refrigerant Coils (Indoor and Outdoor for Air-Cooled Units): Seamless copper tubes expanded into aluminum fins.
   a. Corrosion-Resistant Treatment: Phenolic coating applied with multiple dips and baked.
   b. Refrigerant Circuits: A separate circuit for each compressor, with externally equalized thermal-expansion valve with adjustable superheat, filter dryer, sight glass, high-pressure relief valve, and charging valves.
   c. Mount coil assembly over stainless-steel drain pan complying with ASHRAE 62.1 and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir.
   d. Refrigerant: R-407C or R-410A.
   e. Expansion valve with replaceable thermostatic element.
   f. Refrigerant dryer.
   g. High-pressure switch.
   h. Low-pressure switch.
   i. Thermostat for coil freeze-up protection during low ambient temperature operation or loss of air.
   j. Low ambient temperature switch.
   k. Brass service valves installed in discharge and liquid lines.
3. Water-Cooled Condenser:
   a. Description: Factory assembled and tested; tube in tube coaxial type with water-regulating valve.
   b. Tubing: Nonferrous **OR** Copper **OR** Cupro-nickel, **as directed,** inner tube; steel with corrosion-resistant coating; refrigerant and water-side leak tested to 400 psig (2760 kPa) underwater.
4. Water-Side Economizer Section:
   a. Description: Factory assembled and tested; consisting of water coil, modulating valves, controls, piping with cleanouts, and access panels.
   b. Water Coil: Two **OR** Four rows, **as directed**, copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm), and copper **OR** cast-iron, **as directed** headers; leak tested to 300 psig (2070 kPa) underwater; and having a two-position control valve.

E. Heating Coil
1. Water Coil: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch (2.5 mm); leak tested to 300 psig (2070 kPa) underwater; and having a two-position control valve.
2. Electric Coil: Helical, nickel-chrome, resistance-wire heating elements with refractory ceramic support bushings; automatic-reset thermal cutout; built-in magnetic contactors; manual-reset thermal cutout; airflow-proving device; and one-time fuses in terminal box for overcurrent protection.

F. Controls
1. Control Package: Factory wired, including contactor, high- and low-pressure cutouts, internal-winding thermostat for compressor, control-circuit transformer, and noncycling reset relay.
2. Time-Delay Relay: Five-minute delay to prevent compressor cycling.
3. Adjustable Thermostat: Unit mounted **OR** Remote, **as directed**, to control the following:
   a. Supply fan.
   b. Compressor.
   c. Condenser.

d. Hot-water coil valve.
e. Electric heater.

4. System Selector Switch: Heat-off-cool **OR** Off-heat-auto-cool, **as directed**.
5. Fan Control Switch: Auto-on.
6. Time Clock, **as directed**: Cycle unit on and off.
7. Microprocessor Control Panel: Controls unit functions, including refrigeration and safety controls, and the following:
   a. Supply fan.
   b. Supply-fan motor speed.
   c. Compressors.
   d. Air-cooled condenser.
   e. Cooling tower pump.
   f. Modulating, hot-water coil valve.
   g. Multistep, electric heater.
   h. Time-of-day control to cycle unit on and off.
   i. Night-heat, morning warm-up cycle.
   j. Economizer control.
   k. Panel-mounted control switch to operate unit in remote or local control mode, or to stop or reset.
   l. Panel-mounted indication of the following:
      1) Operating status.
      2) System diagnostics and safety alarms.
      3) Supply-air temperature set point.
      4) Zone heating-temperature set point.
      5) Supply-air pressure set point.
      6) Economizer minimum position set point.
      7) Supply-air-pressure, high-limit set point.
      8) Monitor constant and variable motor loads.
      9) Monitor variable-frequency drive operation.
      10) Monitor economizer cycle.
      11) Monitor cooling load.
      12) Monitor air distribution static pressure and ventilation air volumes.

G. Evaporator Coil
1. Direct-Expansion Coil: Seamless copper tubes expanded into aluminum fins.
   a. Corrosion-Resistant Treatment, **as directed**: Phenolic coating applied with multiple dips and baked.
2. Refrigerant Circuits: A separate circuit for each compressor, with externally equalized thermal-expansion valve with adjustable superheat, **as directed**, filter-dryer, sight glass, high-pressure relief valve, **as directed**, and charging valves.

H. Remote Air-Cooled Condenser
1. Description: Factory assembled and tested; consisting of condenser coil, fans and motors, and operating controls; suitable for roof mounting.
   a. Condenser Coil: Aluminum-fin copper tube with integral subcooler; leak tested to 450 psig (3110 kPa).
   b. Condenser Fans: Direct-drive propeller type.
   c. Fan Motors: Three-phase, permanently lubricated, ball-bearing motors with built-in thermal-overload protection. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   d. Refrigerant Line Kits: Annealed-copper suction and liquid lines that are factory cleaned, dried, pressurized, and sealed; insulated suction line; flared fittings at evaporator end, no fitting at condenser end; and service valves for both suction and liquid lines.
   e. Terminate suction and liquid refrigerant piping with service valves within unit.
   f. Low Ambient Control: Cycles fans to permit operation down to 45 deg F (7 deg C).

OR
Low Ambient Control: Cycles fans and modulates condenser fan damper assembly to permit operation down to 0 deg F (minus 18 deg C).

g. Coil Guard: Painted galvanized steel with louvered grilles.
h. Corrosion-Resistant Treatment: Phenolic coating applied in multiple dips and baked.

I. Integral Air-Cooled Condenser For Units 15 Tons (50 kW) And Smaller
1. Description: Factory assembled and tested; consisting of condenser coil, fans and motors, and cabinet.
a. Condenser Coil: Aluminum-fin copper tube with integral subcooler; leak tested to 425 psig (2930 kPa).
b. Condenser Fan: Direct-drive propeller type with permanently lubricated motor with built-in thermal-overload protection.
c. Low Ambient Control: Cycles fans to permit operation down to 0 deg F (minus 18 deg C).

J. Air Filters
1. Permanent Filters: 1-inch- (25-mm-) thick, cleanable panel filters.
OR
Disposable Filters: 1-inch- (25-mm-) **OR** 2-inch- (50-mm-), **as directed**, thick, glass-fiber, flat **OR** pleated, **as directed**, panel filters.
OR
Extended-Surface, Disposable Panel Filters: 2-inch- (50-mm-) **OR** 4-inch- (100-mm-), **as directed**, thick, dry, filters with fibrous media material formed into deep-V-shaped pleats and held by self-supporting wire grid holding frames, with nonflammable cardboard media and media-grid frame.
a. Efficiency: ASHRAE 52.2 MERV rating of 6 or higher.
2. Air-Pressure Switch (for units larger than 15 tons (50 kW)): Indicates dirty filters.

K. Accessories:

1. Manual outdoor-air damper.
2. Motorized outdoor-air damper.
3. Air-side economizer.
4. Water-side economizer.
5. Hot-gas bypass.
6. Air Pressure Switch: Indicates when differential pressure exceeds set point representing dirty filters.

L. Single-Point Electrical Characteristics:

1. Volts: 120 **OR** 208 **OR** 230 **OR** 460**, as directed**.
2. Phase: Single **OR** Three**, as directed**.
3. Hertz: 60.
4. Full-Load Amperes: **as directed**.
5. Minimum Circuit Ampacity: **as directed**.
6. Maximum Overcurrent Protection: **as directed**.

1.3 EXECUTION

A. Installation
1. Install units level and plumb.
2. Anchor units to structure.
3. Install seismic restraints.
4. Install static-pressure probe (for units larger than 15 tons (50 kW) equipped with inlet vanes).

5. Install water-cooled units with thermometer and pressure gage at the water supply and return connection.
6. Install vibration spring isolators under base of unit, with minimum static deflection of 1 inch (25 mm). Refer to Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".

B. Connections
1. Piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
   a. Water Coil Connections: Comply with requirements in Division 23 Section "Hydronic Piping". Connect to supply and return coil with shutoff-duty valve and union or flange on the supply connection and with throttling-duty valve and union or flange on the return connection.
   b. Water-Cooled Condenser Connections: Comply with requirements in Division 23 Section "Hydronic Piping". Connect to supply and return with shutoff-duty valve and union or flange on the supply connection and with throttling-duty valve and union or flange on the return connection.
2. Where installing piping adjacent to equipment, allow space for service and maintenance of equipment.
3. Duct Connections: Duct installation requirements are specified in Division 23 Section "Metal Ducts". Drawings indicate the general arrangement of ducts. Connect supply and return, **as directed**, ducts to self-contained air-conditioners with flexible duct connectors. Flexible duct connectors are specified in Division 23 Section "Air Duct Accessories".

C. Field Quality Control
1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.
2. Perform tests and inspections.
   a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
3. Tests and Inspections:
   a. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   b. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
4. Units will be considered defective if they do not pass tests and inspections.
5. Prepare test and inspection reports.

D. Startup Service
1. Engage a factory-authorized service representative to perform **OR** perform startup service, **as directed**.

E. Demonstration
1. Engage a factory-authorized service representative to train **OR train** the Owner's maintenance personnel, **as directed** to adjust, operate, and maintain units.

END OF SECTION 23 74 13 00

SECTION 23 74 23 00 - DIRECT-FIRED, MAKEUP AIR UNITS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for direct-fired H&V units. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes direct-fired H&V units with an evaporative cooling package, **as directed**.

C. Submittals
1. Product Data: Include rated capacities, furnished specialties, and accessories.
2. LEED Submittal:
   a. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
3. Shop Drawings:
   a. Mounting Details: For securing and flashing roof curb to roof structure. Indicate coordinating requirements with roof membrane system.
   b. Wiring Diagrams: Power, signal, and control wiring.
4. Operation and maintenance data.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Comply with NFPA 70.
3. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."
4. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."

1.2 PRODUCTS

A. Packaged Units
1. Factory-assembled, prewired, self-contained unit consisting of cabinet, supply fan, controls, filters, **as directed**, evaporative cooling package, **as directed**, and direct-fired gas furnace to be installed outside **OR** inside, **as directed**, the building.

B. Cabinet
1. Cabinet: Single-wall **OR** Double-wall, **as directed**, galvanized-steel panels, formed to ensure rigidity and supported by galvanized-steel channels or structural channel supports with lifting lugs. Cabinet shall be fully weatherized for outside installation, **as directed**.
2. Access Panels: Lift-out **OR** Piano hinged with cam-lock fasteners, **as directed**, for furnace and fan motor assemblies on both sides of unit.
3. Internal Insulation: Fibrous-glass duct lining, comply with ASTM C 1071, Type II, applied on complete unit **OR** furnace and fan sections only, **as directed**.
   a. Thickness: 1 inch (25 mm) **OR** 2 inches (50 mm), **as directed**.
   b. Insulation Adhesive: Comply with ASTM C 916, Type I.

c. Mechanical Fasteners: Galvanized steel suitable for adhesive attachment, mechanical attachment, or welding attachment to casing without damaging liner when applied as recommended by manufacturer and without causing air leakage.

4. Finish: Heat-resistant, baked enamel.
5. Discharge: Horizontal **OR** Vertical, **as directed**,-pattern, galvanized-steel assembly with diffusers incorporating individually adjustable vanes.
6. Roof Curb: Full-perimeter curb of sheet metal, minimum 16 inches (400 mm) high, with wood nailer, neoprene sealing strip, and welded Z-bar flashing.
7. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

C. Supply-Air Fan

1. Fan Type: Centrifugal, rated according to AMCA 210; statically and dynamically balanced, galvanized steel; mounted on solid-steel shaft with heavy-duty, self-aligning, permanently lubricated ball bearings **OR** pillow-block bearings rated for L50 or 200,000 hours with external grease fittings, **as directed**.
2. Motor: Open dripproof **OR** Totally enclosed, **as directed**, single **OR** two, **as directed**,-speed motor.
3. Drive: V-belt drive with matching fan pulley and adjustable motor sheaves and belt assembly.
4. Mounting: Fan wheel, motor, and drives shall be mounted in fan casing with restrained, **as directed**, elastomeric **OR** spring, **as directed**, isolators.

D. Outdoor-Air Intake

1. Outdoor-Air Hood: Galvanized steel with rain baffles, bird screen complying with ASHRAE 62.1, **as directed**, and finish to match cabinet; and sized to supply maximum 100 percent outdoor air.

E. Air Filters

1. Comply with NFPA 90A.
2. Cleanable Filters: 1-inch- (25-mm-) **OR** 2-inch-0 (50-mm-), **as directed**, thick, cleanable metal mesh.
3. Disposable Panel Filters: 1-inch- (25-mm-) **OR** 2-inch- (50-mm-), **as directed**, thick, factory-fabricated, flat-panel-type, disposable air filters with holding frames, with a minimum efficiency report value of 6 according to ASHRAE 52.2 and 90 percent average arrestance according to ASHRAE 52.1, **as directed**.
   a. Media: Interlaced glass **OR** polyester, **as directed**, fibers.
   b. Frame: Galvanized steel.

F. Dampers

1. Outdoor-Air and Return-Air, **as directed**, Damper: Galvanized-steel, opposed-blade dampers with vinyl blade seals and stainless-steel jamb seals, having a maximum leakage of 10 cfm/sq. ft. (51 L/s per sq. m) of damper area, at differential pressure of 2-inch wg (448 Pa).
2. Fan-Discharge Dampers: Galvanized-steel, opposed-blade damper.
3. Balancing/Bypass Dampers: Galvanized-steel, opposed-blade damper.
4. Damper Operator: Direct coupled, electronic with spring return or fully modulating as required by the control sequence.

G. Direct-Fired Gas Furnace

1. Description: Factory assembled, piped, and wired; and complying with ANSI Z83.4, "Direct Gas-Fired Make-Up Air Heaters"; ANSI Z83.18, "Direct Gas-Fired Industrial Air Heaters"; and NFPA 54, "National Fuel Gas Code."
2. Inside Unit External Housing: Steel cabinet with integral support inserts.
3. Outside Unit External Housing: Weatherproof steel cabinet with integral support inserts.
   a. External Casing and Cabinet Finish: Baked enamel **OR** Powder coating, **as directed**, over corrosion-resistant-treated surface in color to match fan section.
4. Burners: Cast-iron burner with stainless-steel mixing plates.

a. Control Valve: Single stage **OR** Two stage **OR** Modulating with minimum turndown ratio of 25:1or as otherwise directed**, as directed**.
b. Fuel: Natural **OR** Propane, **as directed**, gas.
c. Pilot: Electrically ignited by hot-surface ceramic igniter.

5. Safety Controls:
   a. Gas Manifold: Safety switches and controls to comply with ANSI standards **OR** FMG **OR** IRI, **as directed**.
   b. Purge-Period Timer: Automatically delays burner ignition and bypasses low-limit control.
   c. Airflow Proving Switch: Dual pressure switch senses correct airflow before energizing pilot and requires airflow to be maintained within minimum and maximum pressure settings across burner.
   d. Manual-Reset, High-Limit Control Device: Stops burner and closes main gas valve if high-limit temperature is exceeded.
   e. Gas Train: Redundant, automatic main gas valves, electric pilot valve, hydraulic **OR** electronic, **as directed**,-modulating temperature control valve, main and pilot gas regulators, main and pilot manual shutoff valves, main and pilot pressure taps, and high-low gas pressure switches, **as directed**, to comply with IRI requirements **OR** to comply with FMG requirements, **as directed**.
   f. Safety Lockout Switch: Locks out ignition sequence if burner fails to light after three tries. Controls are reset manually by turning the unit off and on.
   g. Control Transformer: Integrally mounted 24-V ac.

H. Evaporative Cooling Package
1. Cabinet: Single-wall **OR** Double-wall, **as directed**, galvanized- or aluminized-steel panels lined with ABS polymer, **as directed**, formed to ensure rigidity and supported by galvanized-steel channels or structural channel supports with lifting lugs and having a stainless-steel reservoir with overflow and drain with full-port, brass-fitted ball valve. Cabinet shall be fully weatherized for outside installation, **as directed**.
   a. External Casing and Cabinet Finish: Baked enamel **OR** Powder coating, **as directed**, over corrosion-resistant-treated surface in color to match fan section.
2. Media: UL 900, Class 2, 6-inch- (150-mm-) **OR** 8-inch- (200-mm-) **OR** 12-inch- (300-mm-), **as directed**, thick cellulose **OR** glass-fiber, **as directed**, media with rigidizing agents, fungicides, and wetting agents. Minimum 90 percent contact factor.
   a. Moisture elimination pad.
3. Water-Circulation System: Submersible centrifugal sump pump with inlet strainer, brass balancing valve located in pump discharge, and thermally protected motor; water distribution troughs or piping at top of media pads; and float-operated, makeup water and bleed-off valves.
   a. Automatic Fill and Drain Kit: Water supply and drain, solenoid valves for initial sump fill and for draining sump.
4. Water-Saver System: Timer, solenoid valve, and water distribution piping to apply the water supply to the media.
5. Comply with applicable requirements in ASHRAE 62.1.

I. Controls
1. Factory-wired, fuse-protected control transformer, connection for power supply and field-wired unit to remote control panel.
2. Control Panel: Surface-mounted **OR** Recessed, with trim ring, **as directed**, remote panel, with engraved plastic cover, and the following lights and switches:
   a. On-off **OR** On-off-auto, **as directed**, switch.
   b. Summer-winter **OR** Heat-off-cool, **as directed**, switch. Automatic changeover, **as directed**.
   c. Supply-fan operation indicating light.
   d. Heating operation indicating light.
   e. Damper position potentiometer.
   f. Thermostat.
   g. Cooling operation indicating light.

h. Dirty-filter indicating light operated by unit-mounted differential pressure switch.
i. Safety-lockout indicating light.

3. Refer to Division 23 Section "Instrumentation And Control For Hvac" for control equipment and sequence of operation.
4. Control Devices:
   a. Remote Thermostat: Adjustable room thermostat with temperature readout.
   b. Remote Setback Thermostat: Adjustable room thermostat without temperature readout.
   c. Static-Pressure Transmitter: Nondirectional sensor with suitable range for expected input, and temperature compensated.
   d. Fire-Protection Thermostats: Fixed or adjustable settings to operate at not less than 75 deg F (24 deg C) above normal maximum operating temperature.
   e. Timers: Seven-day, programming-switch timer with synchronous-timing motor and seven-day dial; continuously charged, nickel-cadmium-battery-driven, eight-hour, power-failure carryover; multiple-switch trippers; minimum of two and maximum of eight signals per day with two normally open and two normally closed output contacts.
      OR
      Timers: Solid-state, programmable time control with 4 separate programs; 24-hour battery carryover; individual on-off-auto switches for each program; 365-day calendar with 20 programmable holidays; choice of fail-safe operation for each program; and system fault alarm.
   f. Ionization-Type Smoke Detectors: 24-V dc, nominal; self-restoring; plug-in arrangement; integral visual-indicating light; sensitivity that can be tested and adjusted in place after installation; integral addressable module; remote controllability; responsive to both visible and invisible products of combustion; self-compensating for changes in environmental conditions.
   g. Fan-Speed Controllers: Solid-state model providing field-adjustable proportional control of motor speed. Equip with filtered circuit to eliminate radio interference.
5. Fan Control: Interlock fan to start with exhaust fan(s). See Division 23 Section(s) "Axial Hvac Fans" OR "Centrifugal Hvac Fans" OR "Hvac Power Ventilators" OR "Sequence Of Operations For Hvac Controls", **as directed**, for exhaust fan controls.
   OR
   Fan Control: Timer starts and stops direct-fired H&V unit and exhaust fan(s).
   a. Fan-Discharge Thermostat: Stops fan when discharge-air temperature is less than 40 deg F (4 deg C).
   b. Smoke detectors, located in supply and return, **as directed**, air, shall stop fans when the presence of smoke is detected.
   c. Controls two **OR** variable, **as directed**,-speed motor controller using speed switch on control panel **OR** variable-speed potentiometer on control panel **OR** static-pressure transmitter, **as directed**.
6. Outdoor-Air Damper Control, 100 Percent Outdoor-Air Units: Outdoor-air damper shall open when supply fan starts, and close when fan stops.
   OR
   Outdoor-Air and Fan-Discharge Damper Control, 100 Percent Outdoor-Air Units:
   a. Outdoor-air damper shall open when supply fan starts, and close when fan stops.
   b. Fan-discharge dampers shall operate to vary the amount of outdoor air to match exhaust-fan operation.
   OR
   Outdoor-Air and Balancing/Bypass Damper Control, Variable Outdoor-Air Units:
   a. Outdoor-air damper shall open when supply fan starts, and close when fan stops.
   b. Balancing/bypass dampers shall modulate to maintain minimum air velocity through burner.
   OR
   Outdoor-Air, Balancing/Bypass, and Return-Air Damper Control:
   a. Outdoor-air damper shall open when supply fan starts, and close when fan stops.

b. Return-air dampers shall modulate in response to potentiometer on control panel **OR** building pressure control, **as directed**.
c. Balancing/bypass dampers shall modulate to maintain minimum air velocity through the burner.

7. Temperature Control: Operates gas valve to maintain supply-air or room temperature.
   a. Operates gas valve to maintain discharge-air temperature with factory-mounted sensor in fan outlet.
      OR
      Operates gas valve to maintain space temperature with wall-mounting, field-wired sensor with temperature adjustment, **as directed**, and unit-mounted control adjustment **OR** and adjustment on remote control panel, **as directed**.
   b. Timer shall select remote setback thermostat to maintain space temperature at 50 deg F (10 deg C).
8. Evaporative Cooling Controls:
   a. Start and stop water-circulation-system sump pump to maintain space temperature.
   b. Automatic Fill Control: A switch in the unit control panel shall close sump drain valve and open makeup water valve.
   c. Automatic Drain Control: Opens sump drain valve and closes makeup water valve from a switch in the unit control panel **OR** when an outside thermostat senses 40 deg F (4 deg C) or less, **as directed**.
   d. Water-Saver System: Remote thermostat shall open water-supply valve to maintain dry-bulb temperature in space. Timer shall activate thermostat circuit.
9. DDC: Stand-alone control module for link between unit controls and DDC system. Control module shall be compatible with temperature-control system specified in Division 23 Section "Instrumentation And Control For Hvac".
   a. Provide start and stop interface relay, and relay to notify DDC system alarm condition.
   b. Provide hardware interface or additional sensors as follows:
      1) Room temperature.
      2) Discharge-air temperature.
      3) Furnace operating.

J. Motors
1. Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".

1.3 EXECUTION

A. Installation
1. Install gas-fired units according to NFPA 54, "National Fuel Gas Code."
2. Install roof curb on roof structure, according to ARI Guideline B **OR** NRCA's "Low-Slope Membrane Roofing Construction Details Manual," Illustration "Raised Curb Detail for Rooftop Air Handling Units and Ducts", **as directed**. Install and secure direct-fired H&V units on curbs, and coordinate roof penetrations and flashing with roof construction.
   OR
   Install restrained vibration isolation roof-curb rails on roof structure according to ARI Guideline B **OR** NRCA's "Low-Slope Membrane Roofing Construction Details Manual," Illustration "Raised Curb Detail for Rooftop Air Handling Units and Ducts", **as directed**. Install and secure direct-fired H&V units on rails, and coordinate roof penetrations and flashing with roof construction. Restrained isolation roof-curb rails are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
3. Install suspended units from spring hangers with minimum 1-inch (25-mm) static deflection; refer to Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   OR

Install floor-mounted units on restrained, **as directed**, spring isolators with minimum 1-inch (25-mm) static deflection; refer to Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".

4. Install controls and equipment shipped by manufacturer for field installation with direct-fired H&V units.

B. Connections

1. Piping Connections: Drawings indicate general arrangement of piping, fittings, and specialties. Install piping adjacent to machine to allow service and maintenance.
   a. Gas Piping: Comply with requirements in Division 23 Section(s) "Facility Natural-gas Piping" OR "Facility Liquefied-petroleum Gas Piping", **as directed**. Connect gas piping with shutoff valve and union and with sufficient clearance for burner removal and service. Provide AGA-approved flexible connectors.
   b. Makeup Water: Comply with requirements in Division 22 Section "Domestic Water Piping" for valves and accessories on piping connections to evaporative cooling units.
   c. Drain: Comply with requirements in Division 22 Section "Sanitary Waste And Vent Piping" for traps and accessories on piping connections to evaporative cooling units.
2. Duct Connections: Duct installation requirements are specified in Division 23 Section "Metal Ducts". Drawings indicate the general arrangement of ducts. Connect supply and return, **as directed**, ducts to direct-fired H&V units with flexible duct connectors. Flexible duct connectors are specified in Division 23 Section "Air Duct Accessories".
3. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
4. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

C. Startup Service

1. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
   a. Inspect for visible damage to furnace combustion chamber.
   b. Inspect casing insulation for integrity, moisture content, and adhesion.
   c. Verify that clearances have been provided for servicing.
   d. Verify that controls are connected and operable.
   e. Verify that filters are installed.
   f. Purge gas line.
   g. Inspect and adjust vibration isolators and seismic restraints, **as directed**.
   h. Verify bearing lubrication.
   i. Inspect fan-wheel rotation for movement in correct direction without vibration and binding.
   j. Adjust fan belts to proper alignment and tension.
   k. Start unit according to manufacturer's written instructions.
   l. Complete startup sheets and attach copy with Contractor's startup report.
   m. Inspect and record performance of interlocks and protective devices; verify sequences.
   n. Operate unit for run-in period recommended by manufacturer.
   o. Perform the following operations for both minimum and maximum firing and adjust burner for peak efficiency:
      1) Measure gas pressure on manifold.
      2) Measure combustion-air temperature at inlet to combustion chamber.
      3) Measure supply-air temperature and volume when burner is at maximum firing rate and when burner is off. Calculate useful heat to supply air.
   p. Calibrate thermostats.
   q. Adjust and inspect high-temperature limits.
   r. Inspect dampers, if any, for proper stroke and interlock with return-air dampers.
   s. Start evaporative cooler system and measure and record the following:
      1) Leaving-air, dry- and wet-bulb temperatures.
      2) Entering-air, dry- and wet-bulb temperatures.

t. Inspect controls for correct sequencing of heating, mixing dampers, refrigeration, and normal and emergency shutdown.
u. Measure and record airflow. Plot fan volumes on fan curve.
v. Verify operation of remote panel, including pilot-operation and failure modes. Inspect the following:
   1) High-limit heat.
   2) Alarms.
w. After startup and performance testing, change filters, verify bearing lubrication, and adjust belt tension.

2. Remove and replace malfunctioning components that do not pass tests and inspections and retest as specified above.
3. Prepare written report of the results of startup services.

D. Adjusting
1. Adjust initial temperature set points.
2. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
3. Occupancy Adjustments: When requested within 12 months of date of Final Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.

E. Demonstration
1. Train Owner's maintenance personnel to adjust, operate, and maintain direct-fired H&V units.

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SECTION 23 74 23 00a - INDIRECT-FIRED, PACKAGED H&V UNITS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for indirect-fired, H&V units. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes indirect-fired H&V units with the following accessories:
a. Gas or Oil furnace.
b. Evaporative cooling package.

C. Submittals
1. Product Data: Include rated capacities, furnished specialties, and accessories.
2. Shop Drawings:
a. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
b. Mounting Details: For securing and flashing roof curb to roof structure. Indicate coordinating requirements with roof membrane system.
c. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.
d. Wiring Diagrams: Power, signal, and control wiring.
3. Operation and maintenance data.
4. Warranty: Special warranty specified in this Section.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Comply with NFPA 70.

E. Warranty
1. Manufacturer's standard form in which manufacturer agrees to replace heat exchangers of indirect-fired H&V units that fail in materials or workmanship within five years **OR** 10 years, **as directed**, from date of Final Completion.

1.2 PRODUCTS

A. Packaged Units
1. Factory-assembled, prewired, self-contained unit consisting of cabinet, supply fan, controls, filters, evaporative cooling package, **as directed**, and indirect-fired gas **OR** oil, **as directed**, furnace to be installed outside **OR** inside, **as directed**, the building.

B. Cabinet
1. Cabinet: Single-wall **OR** Double-wall, **as directed**, galvanized-steel panels, formed to ensure rigidity and supported by galvanized-steel channels or structural channel supports with lifting lugs. Cabinet shall be fully weatherized for outside installation, **as directed**.
2. Access Panels: Lift-out **OR** Piano hinged with cam-lock fasteners, **as directed**, for furnace and fan motor assemblies on both sides of unit.

3. Internal Insulation: Fibrous-glass duct lining, comply with ASTM C 1071, Type II, applied on complete unit for outside unit or furnace and fan sections only for inside unit.
   a. Thickness: 1 inch (25 mm) **OR** 2 inches (50 mm), **as directed**.
   b. Insulation Adhesive: Comply with ASTM C 916, Type I.
   c. Mechanical Fasteners: Galvanized steel suitable for adhesive attachment, mechanical attachment, or welding attachment to casing without damaging liner when applied as recommended by manufacturer and without causing air leakage.
4. Finish: Heat-resistant, baked enamel.
5. Discharge: Horizontal-pattern **OR** Vertical-pattern, **as directed**, galvanized-steel assembly with diffusers incorporating individually adjustable vanes.
6. Roof Curb: Full-perimeter curb of sheet metal, minimum 16 inches (400 mm), unless directed otherwise, high, with wood nailer, neoprene sealing strip, and welded Z-bar flashing.

C. Supply-Air Fan
1. Fan Type: Centrifugal, rated according to AMCA 210; statically and dynamically balanced, galvanized steel; mounted on solid-steel shaft with heavy-duty, self-aligning, permanently lubricated ball bearings **OR** pillow-block bearings rated for L50 or 200,000 hours with external grease fittings, **as directed**.
2. Motor: Open dripproof **OR** Totally enclosed, **as directed**, single-speed motor.
3. Drive: V-belt drive with matching fan pulley and adjustable motor sheaves and belt assembly.
4. Mounting: Fan wheel, motor, and drives shall be mounted in fan casing with restrained (for seismic areas), elastomeric **OR** spring, **as directed**, isolators.

D. Outdoor-Air Intake
1. Outdoor-Air Hood: Galvanized steel with rain baffles, bird screen, and finish to match cabinet; and sized to supply maximum 30 percent **OR** 100 percent, **as directed**, outdoor air.

E. Air Filters
1. Comply with NFPA 90A.
2. Cleanable Filters: 1-inch- (25-mm-) **OR** 2-inch- (50-mm-), **as directed**, thick, cleanable metal mesh.
3. Disposable Panel Filters: 1-inch- (25-mm-) **OR** 2-inch- (50-mm-), **as directed**, thick, factory-fabricated, flat-panel-type, disposable air filters with holding frames, with a minimum efficiency report value of 6 according to ASHRAE 52.2 and 90 percent average arrestance according to ASHRAE 52.1.
   a. Media: Interlaced glass **OR** polyester, **as directed**, fibers.
   b. Frame: Galvanized steel.

F. Dampers
1. Outdoor-Air and Return-Air, **as directed**, Damper: Galvanized-steel, opposed-blade dampers with vinyl blade seals and stainless-steel jamb seals, having a maximum leakage of 10 cfm/sq. ft. (51 L/s per sq. m) of damper area, at differential pressure of 2-inch wg (448 Pa).
2. Damper Operator: Direct coupled, electronic with spring return or fully modulating as required by the control sequence.

G. Indirect-Fired Gas Furnace
1. Description: Factory assembled, piped, and wired; and complying with ANSI Z21.47, "Gas-Fired Central Furnaces," and NFPA 54, "National Fuel Gas Code."
   a. AGA Approval: Designed and certified by and bearing label of AGA.
   b. Burners: Aluminized steel with stainless-steel inserts **OR** Stainless steel, **as directed**.
      1) Gas Control Valve: Single stage **OR** Two stage **OR** Modulating, **as directed**.
      2) Fuel: Natural **OR** Propane, **as directed**, gas.
      3) Minimum Thermal Efficiency: 80 percent.
      4) Ignition: Electronically controlled electric spark with flame sensor.
      5) High-Altitude Model **OR** Kit, **as directed**: For Project elevation above sea level.

2. Venting: Gravity vented.
3. Power Vent: Integral, motorized centrifugal fan interlocked with gas valve.
4. Combustion-Air Intake: Separate combustion-air intake and vent terminal assembly.
5. Inside Unit External Housing: Steel cabinet with integral support inserts and removable bottom arranged to serve as drain pan.
6. Outside Unit External Housing: Weatherproof steel cabinet with integral support inserts and removable bottom arranged to serve as drain pan.
   a. External Casing and Cabinet Finish: Baked enamel **OR** Powder coating, **as directed**, over corrosion-resistant-treated surface in color to match fan section.
7. Internal Casing: Aluminized steel, arranged to contain airflow, with duct flanges at inlet and outlet.
8. Heat Exchanger: Aluminized **OR** Stainless steel, **as directed**.
9. Heat-Exchanger Drain Pan: Stainless steel.
10. Safety Controls:
    a. Vent Flow Verification: Differential pressure switch to verify open vent **OR** Flame rollout switch, **as directed**.
    b. Control Transformer: 24-V ac.
    c. High Limit: Thermal switch or fuse to stop burner.
    d. Gas Train: Regulated, redundant, 24-V ac gas valve assembly containing pilot solenoid valve, hydraulic-modulating **OR** electronic-modulating, **as directed**, temperature control valve, pilot filter, pressure regulator, pilot shutoff, and manual shutoff all in one body.
    e. Purge-period timer shall automatically delay burner ignition and bypass low-limit control.
    f. Gas Manifold: Safety switches and controls to comply with ANSI standards and FMG **OR** IRI, **as directed**.
    g. Airflow Proving Switch: Differential pressure switch senses correct airflow before energizing pilot.
    h. Automatic-Reset, High-Limit Control Device: Stops burner and closes main gas valve if high-limit temperature is exceeded.
    i. Safety Lockout Switch: Locks out ignition sequence if burner fails to light after three tries. Controls are reset manually by turning the unit off and on.

H. Oil-Fired Furnace
1. Description: Factory assembled, piped, and wired; and complying with UL 727, "Oil-Fired Central Furnaces."
2. Inside Unit External Housing: Steel cabinet with integral support inserts and removable bottom arranged to serve as a drain pan.
3. Outside Unit External Housing: Weatherproof steel cabinet with integral support inserts and removable bottom arranged to serve as drain pan.
   a. External Casing and Cabinet Finish: Baked enamel **OR** Powder coating, **as directed**, over corrosion-resistant-treated surface in color to match fan section.
4. Internal Casing: Aluminized steel, arranged to contain airflow, with duct flanges at inlet and outlet.
5. Heat Exchanger: Welded, stainless steel, unless directed otherwise, with flame observation port, carbon dioxide sample port, and access panels for clean-out and service.
6. Burners: Flame-retention, pressure-atomizing, forced-draft, gun type; with integral fuel pump and electronic spark ignition.
   a. Fuel: No. 2, unless directed otherwise, fuel oil.
   b. Minimum Thermal Efficiency: 80 percent **OR** 81 percent, **as directed**.
   c. Ignition: Electronically controlled electric spark with flame sensor.
7. Safety Controls:
   a. Factory piped and wired to electrical junction box mounted on unit.
   b. Oil-pressure switch.
   c. Control Transformer: Integrally mounted 24-V ac.
   d. Cad-cell safety system.
   e. Manual reset flame safety.
8. Accessories:

a. Factory mounted and wired to electrical junction box on unit.
b. Oil Booster Pump: 30-gph (108-L/h) **OR** 70-gph (252-L/h), **as directed**, capacity; motor and 2-stage fuel unit with pressure-regulating valve and strainer.
c. Oil-pressure relief valve.
d. Outdoor Combustion-Air Adapter: Sealed to housing and fitted with quick access cover, or door and fitting for terminating outdoor-air duct.

I. Evaporative Cooling Package
1. Cabinet: Single-wall **OR** Double-wall, **as directed**, galvanized- or aluminized-steel panels lined with ABS polymer, as required, formed to ensure rigidity and supported by galvanized-steel channels or structural channel supports with lifting lugs and having a stainless-steel reservoir with overflow and drain with full-port, brass-fitted ball valve. Cabinet shall be fully weatherized for outside installation, **as directed**.
   a. External Casing and Cabinet Finish: Baked enamel, **unless directed otherwise to be** Powder coating, over corrosion-resistant-treated surface in color to match fan section.
2. Media: UL 900, Class 2, 6-inch- (150-mm-) **OR** 8-inch- (200-mm-) **OR** 12-inch- (300-mm-), **as directed**, thick cellulose **OR** glass-fiber, **as directed**, media with rigidizing agents, fungicides, and wetting agents. Minimum 90 percent contact factor.
   a. Moisture elimination pad.
3. Water-Circulation System: Submersible centrifugal sump pump with inlet strainer, brass balancing valve located in pump discharge, and thermally protected motor; water distribution troughs or piping at top of media pads; and float-operated, makeup water and bleed-off valves.
   a. Automatic Fill and Drain Kit: Water supply and drain, solenoid valves for initial sump fill and for draining sump.
4. Water-Saver System: Timer, solenoid valve, and water distribution piping to apply the water supply to the media.

J. Controls
1. Factory-wired, fuse-protected control transformer, connection for power supply and field-wired unit to remote control panel.
2. Control Panel: Surface-mounted **OR** Recessed, **as directed**, with trim ring, remote panel, with engraved plastic cover, and the following lights and switches:
   a. On-off **OR** On-off-auto, **as directed**, fan switch.
   b. Summer-winter **OR** Heat-off-cool, **as directed**, switch. Automatic changeover, **as directed**.
   c. Supply-fan operation indicating light.
   d. Heating operation indicating light.
   e. Damper position potentiometer.
   f. Thermostat.
   g. Cooling operation indicating light.
   h. Dirty-filter indicating light operated by unit-mounted differential pressure switch.
   i. Safety-lockout indicating light.
3. Control Devices:
   a. Remote Thermostat: Adjustable room thermostat with temperature readout.
   b. Remote Setback Thermostat: Adjustable room thermostat without temperature readout.
   c. Static-Pressure Transmitter: Nondirectional sensor with suitable range for expected input, and temperature compensated.
   d. Fire-Protection Thermostats: Fixed or adjustable settings to operate at not less than 75 deg F (24 deg C) above normal maximum operating temperature.
   e. Timers: Seven-day, programming-switch timer with synchronous-timing motor and seven-day dial; continuously charged, nickel-cadmium-battery-driven, eight-hour, power-failure carryover; multiple-switch trippers; minimum of two and maximum of eight signals per day with two normally open and two normally closed output contacts.
      OR

Timers: Solid-state, programmable time control with 4 separate programs; 24-hour battery carryover; individual on-off-auto switches for each program; 365-day calendar with 20 programmable holidays; choice of fail-safe operation for each program; and system fault alarm.

f. Ionization-Type Smoke Detectors: 24-V dc, nominal; self-restoring; plug-in arrangement; integral visual-indicating light; sensitivity that can be tested and adjusted in place after installation; integral addressable module; remote controllability; responsive to both visible and invisible products of combustion; self-compensating for changes in environmental conditions.

4. Fan Control: Interlock fan to start with exhaust fan(s). See Division 23 Section(s) "Axial Hvac Fans" OR "Centrifugal Hvac Fans" OR "Hvac Power Ventilators" OR "Sequence Of Operations For Hvac Controls", **as directed**, for exhaust fan controls.
5. Fan Control: Timer starts and stops direct-fired H&V unit and exhaust fan(s).
   a. Fan-Discharge Thermostat (for units with evaporative cooling package): Stops fan when discharge-air temperature is less than 40 deg F (4 deg C).
   b. Smoke detectors, located in supply and return, **as directed**, air, shall stop fans when the presence of smoke is detected.
6. Outdoor-Air Damper Control, 100 Percent Outdoor-Air Units: Outdoor-air damper shall open when supply fan starts, and close when fan stops.
7. Mixed Outdoor- and Return-Air Damper Control: When fan is running, outdoor- and return-air dampers shall modulate to supply minimum outdoor air as follows:
   a. Minimum 30 percent outdoor air.
   b. Outdoor-air quantity adjusted by potentiometer on control panel.
   c. Outdoor-air quantity to maintain minimum building static pressure.
8. Temperature Control: Operates gas valve to maintain supply-air temperature.
   a. Operates gas valve to maintain discharge-air temperature with factory-mounted sensor in blower outlet.
   b. Operates gas valve to maintain space temperature with wall-mounting, field-wired sensor with temperature adjustment, **as directed**, and unit-mounted control adjustment, **OR** and adjustment on remote-control panel, **as directed**.
   c. Timer shall select remote setback thermostat to maintain space temperature at 50 deg F (10 deg C).
   d. Furnace Control: Two or four steps of control using one or two furnace sections in series.
      OR
      Furnace Control: 20 to 100 percent modulation of the firing rate. 10 to 100 percent with dual furnace units.
9. Evaporative Cooling Controls:
   a. Start and stop water-circulation-system sump pump to maintain space temperature.
   b. Automatic Fill Control: A switch in the unit control panel shall close sump drain valve and open makeup water valve.
   c. Automatic Drain Control: Opens sump drain valve and closes makeup water valve from a switch in the unit control panel **OR** when an outside thermostat senses 40 deg F (4 deg C) or less, **as directed**.
   d. Water-Saver System: Remote thermostat shall open water-supply valve to maintain dry-bulb temperature in space. Timer shall activate thermostat circuit.
10. DDC: Stand-alone control module for link between unit controls and DDC system. Control module shall be compatible with temperature-control system specified in Division 23 Section "Instrumentation And Control For Hvac".
    a. Provide start and stop interface relay, and relay to notify DDC system alarm condition.
    b. Provide hardware interface or additional sensors as follows:
       1) Room temperature.
       2) Discharge-air temperature.
       3) Furnace operating.

K. Motors

1. Comply with requirements are specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".

1.3 EXECUTION

A. Installation
1. Install gas-fired units according to NFPA 54, "National Fuel Gas Code."
2. Install oil-fired duct heaters and associated fuel and vent piping according to NFPA 31 and applicable local codes and regulations.
3. Install roof curb on roof structure, according to ARI Guideline B **OR** NRCA's "Low-Slope Membrane Roofing Construction Details Manual," Illustration "Raised Curb Detail for Rooftop Air Handling Units and Ducts," **as directed**. Install and secure direct-fired H&V units on curbs, and coordinate roof penetrations and flashing with roof construction.
OR
Install restrained vibration isolation roof-curb rails on roof structure according to ARI Guideline B **OR** NRCA's "Low-Slope Membrane Roofing Construction Details Manual," Illustration "Raised Curb Detail for Rooftop Air Handling Units and Ducts," **as directed**. Install and secure indirect-fired H&V units on rails, and coordinate roof penetrations and flashing with roof construction. Restrained isolation roof-curb rails are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
4. Install suspended units from spring hangers with minimum 1-inch (25-mm) static deflection; refer to Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
5. Install floor-mounted units on restrained, **as directed**, spring isolators with minimum 1-inch (25-mm) static deflection; refer to Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
6. Install controls and equipment shipped by manufacturer for field installation with indirect-fired H&V units.
7. Piping Connections: Drawings indicate general arrangement of piping, fittings, and specialties. Install piping adjacent to machine to allow service and maintenance.
   a. Gas Piping: Comply with requirements in Division 23 Section(s) "Facility Natural-gas Piping" OR "Facility Liquefied-petroleum Gas Piping", **as directed**. Connect gas piping with shutoff valve and union and with sufficient clearance for burner removal and service. Provide AGA-approved flexible connectors.
   b. Fuel Oil Piping: Comply with requirements in Division 23 Section "Facility Fuel-oil Piping". Connect to fuel oil supply and return piping with shutoff valve and union at each connection.
   c. Makeup Water: Comply with requirements in Division 22 Section "Domestic Water Piping" for valves and accessories on piping connections to evaporative cooling units.
   d. Drain: Comply with requirements in Division 22 Section "Sanitary Waste And Vent Piping" for traps and accessories on piping connections to evaporative cooling units.
8. Duct Connections: Duct installation requirements are specified in Division 23 Section "Metal Ducts". Drawings indicate the general arrangement of ducts. Connect supply and return, **as directed**, ducts to indirect-fired H&V units with flexible duct connectors. Flexible duct connectors are specified in Division 23 Section "Air Duct Accessories".
9. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
10. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

END OF SECTION 23 74 23 00a

SECTION 23 76 13 00 - DEHUMIDIFICATION UNITS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for mechanical dehumidification units. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section includes packaged, factory-assembled and -tested, refrigerant-type, mechanical dehumidification units designed for outdoor and indoor installation.

C. Performance Requirements
1. Seismic Performance: Dehumidification units shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
   a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

D. Submittals
1. Product Data: For each dehumidification unit indicated. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.
2. LEED Submittals:
   a. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.
   b. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5, "Systems and Equipment."
3. Shop Drawings: For each dehumidification unit indicated. Include plans, elevations, sections, details, and attachments to other work.
   a. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   b. Wiring Diagrams: For power, signal, and control wiring.
4. Delegated-Design Submittal: For dehumidification units indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
   a. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
   b. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
5. Seismic Qualification Certificates: For accessories, and components, from manufacturer.
   a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
   c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
6. Source quality-control reports.
7. Field quality-control reports.
8. Operation and Maintenance Data: For dehumidification units to include in emergency, operation, and maintenance manuals.
9. Warranty: Sample of special warranty.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. ASHRAE Compliance:
   a. Applicable requirements in ASHRAE 62.1, Section 5, "Systems and Equipment" and Section 7, "Construction and Startup."
   b. Applicable requirements in ASHRAE 15, "Safety Standard for Refrigeration Systems."
3. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6, "Heating, Ventilating, and Air-Conditioning."

F. Coordination
1. Coordinate sizes and locations of concrete bases. Cast anchor-bolt inserts into bases.
2. Coordinate installation of roof curbs, equipment supports, and roof penetrations.

G. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of dehumidification units that fail in materials or workmanship within specified warranty period.
   a. Warranty Period for Compressors: Manufacturer's standard, but not less than two **OR** five, **as directed**, years from date of Final Completion.
   b. Warranty Period for Refrigerant Coils: Manufacturer's standard, but not less than five years from date of Final Completion.

1.2 PRODUCTS

A. Casings
1. Casing: Single-wall **OR** Double-wall, **as directed**, construction with corrosion-protective coating and exterior baked-enamel **OR** powder-coated, **as directed**, finish, stainless-steel fasteners, knockouts for electrical and piping connections, condensate drain connection, and lifting lugs.
   a. Access: Removable panels **OR** Hinged access doors, **as directed**, with neoprene gaskets.
   b. Insulation: Minimum 1/2-inch- (13-mm-) thick thermal insulation **OR** 2-inch- (50-mm-) thick, glass-fiber-insulation fill with no metal structure through the insulation, **as directed**.
   c. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
2. Drain Pan and Connection: Plastic **OR** Stainless steel, **as directed**; insulated and complying with ASHRAE 62.1, **as directed**.

B. Fans
1. Supply Fans: Forward curved **OR** Backward inclined, **as directed**, centrifugal; galvanized steel with baked-enamel **OR** powder-coated, **as directed**, finish; belt driven with adjustable sheaves and self-aligning, grease-lubricated ball bearings with extended grease fittings easily accessible inside the casing of dehumidification unit.
2. Exhaust **OR** Return, **as directed**, Fans: Forward curved **OR** Backward inclined, **as directed**, centrifugal; galvanized steel with baked-enamel **OR** powder-coated, **as directed**, finish; belt driven with adjustable sheaves and self-aligning, grease-lubricated ball bearings with extended grease fittings easily accessible inside the casing of dehumidification unit.
3. Fan Motor: Comply with requirements in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   a. Enclosure Type: Totally enclosed, fan cooled.

C. Filters
1. Glass Fiber: Minimum 80 percent arrestance according to ASHRAE 52.1, and MERV 5 according to ASHRAE 52.2.

2. Pleated: Minimum 90 percent arrestance according to ASHRAE 52.1, and MERV 7 according to ASHRAE 52.2.

D. Refrigeration System
1. Energy Efficiency: Equal to or greater than prescribed by ASHRAE/IESNA 90.1.
2. Refrigerant Coils: Copper tubes with mechanically bonded aluminum fins; factory fabricated and tested to comply with ASHRAE 33 and ARI 410; with multiple refrigerant circuits, seamless-copper headers with brazed connections, and galvanized **OR** stainless, **as directed**,-steel frame. Coil and fins shall have a polyester coating. Coils shall have a minimum 300-psig (2070-kPa) working-pressure rating and be factory tested to 450 psig (3105 kPa) and to 300 psig (2070 kPa) while underwater.
3. Compressors: Hermetic, scroll compressors with integral vibration isolators and crankcase heaters that de-energize during compressor operation; with thermal-expansion valves, filter-dryers, sight glasses, compressor service valves, and liquid- and suction-line service valves.
   a. Number of Refrigerant Circuits: Two for compressor capacities more than 7-1/2 tons (26.4 kW).
   b. Refrigerant: R-134a **OR** R-407C **OR** R-410A, **as directed**.
   c. Capacity Control:
      1) Hot-gas bypass valve and piping on one compressor.
      2) Cycle compressor.
   d. Low-Pressure Cutout: Manual reset after three automatic-reset failures.
   e. High-Pressure Cutout: Manual reset.
   f. Compressor Motor Overload Protection: Manual reset.
   g. Antirecycling Timing Device: Prevent compressor restart for five minutes after shutdown.
   h. Defrost Cycle (for ice rinks): Adjustable timer shuts off supply fan. Compressor cycles until suction line temperature confirms thawed evaporator coil. Timer limits defrost time to 10 minutes.
4. Energy Recovery Heat Exchanger (Pool Heater): Cupronickel, coaxial, vented, double-wall construction for potable-water service.

E. Remote-Mounted, Air-Cooled Condenser Unit
1. Casing: Steel, finished with baked enamel; with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Provide brass service valves, fittings, and gage ports on exterior of casing.
2. Refrigerant Coil: ARI 210/240, copper tube with mechanically bonded aluminum fins; with liquid subcooler.
3. Fan: Aluminum-propeller type, directly connected to permanently lubricated motor with integral thermal-overload protection.
4. Adjustable, Low Ambient Head-Pressure Control: Designed to operate at temperatures as low as 0 deg F (minus 18 deg C) by cycling condenser fans and controlling speed of last fan of each circuit.
5. Mounting Base: Polyethylene.

F. Heating Coils
1. Hot-Water Coil: Continuous circuit coil fabricated according to ARI 410.
   a. Tubes: Copper.
   b. Fins: Aluminum **OR** Copper, **as directed**, with fin spacing 0.125 inch (3.18 mm) **OR** 0.091 inch (2.31 mm) **OR** 0.071 inch (1.80 mm) **OR** 0.067 inch (1.70 mm) **OR** 0.056 inch (1.42 mm) **OR** 0.0075 inch (0.19 mm), **as directed**.
   c. Fin and Tube Joints: Mechanical bond.
   d. Headers: Cast iron with drain and air vent tappings.
   e. Frames: Galvanized-steel channel, 0.052 inch (1.3 mm).
   f. Ratings: Design tested and rated according to ASHRAE 33 and ARI 410.
      1) Working-Pressure Ratings: 200 psig (1380 kPa), 325 deg F (163 deg C).
   g. Source Quality Control: Test to 300 psig (2070 kPa).

2. Steam Coil: Distribution header coil fabricated according to ARI 410, with threaded steam supply and condensate connections.
   a. Tubes: Copper.
   b. Fins: Aluminum **OR** Copper, **as directed**, with fin spacing 0.125 inch (3.18 mm) **OR** 0.091 inch (2.31 mm) **OR** 0.071 inch (1.80 mm) **OR** 0.067 inch (1.70 mm) **OR** 0.056 inch (1.42 mm) **OR** 0.0075 inch (0.19 mm), **as directed**.
   c. Fin and Tube Joints: Mechanical bond.
   d. Headers: Cast iron with drain and air vent tappings.
   e. Frames: Galvanized-steel channel, 0.052 inch (1.3 mm).
   f. Ratings: Design tested and rated according to ASHRAE 33 and ARI 410.
      1) Working-Pressure Ratings: 100 psig (690 kPa), 400 deg F (205 deg C).
   g. Source Quality Control: Test to 200 psig (1380 kPa).
3. Electric-Resistance Heating Coil: Comply with UL 1995.
   a. Heating Element: Coiled resistance wire of 80 percent nickel and 20 percent chromium; surrounded by compacted magnesium oxide powder in tubular-steel sheath; with spiral-wound, copper-plated steel fins continuously brazed to sheath.
      OR
      Heating Element: Open-coil resistance wire of 80 percent nickel and 20 percent chromium; supported and insulated by floating ceramic bushings recessed into casing openings; fastened to supporting brackets and mounted in galvanized-steel frame.
   b. Overtemperature Protection: Disk-type, automatic-reset, thermal-cutout safety device; serviceable through terminal box without removing heater from unit.
   c. Thermal Cutouts: Load carrying, manual reset or replaceable, and factory wired in series with each heater stage.
   d. Control: Disconnecting means, overcurrent protection, and airflow proving switch.

G. Dampers
1. Outdoor-Air Dampers: Opposed-blade, galvanized-steel **OR** aluminum **OR** extruded-aluminum, **as directed**, dampers with steel **OR** cadmium-plated steel, **as directed**, operating rod rotating in sintered bronze or nylon bearings. Provide blade gaskets and edge seals, and mechanically fasten blades to operating rod. Size for 0 to 25 percent outdoor air, with manual **OR** motorized, **as directed**, operator and filter.
2. Face-and-Bypass Dampers: Opposed-blade, galvanized-steel **OR** aluminum **OR** extruded-aluminum, **as directed**, dampers with steel **OR** cadmium-plated steel, **as directed**, operating rods rotating in sintered bronze or nylon bearings with operating rods connected with a common linkage. Provide blade gaskets and edge seals, and mechanically fasten blades to operating rod.
3. Outdoor- and Return-Air **OR** Outdoor-, Return-, and Exhaust-Air, **as directed**, Dampers: Parallel-blade, galvanized-steel **OR** aluminum **OR** extruded-aluminum, **as directed**, dampers mechanically fastened to steel **OR** cadmium-plated steel, **as directed**, operating rod in reinforced cabinet. Connect operating rods with common linkage and interconnect linkages so dampers operate simultaneously.
4. Outdoor- and Return-Air **OR** Outdoor-, Return-, and Exhaust-Air, **as directed**, Dampers: Low-leakage, double-skin, airfoil-blade, galvanized-steel **OR** aluminum **OR** extruded-aluminum, **as directed**, dampers with compressible jamb seals and extruded-vinyl blade edge seals in opposed-blade **OR** parallel-blade, **as directed**, arrangement with steel **OR** cadmium-plated steel, **as directed**, operating rods rotating in stainless-steel sleeve **OR** sintered bronze or nylon, **as directed**, bearings mounted in a single galvanized-steel **OR** aluminum **OR** extruded-aluminum, **as directed**, frame, and with operating rods connected with a common linkage. Leakage rate shall not exceed 5 cfm/sq. ft. (0.22 L/s per sq. m) at 1-inch wg (250 Pa) and 9 cfm/sq. ft. (0.4 L/s per sq. m) at 4-inch wg (1.0 MPa).
5. Damper Operator: 115 **OR** 24, **as directed**,-V ac, close coupled, with gear train sealed in oil and with spring return.

H. Controls

1. Comply with requirements in Division 23 Section "Instrumentation And Control For Hvac" for control equipment and in Division 23 Section "Sequence Of Operations For Hvac Controls".
2. Control Panel: Integral service compartment containing fan-motor thermal and overload cutouts, compressor thermal and overload cutouts, 115-V control transformer if required, magnetic contactors for fan and compressor motors, and a nonfused factory-mounted and -wired disconnect switch for single external electrical power connection.
3. Building Automation System Interface: Factory-installed hardware and software to enable the building automation system to monitor, control, and display status and alarms.
4. Operating Control: Space humidistat cycles the compressor. Humidistat shall incorporate fan on-off-auto switch.
5. Operating Controls (for indoor pool units with typical manufacturer's control panel): Factory-installed microprocessor controller, capable of being remotely mounted.
    a. Display the following on the face of controller:
        1) System on.
        2) System dehumidifying mode.
        3) System air-conditioning mode.
        4) System outdoor-air (economizer) mode.
        5) System heating pool water.
        6) Auxiliary space heat is operating.
        7) Unit requires service.
        8) Return-air (space) temperature.
        9) Return-air (space) humidity.
        10) Pool-water temperature.
        11) Outdoor-air temperature.
    b. Indicate the following sensor failures on panel:
        1) Airflow: Dirty air filter, blocked airflow, and fan failure.
        2) Refrigerant high and low pressure.
        3) High water temperature.
        4) High and low evaporator temperature.
        5) Low water flow.
        6) Communication fault.
        7) System off.
        8) Antishort cycle delay.
        9) Power failure.
    c. Provide access to the following set points on panel:
        1) Space temperature.
        2) Space relative humidity.
        3) Outdoor ventilation/air-conditioning changeover temperature.
        4) Airflow alarm.
    d. Provide the following displays on panel:
        1) Space temperature.
        2) Space relative humidity.
        3) Outdoor-air temperature.
        4) Supply-air temperature.
        5) Return-air temperature.
        6) Airflow rating.
        7) Air-off evaporator temperature.
        8) Return-air relative humidity.
        9) Service codes.
    e. Provide the following controls on panel:
        1) System on-off, fan continues to run.
        2) Fan on-off.
        3) Service code access.
        4) System dehumidifying mode.
        5) System air-conditioning mode.
        6) System outdoor-air (economizer) mode.

7) Auxiliary space heat is operating.
8) Outdoor-air-temperature, conditioned-space-temperature, and control set-point-temperature digital display.
9) Outdoor enthalpy digital display.
10) Filter pressure drop digital display.
11) Status: Airflow, fans, system, unit operation, and operating mode.
12) Alarm digital display.

6. Operating Controls: Factory-installed microprocessor controller.
   a. Factory-installed operator panel with backlit display, capable of being remotely mounted, allows menu-driven display for navigation and control of unit.
   b. Integral clock.
   c. Personal computer interface.
   d. Integral local area network for direct connection to BACnet **OR** LonWorks **OR** MODBUS, **as directed**.
   e. Factory programmed.
   f. Unit-Mounted Sensors:
      1) Airflow switch.
      2) Compressor-discharge temperature.
      3) Evaporator-air temperature.
      4) Pool-water-out temperature.
      5) Pool-water-in temperature.
      6) Relative humidity.
      7) Return-air temperature.
      8) Supply-air temperature.
   g. Integral diagnostics.
   h. Nonvolatile memory.
   i. IP or SI display.
   j. Provide the following status and alarm functions:
      1) System: On-off.
      2) Power failure.
      3) Fan: Off, overload.
      4) Compressor: On, turned off, overload, high pressure, low pressure, overheat, oil failure, and pumpdown.
      5) Evaporator damper closed.
      6) Pool: Low water flow, heating on.
      7) Dehumidification: Call for, on.
      8) Air Conditioning: Call for, on.
      9) System outdoor-air (economizer) mode.
      10) Auxiliary space heat on.
      11) Alarms: Firestat, freezestat, and filters.
   k. Provide the following controls via operator panel:
      1) Compressor auto-off.
      2) Fan auto-off.
      3) Set-Point Adjustments: Relative humidity, temperatures, deadbands, and differentials.
      4) Sensor calibration.
   l. Monitor constant and variable motor loads.
   m. Monitor cooling load.
   n. Monitor economizer cycles.
   o. Monitor ventilation air volumes.

I. Accessories
   1. Water-Cooling Heat Exchanger: Coaxial, vented, double-wall construction; with three-way refrigerant control valve.
   2. Smoke Detectors: Photoelectric detector located in return-air plenum, to de-energize unit.

a. Operating Voltage: 24-V dc, nominal.
b. Self-Restoring: Detectors do not require resetting or readjusting after actuation to restore them to normal operation.
c. Plug-in Arrangement: Detector and associated electronic components mounted in module with tamper-resistant connection to fixed base with twist-locking plug. Terminals in fixed base accept building wiring.
d. Integral Visual-Indicating Light: Digital-display type indicating detector operation.
e. Sensitivity: Can be tested and adjusted in-place after installation.
f. Integral Addressable Module: Arranged to communicate detector status (normal, alarm, or trouble) to the fire-alarm control panel.
g. Sensor: Digital display or infrared light source with matching silicon-cell receiver.
h. Detector Sensitivity: Between 2.5 and 3.5 percent/foot (0.008 and 0.011 percent/mm) of smoke obscuration when tested according to UL 268A.
i. Integral Thermal Detector: Fixed-temperature type with 135 deg F (57 deg C) setting.

3. Electrical Convenience Outlet: 115-V ac fused, duplex, straight-blade receptacles, separately fused and located inside casing of dehumidification unit or in roof-curb perimeter.

J. Roof Curbs
1. Roof curbs with vibration isolators and wind or seismic restraints are specified in Division 15 Section "Vibration and Seismic Controls for HVAC Piping and Equipment."
2. Materials: Galvanized steel with corrosion-protection coating, watertight gaskets, and factory-installed wood nailer; complying with NRCA standards.
3. Curb Insulation and Adhesive: Comply with NFPA 90A or NFPA 90B.
a. Materials: ASTM C 1071, Type I or II.
b. Thickness: 1 inch (25 mm) **OR** 1-1/2 inches (38 mm) **OR** 2 inches (50 mm), **as directed**.
c. Application: Factory applied with adhesive and mechanical fasteners to the internal surface of curb.
d. Liner Adhesive: Comply with ASTM C 916, Type I.
e. Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, mechanical attachment, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in cabinet.
f. Liner materials applied in this location shall have airstream surface coated with a temperature-resistant coating or faced with a plain or coated fibrous mat or fabric, depending on service-air velocity.
4. Curb Height: 14 inches (355 mm) **OR** 24 inches (610 mm) **OR** 36 inches (910 mm), **as directed**.
5. Wind and Seismic Restraints: Metal brackets compatible with the curb and casing, painted to match dehumidification unit; used to anchor unit to the curb and designed for loads at Project site. Comply with requirements in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment" for wind-load requirements.

K. Source Quality Control
1. Verification of Performance: Factory test and rate dehumidification units according to ARI 910.
2. Sound-Power-Level Ratings: Factory test and rate dehumidification units according to ARI 575.

1.3 EXECUTION

A. Examination
1. Examine areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
2. Examine roughing-in for hot-water **OR** steam **OR** refrigerant, **as directed**, piping systems to verify actual locations of piping connections before equipment installation.
3. Examine walls, floors, and roofs for suitable conditions where dehumidification units will be installed.
4. Proceed with installation only after unsatisfactory conditions have been corrected.

B. Installation

1. Equipment Mounting (for indoor or outdoor equipment supported on slabs-on-grade without vibration isolation devices): Install dehumidification units on concrete base(s). Comply with requirements for concrete base(s) specified in Division 03 Section "Cast-in-place Concrete".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base, and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   d. Install anchor bolts to elevations required for proper attachment to supported equipment.
2. Equipment Mounting (for indoor or outdoor equipment supported on concrete equipment base with vibration isolation devices): Install dehumidification units on concrete base(s) using elastomeric pads **OR** elastomeric mounts **OR** restrained spring isolators, **as directed**. Comply with requirements for concrete base(s) specified in Division 03 Section "Cast-in-place Concrete". Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   a. Minimum Deflection: 1/4 inch (6 mm) **OR** 1 inch (25 mm), **as directed**.
   b. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   c. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base, and anchor into structural concrete floor.
   d. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   e. Install anchor bolts to elevations required for proper attachment to supported equipment.
3. Equipment Mounting (for installation of indoor or outdoor equipment on vibration isolation devices without concrete base): Install dehumidification units using elastomeric pads **OR** elastomeric mounts **OR** restrained spring isolators, **as directed**. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   a. Minimum Deflection: 1/4 inch (6 mm) **OR** 1 inch (25 mm), **as directed**.
4. Equipment Mounting (for installation of indoor or outdoor equipment on vibration isolation equipment base): Install dehumidification units on vibration isolation equipment base. Comply with requirements specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
5. For installation of indoor or outdoor equipment without vibration isolation devices, with seismic restraints, and without concrete base: Install dehumidification units with <**Insert seismic-restraint device**>. Comply with requirements for seismic-restraint devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
6. For indoor units suspended from structure: Install continuous-thread hanger rods and elastomeric hangers **OR** spring hangers **OR** spring hangers with vertical-limit stop, **as directed**, of size required to support weight of dehumidification unit.
   a. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment". Fabricate brackets or supports as required.
   b. Comply with requirements for hangers and supports specified in Division 23 Section "Hangers And Supports For Hvac Piping And Equipment".
7. Curb Support (if curbs are furnished with dehumidification units for rooftop installations): Install roof curb on roof structure, level and secure, according to NRCA's "The NRCA Roofing and Waterproofing Manual, Fifth Edition." Install and secure dehumidification units on curbs, and coordinate roof penetrations and flashing with roof construction. Secure units to curb support with anchor bolts.
8. Unit Support: Install dehumidification units level on structural curbs **OR** pilings, **as directed**. Coordinate wall penetrations and flashing with wall construction. Secure units to structural support with anchor bolts.

9. Isolation Curb Support (for units mounted on isolation curbs): Install dehumidification units on isolation curbs, and install flexible duct connectors and vibration isolation and seismic-control devices. Flexible duct connectors are specified in Division 23 Section "Air Duct Accessories". Vibration isolation and seismic-control devices are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".

C. Connections
1. Where piping is installed adjacent to dehumidification units, allow space for service and maintenance of dehumidification units.
2. Connect piping to dehumidification units mounted on vibration isolators with flexible connectors.
3. Connect condensate drain pans using minimum NPS 1-1/4 (DN 32) copper tubing. Extend to nearest equipment or floor drain. Construct deep trap at connection to drain pan, and install cleanout at changes in direction.
4. Refrigerant Piping: Comply with requirements in Division 23 Section "Refrigerant Piping". Connect to supply and return coil tappings with shutoff valve and union or flange at each connection.
5. Hot-Water Piping: Comply with requirements in Division 23 Section "Hydronic Piping". Connect to supply coil tappings with shutoff valve, return coil tappings with balancing valve, and union or flange at each connection.
6. Steam and Condensate Piping: Comply with requirements in Division 23 Section "Steam And Condensate Heating Piping". Connect with shutoff valve and union or flange.
7. Duct installation requirements are specified in other Division 21. Drawings indicate the general arrangement of ducts. The following are specific connection requirements:
   a. Install ducts to termination in roof-mounted frames. Where indicated, terminate return-air duct through roof structure and insulate the space between roof and bottom of dehumidification unit.

D. Field Quality Control
1. Perform tests and inspections.
2. Tests and Inspections:
   a. Leak Test: After installation, fill water coils with water, and test coils and connections for leaks. Repair leaks and retest until no leaks exist.
   b. Charge refrigerant coils with refrigerant and test for leaks. Repair leaks and retest until no leaks exist.
   c. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
3. Dehumidification unit will be considered defective if it does not pass tests and inspections.
4. Prepare test and inspection reports.

E. Startup Service
1. Perform startup service.
   a. Complete installation and startup checks according to manufacturer's written instructions.
2. Perform the following final checks before startup:
   a. Verify that shipping, blocking, and bracing are removed.
   b. Verify that unit is secure on mountings and supporting devices and that connections to piping, ducts, and electrical systems are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
   c. Perform cleaning and adjusting specified in this Section.
   d. Disconnect fan drive from motor, verify proper motor rotation direction, and verify free fan wheel rotation and smooth bearing operations. Reconnect fan drive system, align belts, and install belt guards.
   e. Check lubrication of bearings, pulleys, belts, and other moving parts.
   f. Set outside- and return-air mixing dampers to minimum outside-air setting.
   g. Install clean filters.
   h. Verify that manual and automatic volume control and fire and smoke dampers in connected duct systems are in fully open position.

3. Starting procedures for dehumidification units include the following:
   a. Energize motor; verify proper operation of motor, drive system, and fan wheel. Adjust fan to indicated rpm. Replace malfunctioning motors, bearings, and fan wheels.
   b. Measure and record motor's electrical values for voltage and amperage.
   c. Manually operate dampers from fully closed to fully open position and record fan performance.
4. Comply with requirements in Division 23 Section "Testing, Adjusting, And Balancing For Hvac" for testing, adjusting, and balancing of dehumidification unit.
5. Startup Report: Report findings during startup. Identify startup steps, corrective measures taken, and final results.

F. Adjusting
1. Adjust damper linkages for proper damper operation.
2. Adjust initial temperature and humidity set points.

G. Cleaning
1. Clean dehumidification units internally, on completion of installation, according to manufacturer's written instructions. Clean fan interiors to remove foreign material and construction dirt and dust. Vacuum clean fan wheels, cabinets, and coils' entering-air face.
2. After completing system installation, testing, and startup service of dehumidification units, clean filter housings and install new filters.

H. Demonstration
1. Train Owner's maintenance personnel to adjust, operate, and maintain dehumidification units.

END OF SECTION 23 76 13 00

Task	Specification	Specification Description
23 76 13 00	23 74 23 00	Direct-Fired, Makeup Air Units
23 76 13 00	23 74 23 00a	Indirect-Fired, Packaged H&V Units

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SECTION 23 81 13 00 - PACKAGED TERMINAL AIR CONDITIONERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for packaged terminal air conditioners. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section includes packaged terminal air conditioners and their accessories and controls, in the following configurations:
   a. Through-the-wall and freestanding air conditioners.
   b. Cooling-only units.
   c. Heat-pump units.
   d. Cooling units with electric heat.
   e. Cooling units with hydronic heat.
   f. Cooling units with indirect-fired gas heat.

C. Submittals
1. Product Data: For each type of product indicated.
2. LEED Submittals:
   a. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.
   b. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
3. Shop Drawings: For packaged terminal air conditioners. Include plans, elevations, sections, details for wall penetrations, seismic bracing, **as directed**, and attachments to other work.
   a. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   b. Wiring Diagrams: For power, signal, and control wiring.
4. Color Samples: For unit cabinet, discharge grille, and exterior louver, and for each color and texture specified.
5. Field quality-control reports.
6. Operation and maintenance data.
7. Warranty: Sample of special warranty.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality," Section 5 - "Systems and Equipment," Section 6 - "Ventilation Rate Procedures," and Section 7 - "Construction and Startup."
3. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1.

E. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of packaged terminal air conditioners that fail in materials or workmanship within specified warranty period.
   a. Warranty Period for Sealed Refrigeration System: Manufacturer's standard, but not less than five years from date of Final Completion, including components and labor.
   b. Warranty Period for Nonsealed System Parts: Manufacturer's standard, but not less than five years from date of Final Completion, including only components and excluding labor.

c. Warranty Period for Heat Exchangers: Manufacturer's standard, but not less than five years from date of Final Completion.

1.2 PRODUCTS

A. Manufactured Units
1. Description: Factory-assembled and -tested, self-contained, packaged terminal air conditioner with room cabinet, electric refrigeration system, heating, **as directed**, and temperature controls; fully charged with refrigerant and filled with oil; with cord-connected **OR** hardwired, **as directed**, chassis.

B. Chassis
1. Cabinet: 0.052-inch- (1.32-mm-) thick steel with removable front panel with concealed latches.
   a. Mounting: Wall with wall sleeve **OR** Floor with subbase, **as directed**.
   b. Discharge Grille: Punched-louver discharge grille allowing four-way discharge-air pattern **OR** Extruded-aluminum discharge grille **OR** Reversible polycarbonate discharge grille allowing upward and horizontal airflow, **as directed**.
   c. Louvers: Extruded aluminum with enamel finish **OR** Stamped aluminum with clear-anodized finish **OR** Stamped steel with enamel finish, **as directed**; white **OR** bronze **OR** brown **OR** beige, **as directed**, color.
   d. Finish: Epoxy coating **OR** Baked enamel, **as directed**.
   e. Access Door: Hinged door in top of cabinet for access to controls.
   f. Cabinet Extension: Matching cabinet in construction and finish, allowing diversion of airflow to adjoining room; with grille.
   g. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
   h. Subbase: Enameled steel with adjustable leveling feet and adjustable end plates, with factory-installed and -wired, fused disconnect switch and receptacle sized for unit, **as directed**.
   i. Wall Sleeves: Galvanized steel with polyester finish **OR** Molded polymer **OR** Molded fiberglass-reinforced polyester, **as directed**.
2. Refrigeration System: Direct-expansion indoor coil with capillary restrictor; and hermetically sealed scroll compressor with vibration isolation and overload protection.
   a. Indoor and Outdoor Coils: Seamless copper tubes mechanically expanded into aluminum fins with capillary tube distributor on indoor coil, **as directed**.
   b. Accumulator.
   c. Constant-pressure expansion valve.
   d. Reversing valve.
   e. Charge: R-407C **OR** R-410A, **as directed**.
3. Indoor Fan: Forward curved, centrifugal; with motor and positive-pressure ventilation damper with concealed manual **OR** electric, **as directed**, operator.
4. Filters: Washable polyurethane in molded plastic frame.
5. Condensate Drain: Drain pan to direct condensate to outdoor coil for re-evaporation **OR** and piping to direct condensate to building waste and vent piping, **as directed**.
   a. Comply with ASHRAE 62.1 for drain pan construction and connections.
6. Outdoor Fan: Forward curved, centrifugal **OR** Propeller, **as directed**, type with separate **OR** driven by indoor fan, **as directed**, motor.
   a. Indoor and Outdoor Fan Motors: Two speed; comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
      1) Fan Motors: Permanently lubricated split capacitor.
      2) Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.

3) Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 22.

C. Heating

1. Electric-Resistance Heating Coil: Nickel-chromium-wire, electric-resistance heating elements with contactor and high-temperature-limit switch.
OR
Hot-Water Heating Coil: Seamless copper tubes mechanically expanded into aluminum fins with two-way modulating control valve and air vent.
OR
Gas Heat:
   a. General Requirements for Gas-Fired, Noncondensing Furnaces: Factory assembled, piped, wired, and tested; complying with ANSI Z21.86/CSA 2.32, "Vented Gas-Fired Space Heating Appliances," and with NFPA 54.
   b. Type of Gas: Natural **OR** Propane, **as directed**.
   c. Heat Exchanger: Aluminized-steel **OR** Stainless steel, **as directed**.
   d. Burner:
      1) Gas Valve: 100 percent safety two-stage **OR** modulating, **as directed**, main gas valve, main shutoff valve, pressure regulator, safety pilot with electronic flame sensor, limit control, transformer, and combination ignition/fan timer control board.
      2) Ignition: Electric pilot ignition with hot-surface igniter or electric spark ignition.
   e. Gas-Burner Safety Controls:
      1) Electronic Flame Sensor: Prevents gas valve from opening until pilot flame is proven; stops gas flow on ignition failure.
      2) Flame Rollout Switch: Installed on burner box; prevents burner operation.
      3) Limit Control: Fixed stop at maximum permissible setting; de-energizes burner on excessive bonnet temperature; automatic reset.
   f. Combustion-Air Inducer: Centrifugal fan prepurges heat exchanger and vents combustion products; thermally protected motor with sleeve bearings; pressure switch prevents operation if combustion-air inlet or flue outlet is blocked.
   g. Furnace Controls: Solid-state board integrates ignition, heat, cooling, and fan speeds; adjustable fan-on and fan-off timing; and terminals for connection to accessories.

D. Controls

1. Control Module: Unit-mounted digital panel with touchpad temperature control and with touchpad for heating, cooling, and fan operation. Include the following features:
   a. Low Ambient Lockout Control: Prevents cooling-cycle operation below 40 deg F (5 deg C) outdoor air temperature.
   b. Heat-Pump Ambient Control: Field-adjustable switch changes to heat-pump heating operation above 40 deg F (5 deg C) and to supplemental heating below plus 25 deg F (minus 4 deg C).
   c. Temperature-Limit Control: Prevents occupant from exceeding preset setback **OR** setup, **as directed**, temperature.
   d. Building Automation System Interface: Allows remote on-off control with setback temperature control.
   e. Reverse-Cycle Defrost: Solid-state sensor monitors frost buildup on indoor **OR** outdoor, **as directed**, coil and reverses unit to melt frost.
2. Remote Control: Standard unit-mounted controls with remote-mounted, low-voltage adjustable thermostat with heat anticipator, heat-off-cool-auto **OR** heat-off-cool, **as directed**, switch, and on-auto, **as directed**, fan switch.
3. Outdoor Air: Manual **OR** Motorized, **as directed**, intake damper. Open intake when unit indoor air fan runs, **as directed**.

E. Source Quality Control

1. Sound-Power Level Ratings: Factory test to comply with ARI 300, "Sound Rating and Sound Transmission Loss of Packaged Terminal Equipment."

2. Unit Performance Ratings: Factory test to comply with ARI 310/380/CSA C744, "Packaged Terminal Air-Conditioners and Heat Pumps."

1.3 EXECUTION

A. Installation
1. Install units level and plumb, maintaining manufacturer's recommended clearances and tolerances.
2. Install wall sleeves in finished wall assembly; seal and weatherproof. Joint-sealant materials and applications are specified in Division 07 Section "Joint Sealants".
3. Install and anchor wall sleeves to withstand, without damage to equipment and structure, seismic forces required by building code.

B. Connections
1. Comply with requirements for piping specified in Division 23 Section "Hydronic Piping". Drawings indicate general arrangement of piping, fittings, and specialties.
2. Comply with requirements for piping specified in Division 23 Section "Facility Natural-gas Piping". Drawings indicate general arrangement of piping, fittings, and specialties.
3. Install piping adjacent to machine to allow service and maintenance.

C. Field Quality Control
1. Perform tests and inspections.
2. Tests and Inspections:
   a. Inspect for and remove shipping bolts, blocks, and tie-down straps.
   b. After installing packaged terminal air conditioners and after electrical circuitry has been energized, test for compliance with requirements.
   c. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   d. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
3. Packaged terminal air conditioners will be considered defective if they do not pass tests and inspections.
4. Prepare test and inspection reports.

D. Startup Service
1. Perform startup service.
2. After installation, verify the following:
   a. Unit is level on base and is flashed in exterior wall.
   b. Unit casing has no visible damage.
   c. Compressor, air-cooled condenser coil, and fans have no visible damage.
   d. Labels are clearly visible.
   e. Controls are connected and operable.
   f. Shipping bolts, blocks, and tie-down straps are removed.
   g. Filters are installed and clean.
   h. Drain pan and drain line are installed correctly.
   i. Electrical wiring installation complies with manufacturer's submittal and installation requirements in Division 22.
   j. Installation. Perform startup checks according to manufacturer's written instructions, including the following:
      1) Lubricate bearings on fan.
      2) Check fan-wheel rotation for correct direction without vibration and binding.
3. After startup service and performance test, change filters.

E. Adjusting

1. Adjust initial temperature set points.
2. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

F. Demonstration
1. Train Owner's maintenance personnel to adjust, operate, and maintain packaged terminal air conditioners.

END OF SECTION 23 81 13 00

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Task	Specification	Specification Description
23 81 16 00	23 81 13 00	Packaged Terminal Air Conditioners

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SECTION 23 81 23 00 - COMPUTER-ROOM AIR-CONDITIONERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for computer-room air-conditioners. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Floor-mounted computer-room air conditioners, 6 tons (21 kW) and larger.
b. Floor-mounted computer-room air conditioners, 5 tons (18 kW) and smaller.
c. Ceiling-mounted computer-room air conditioners.
d. Console computer-room air conditioners.

C. Definition
1. BAS: Building automation system.

D. Performance Requirements
1. Seismic Performance: Computer-room air conditioners shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

E. Submittals
1. Product Data: For each type of product indicated.
2. LEED Submittals:
a. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.
b. Product Data for Prerequisite EQ 1: Documentation indicating that units comply with ASHRAE 62.1, Section 5 - "Systems and Equipment."
3. Shop Drawings: For computer-room air conditioners. Include plans, elevations, sections, details, and attachments to other work.
a. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
b. Wiring Diagrams: For power, signal, and control wiring.
4. Color Samples: For unit cabinet, discharge grille, and exterior louver and for each color and texture specified.
5. Seismic Qualification Certificates: For computer-room air conditioners, accessories, and components, from manufacturer.
6. Field quality-control reports.
7. Operation and maintenance data.
8. Warranty: Sample of special warranty.

F. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. ASHRAE Compliance:
a. Fabricate and label refrigeration system to comply with ASHRAE 15, "Safety Standard for Refrigeration Systems."

b. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 4 - "Outdoor Air Quality," Section 5 - "Systems and Equipment," Section 6 - "Ventilation Rate Procedures," and Section 7 - "Construction and Startup."

3. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1.
4. ASME Compliance: Fabricate and label water-cooled condenser shell to comply with ASME Boiler and Pressure Vessel Code: Section VIII, "Pressure Vessels," Division 1.

G. Warranty

1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of computer-room air conditioners that fail in materials or workmanship within specified warranty period.
   a. Warranty Period for Compressors: Manufacturer's standard, but not less than five **OR** 10, **as directed**, years from date of Final Completion.
   b. Warranty Period for Humidifiers: Manufacturer's standard, but not less than three years from date of Final Completion.
   c. Warranty Period for Control Boards: Manufacturer's standard, but not less than three years from date of Final Completion.

1.2 PRODUCTS

A. Floor-Mounted Units 6 Tons (21 kW) And Larger

1. Description: Packaged, factory assembled, prewired, and prepiped; consisting of cabinet, fans, filters, humidifier, and controls.
2. Cabinet and Frame: Welded steel, braced for rigidity, and supporting compressors and other mechanical equipment and fittings.
   a. Doors and Access Panels: Galvanized steel with polyurethane gaskets, hinges, and concealed fastening devices.
   b. Insulation: Thermally and acoustically insulate cabinet interior with 1-inch- (25-mm-) thick duct liner.
   c. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
   d. Finish of Exterior Surfaces: Baked-on, textured vinyl enamel; color as selected from manufacturer's standard colors **OR** to match computer equipment, **as directed**.
   e. Floor Stand: Welded tubular steel with adjustable legs and vibration isolation pads.
3. Supply-Air Fan(s):
   a. Double-inlet, forward-curved centrifugal fan(s); statically and dynamically balanced.
   b. Drive: V-belt, with steel shaft with self-aligning ball bearings and cast-iron or steel sheaves, variable- and adjustable-pitch motor sheave, minimum of two matched belts, with drive rated at a minimum of two times the nameplate rating of motor.
4. Refrigeration System:
   a. Compressors: Semihermetic reciprocating; with suction-gas-cooled, 1750-rpm motors; thermal overloads; oil sight glass; suction-line strainer; and reversible oil pumps; with oil strainer, internal motor overload protection, **as directed**, resilient suspension system, crankcase heater, manual-reset high-pressure switch, and pump-down low-pressure switch.

      OR

      Compressors: Hermetic reciprocating; with oil strainer, internal motor overload protection, **as directed**, resilient suspension system, crankcase heater, manual-reset high-pressure switch, and pump-down low-pressure switch.

      Compressors: Hermetic scroll; with oil strainer, internal motor overload protection, **as directed**, resilient suspension system, crankcase heater, manual-reset high-pressure switch, and pump-down low-pressure switch.

b. Refrigeration Circuits: Two; each with hot-gas mufflers, thermal-expansion valve with external equalizer, liquid-line solenoid valve, liquid-line filter-dryer, sight glass with moisture indicator, service shutoff valves, charging valves, and charge of refrigerant.
c. Refrigerant: R-407C **OR** R-410A, **as directed**.
d. Refrigerant Evaporator Coil: Alternate-row or split-face-circuit, direct-expansion coil of seamless copper tubes expanded into aluminum fins.
   1) Mount coil assembly over stainless-steel drain pan complying with ASHRAE 62.1, **as directed**, and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir, **as directed**.
e. Integral, Water-Cooled Refrigerant Condenser: Shell-and-tube type fabricated and labeled according to ASME Boiler and Pressure Vessel Code: Section VIII **OR** Coaxial tube-in-tube type, **as directed**, with liquid-line stop valve and head-pressure-actuated, two-way **OR** three-way, **as directed**, regulating valve. Terminate fluid connections outside cabinet.
   1) Cooling Medium: Water **OR** Glycol solution, **as directed**.

   OR

   Remote Air-Cooled Refrigerant Condenser: Corrosion-resistant cabinet, copper-tube aluminum-fin coils arranged for two circuits, multiple direct-drive propeller fans with permanently lubricated ball bearings, and single-phase motors with internal overload protection and integral electric control panel and disconnect switch, **as directed**. Control capacity by cycling fans **OR** modulating fan speeds **OR** three-way refrigerant bypass with receiver and isolation valve, **as directed**.

5. Hydronic Cooling Coil: Seamless copper tubes expanded into aluminum fins with modulating two-way **OR** three-way, **as directed**, control valve.
   a. Cooling Medium: Water **OR** Glycol solution, **as directed**.
   b. Control Valve: Class 125 body.
      1) Maximum Pressure Drop: 3 psig (21 kPa) **OR** 5 psig (35 kPa), **as directed**, at design flow rate.
      2) Close-Off (Differential) Pressure Rating: 100 percent of pressure differential across valve or 100 percent of total system (pump) head.
   c. Mount coil assembly over stainless-steel drain pan complying with ASHRAE 62.1, **as directed**, and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir, **as directed**.

   OR

   Remote, Air-Cooled, Glycol-Solution Cooler: Corrosion-resistant cabinet, copper-tube aluminum-fin coil, multiple direct-drive propeller fans with fan guards, and single-phase motors with internal overload protection and integral electric control panel. Control capacity by cycling fans.
   d. Disconnect Switch: Nonautomatic, molded-case circuit breaker with handle accessible when panel is closed and capable of preventing access until switched to off position.
6. Glycol-Solution Pump Package: Weatherproof and vented enclosure of enameled, galvanized steel on structural base frame containing one **OR** two, **as directed**, centrifugal pump(s) with mechanical seals; electrical-control cabinet with starters, lead-lag switch, automatic switchover, and alarm light.
   a. Piping: Interconnecting piping, to and from remote, air-cooled, glycol-solution cooler, with shutoff valves, flow switches, check valves in pump discharge, unions, and pressurized expansion tank with air purge vent and system-charging connection.
   b. Glycol: Inhibited ethylene glycol and water solution mixed 50:50, suitable for operating temperature of minus 40 deg F (minus 40 deg C).
   c. Disconnect Switch: Nonautomatic, molded-case circuit breaker with handle accessible when panel is closed and capable of preventing access until switched to off position.
7. Electric-Resistance Heating Coil: Enclosed finned-tube electric elements arranged for minimum of three stages, with thermal safety switches, manual-reset overload protection, and branch-circuit overcurrent protection.

   OR

   Refrigerant Heating Coil: Hot-gas coil of seamless copper tubes expanded into aluminum fins with three-way solenoid valve on first-stage refrigerant circuit.

   OR

Hot-Water Heating Coil: Seamless copper tubes expanded into aluminum fins with two-way modulating control valve and strainer.

a. Control Valve: Class 125 body.
   1) Maximum Pressure Drop: 3 psig (21 kPa) **OR** 5 psig (35 kPa), **as directed**, at design flow rate.
   2) Close-Off (Differential) Pressure Rating: 100 percent of pressure differential across valve or 100 percent of total system (pump) head.

OR

Steam Heating Coil: Seamless copper tubes expanded into aluminum fins with two-way modulating control valve, strainer, and float-and-thermostatic trap.

b. Control Valve: Class 125 body.
   1) Maximum Pressure Drop (15-psig (103-kPa) Steam): 80 percent of inlet steam pressure.
   2) Close-Off (Differential) Pressure Rating: 150 percent of operating (inlet) pressure.

8. Extended-Surface, Disposable, Panel Filter: Pleated, lofted, nonwoven, reinforced cotton fabric; supported and bonded to welded-wire grid; enclosed in cardboard frame with 2-inch- (50-mm-) thick, disposable, glass-fiber prefilter, **as directed**.
   a. Thickness: 2 inches (50 mm) **OR** 4 inches (100 mm), **as directed**.
   b. Initial Resistance: as directed by the Owner.
   c. Recommended Final Resistance: as directed by the Owner.
   d. Arrestance (ASHRAE 52.1): 90 percent.
   e. Merv (ASHRAE 52.2): 7.
9. Infrared Humidifier: High-intensity quartz lamps mounted above stainless-steel evaporator pan, serviceable without disconnecting water, drain, or electrical connections; prepiped and using condensate water from cooling coils with stainless-steel or brass float-valve mechanism; located in bypass airstream; with flush-cycle timer and solenoid drain valve.
10. Evaporative Pan Humidifier: Stainless-steel pan and cover, serviceable without disconnecting water, drain, or electrical connections; prepiped with stainless-steel or brass float-valve mechanism; electric-resistance heating coil; low-water-cutoff switch; flush-cycle timer; and solenoid drain valve.
11. Electrode Steam Humidifier: Self-contained, microprocessor-controlled unit with disposable, polypropylene-plastic cylinders, and having field-adjustable steel electrodes and stainless-steel steam dispersion tube.
    a. Plumbing Components and Valve Bodies: Plastic, linked by flexible rubber hosing, with water fill with air gap and solenoid valve incorporating built-in strainer, pressure-reducing and flow-regulating orifice, and drain with integral air gap.
    b. Control: Fully modulating to provide gradual 0 to 100 percent capacity with field-adjustable maximum capacity; with high-water probe.
    c. Drain Cycle: Field-adjustable drain duration and drain interval.
12. Integral Electrical Controls: Unit-mounted electrical enclosure with piano-hinged door, grounding lug, combination magnetic starters with overload relays, circuit breakers and cover interlock, and fusible control-circuit transformer.
13. Disconnect Switch: Nonautomatic, molded-case circuit breaker with handle accessible when panel is closed and capable of preventing access until switched to off position.
14. Electronic-Control System: Solid state, with start button, stop button, temporary loss of power indicator, manual-reset circuit breakers, temperature control, humidity control, and monitor panel.
    a. Monitor Panel: Backlighted, with no visible indicator lights until operating function is activated; indicators include cooling, humidification, loss of airflow, change filters, high temperature, low temperature, high humidity, low humidity, high head pressure (each compressor), and low suction pressure (each compressor).
    b. Temperature- and Humidity-Control Modules: Solid state, plug-in; with adjustable set point, push-to-test calibration check button, and built-in visual indicators to show mode of operation.
    c. Location: Behind hinged door in front of unit; isolated from conditioned airstream to allow service while system is operating.

15. Microprocessor-Control System: Continuously monitors operation of process cooling system; continuously displays room temperature and room relative humidity; sounds alarm on system malfunction and simultaneously displays problem. If more than one malfunction occurs, system displays fault in sequence with room temperature and continues to display fault when malfunction is cleared until system is reset.
    a. Malfunctions:
        1) Power loss.
        2) Loss of airflow.
        3) Clogged air filter.
        4) High room temperature.
        5) Low room temperature.
        6) High humidity.
        7) Low humidity.
        8) Smoke/fire.
        9) Water under floor.
        10) Supply fan overload.
        11) Compressor No. 1 - Overload.
        12) Compressor No. 1 - Low Pressure.
        13) Compressor No. 1 - High Pressure.
        14) Compressor No. 2 - Overload.
        15) Compressor No. 2 - Low Pressure.
        16) Compressor No. 2 - High Pressure.
    b. Digital Display:
        1) Control power on.
        2) Humidifying.
        3) Dehumidifying.
        4) Compressor No. 1 - Operating.
        5) Compressor No. 2 - Operating.
        6) Heat operating.
        7) Economy cooling.
    c. Push buttons shall stop and start process cooling system, silence audible alarm, test indicators, and display room's relative humidity.
    d. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display unit status and alarms.
        1) Hardwired Points:
            a) Monitoring: On-off status, common trouble alarm **OR** space temperature **OR** space relative humidity, **as directed**.
            b) Control: On-off operation, space temperature set-point adjustment **OR** space relative humidity set-point adjustment, **as directed**.
        2) ASHRAE 135 (BACnet) **OR** LonTalk **OR** Modbus **OR** Industry-accepted, open-protocol, **as directed**, communication interface with the BAS shall enable the BAS operator to remotely control and monitor the unit from an operator workstation. Control features and monitoring points displayed locally at unit control panel shall be available through the BAS.

B. Floor-Mounted Units 5 Tons (18 kW) And Smaller
1. Description: Self-contained, factory assembled, prewired, and prepiped; consisting of cabinet, fan, filters, and controls; for vertical floor mounting in upflow or downflow configuration.
2. Cabinet and Frame: Welded tubular-steel frame with removable steel panels with baked-enamel finish, insulated with 1-inch- (25-mm-) thick duct liner.
    a. Floor Stand: Welded tubular steel with adjustable legs and vibration isolation pads.
    b. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
3. Supply-Air Fan: Forward curved, centrifugal, and with adjustable V-belt drive.
4. Refrigeration System:

a. Compressor: Hermetic, with oil strainer, internal motor overload protection, resilient suspension system, and crankcase heater.
b. Refrigeration Circuit: Low-pressure switch, manual-reset high-pressure switch, thermal-expansion valve with external equalizer, sight glass with moisture indicator, service shutoff valves, charging valves, and charge of refrigerant.
c. Refrigerant: R-407C **OR** R-410A, **as directed**.
d. Refrigerant Evaporator Coil: Direct-expansion coil of seamless copper tubes expanded into aluminum fins, with two circuits, each with solenoid valve.
   1) Mount coil assembly over stainless-steel drain pan complying with ASHRAE 62.1, **as directed**, and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir, **as directed**.
e. Integral, Water-Cooled Refrigerant Condenser: Brazed-plate type with liquid-line stop valve and head-pressure-actuated, two-way regulating valve.
   1) Cooling Medium: Water **OR** Glycol solution, **as directed**.

   OR

   Remote Air-Cooled Refrigerant Condenser: Integral, copper-tube aluminum-fin coil with propeller **OR** centrifugal, **as directed**, fan, direct **OR** belt, **as directed**, driven.
   2) Split system shall have suction- and liquid-line compatible fittings and refrigerant piping for field interconnection.

5. Hydronic Cooling Coil: Seamless copper tubes expanded into aluminum fins with modulating three-way control valve.
   a. Cooling Medium: Water **OR** Glycol solution, **as directed**.
   b. Mount coil assembly over stainless-steel drain pan complying with ASHRAE 62.1, **as directed**, and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir, **as directed**.

   OR

   Remote Air-Cooled, Glycol-Solution Cooler: Corrosion-resistant cabinet, copper-tube aluminum-fin coil, direct-drive propeller fan with fan guards, and single-phase motors with internal overload protection.
   c. Disconnect Switch: Nonautomatic, molded-case circuit breaker with handle accessible when panel is closed and capable of preventing access until switched to off position.
6. Glycol-Solution Pump Package: Weatherproof and vented enclosure of enameled, galvanized steel on structural base frame containing centrifugal pump with mechanical seal.
   a. Piping: Interconnecting piping, from suction to discharge, with shutoff valves, flow switches, unions, and pressurized expansion tank with air purge vent and system-charging connection.
   b. Glycol: Inhibited ethylene glycol and water solution mixed 50:50, suitable for operating temperature of minus 40 deg F (minus 40 deg C).
   c. Disconnect Switch: Nonautomatic, molded-case circuit breaker with handle accessible when panel is closed and capable of preventing access until switched to off position.
7. Electric-Resistance Heating Coil: Finned-tube electric elements with contactor and high-temperature-limit switches.
8. Filter: 2-inch- (50-mm-) thick, disposable, glass-fiber media.
   a. Initial Resistance: as directed by the Owner.
   b. Recommended Final Resistance: as directed by the Owner.
   c. Arrestance (ASHRAE 52.1): 90 percent.
   d. Merv (ASHRAE 52.2): 7.
9. Infrared Humidifier: High-intensity quartz lamps mounted above stainless-steel evaporator pan, serviceable without disconnecting water, drain, or electrical connections; prepiped and located in bypass airstream; with flush-cycle timer and solenoid drain valve.
10. Electrode Steam Humidifier: Self-contained, microprocessor-controlled unit with disposable, polypropylene-plastic cylinders and having field-adjustable steel electrodes and stainless-steel steam dispersion tube.

a. Plumbing Components and Valve Bodies: Plastic, linked by flexible rubber hosing, with water fill with air gap and solenoid valve incorporating built-in strainer, pressure-reducing and flow-regulating orifice, and drain with integral air gap.
b. Control: Fully modulating to provide gradual 0 to 100 percent capacity with field-adjustable maximum capacity; with high-water probe.
c. Drain Cycle: Field-adjustable drain duration and drain interval.

11. Disconnect Switch: Nonautomatic, molded-case circuit breaker with handle accessible when panel is closed and capable of preventing access until switched to off position.
12. Control System: Unit-mounted panel with main fan contactor, compressor contactor, compressor start capacitor, control transformer with circuit breaker, solid-state temperature- and humidity-, **as directed**, control modules, humidity contactor, **as directed**, time-delay relay, heating contactor, and high-temperature thermostat. Provide solid-state, wall-mounted control panel with start-stop switch, adjustable humidity set point, **as directed**, and adjustable temperature set point.

C. Ceiling-Mounted Units
1. Description: Self-contained, factory assembled, prewired, and prepiped; consisting of cabinet, fan, filters, and controls; for horizontal ceiling mounting to fit T-bar ceiling opening of 24 by 48 inches (610 by 1220 mm).
2. Cabinet: Galvanized steel with baked-enamel finish, insulated with 1/2-inch- (13-mm-) thick duct liner.
a. Integral factory-supplied supply and return grille to fit ceiling grid kit of 24 by 48 inches (610 by 1220 mm), with filter.
b. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
3. Supply-Air Fan: Forward curved, centrifugal, and directly driven by two-speed motor.
4. Refrigeration System:
a. Compressor: Hermetic, with oil strainer, internal motor overload protection, resilient suspension system, and crankcase heater.
b. Refrigeration Circuit: Low-pressure switch, manual-reset high-pressure switch, thermal-expansion valve with external equalizer, sight glass with moisture indicator, service shutoff valves, charging valves, and charge of refrigerant.
c. Refrigerant: R-407C **OR** R-410A, **as directed**.
d. Refrigerant Evaporator Coil: Direct-expansion coil of seamless copper tubes expanded into aluminum fins.
1) Mount coil assembly over stainless-steel drain pan complying with ASHRAE 62.1, **as directed**, and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir, **as directed**.
e. Integral, Water-Cooled Refrigerant Condenser: Coaxial, counterflow, tube-in-tube **OR** Brazed-plate, **as directed**, type with liquid-line stop valve and head-pressure-actuated, water-regulating valve.
1) Cooling Medium: Water **OR** Glycol solution, **as directed**.
OR
Remote Air-Cooled Refrigerant Condenser: Integral, copper-tube aluminum-fin coil with propeller **OR** centrifugal, **as directed**, fan, direct driven.
f. Split system shall have suction- and liquid-line compatible fittings and refrigerant piping for field interconnection.
5. Hydronic Cooling Coil: Seamless copper tubes expanded into aluminum fins with two-way control valve.
a. Cooling Medium: Water **OR** Glycol solution, **as directed**.
b. Mount coil assembly over stainless-steel drain pan complying with ASHRAE 62.1, **as directed**, and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir, **as directed**.
OR
Remote, Air-Cooled, Glycol-Solution Cooler: Corrosion-resistant cabinet, copper-tube aluminum-fin coil, direct-drive propeller fan with fan guards, and single-phase motors with internal overload protection.

6. Glycol-Solution Pump Package: Weatherproof and vented enclosure of enameled, galvanized steel on structural base frame containing centrifugal pump with mechanical seal.
   a. Piping: Interconnecting piping, to and from remote, air-cooled glycol-solution cooler, with shutoff valves, flow switches, unions, and pressurized expansion tank with air purge vent and system-charging connection.
   b. Glycol: Inhibited ethylene glycol and water solution mixed 50:50, suitable for operating temperature of minus 40 deg F (minus 40 deg C).
7. Electric-Resistance Heating Coil: Finned-tube electric elements with contactor, dehumidification relay, and high-temperature-limit switches.
8. Filter: 1-inch- (25-mm-) thick, disposable, glass-fiber media.
   a. Initial Resistance: as directed by the Owner.
   b. Recommended Final Resistance: as directed by the Owner.
   c. Arrestance (ASHRAE 52.1): 90 percent.
   d. Merv (ASHRAE 52.2): 7.
9. Atomizing Humidifier: Centrifugal atomizer with stainless-steel pan, demister pad, and solenoid valve.
10. Electrode Steam Humidifier: Self-contained, microprocessor-controlled unit with disposable, polypropylene-plastic cylinders, and having field-adjustable steel electrodes and stainless-steel steam dispersion tube.
    a. Plumbing Components and Valve Bodies: Plastic, linked by flexible rubber hosing, with water fill with air gap and solenoid valve incorporating built-in strainer, pressure-reducing and flow-regulating orifice, and drain with integral air gap.
    b. Control: Fully modulating to provide gradual 0 to 100 percent capacity with field-adjustable maximum capacity; with high-water probe.
    c. Drain Cycle: Field-adjustable drain duration and drain interval.
11. Disconnect Switch: Nonautomatic, molded-case circuit breaker with handle accessible when panel is closed and capable of preventing access until switched to off position.
12. Control System: Unit-mounted panel with main fan contactor, compressor contactor, compressor start capacitor, control transformer with circuit breaker, solid-state temperature- and humidity-, **as directed**,control modules, humidity contactor, **as directed**, time-delay relay, heating contactor, and high-temperature thermostat. Provide solid-state, wall-mounted control panel with start-stop switch, adjustable humidity set point, **as directed**, and adjustable temperature set point.

D. Console Units
1. Description: Split system consisting of evaporator section for floor or wall mounting and remote condensing section.
2. Evaporator Cabinet: Furniture-grade steel with baked-enamel finish; with front access and containing direct-drive centrifugal fans and two-speed motor.
   a. Finish of Interior Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
3. Condenser Cabinet: Steel with baked-enamel finish and containing compressor and condenser.
4. Refrigeration System:
   a. Compressor: Hermetic, with oil strainer, internal motor overload protection, resilient suspension system, and crankcase heater.
   b. Refrigeration Circuit: Filter/dryer, manual-reset high-pressure switch, thermal-expansion valve with external equalizer, sight glass with moisture indicator, service shutoff valves, charging valves, and charge of refrigerant.
   c. Refrigerant: R-407C **OR** R-410A, **as directed**.
   d. Refrigerant Evaporator Coil: Direct-expansion coil of seamless copper tubes expanded into aluminum fins.
      1) Mount coil assembly over stainless-steel drain pan complying with ASHRAE 62.1, **as directed**, and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir, **as directed**.

e. Integral, Water-Cooled Refrigerant Condenser: Coaxial, counterflow, tube-in-tube **OR** Brazed-plate, **as directed**, type with liquid-line stop valve and head-pressure-actuated, water-regulating valve.
OR
Remote Air-Cooled Refrigerant Condenser: Integral, copper-tube aluminum-fin coil with propeller **OR** centrifugal, **as directed**, fan, direct driven.

f. Split system shall have suction- and liquid-line compatible fittings and refrigerant piping for field interconnection.

5. Hydronic Cooling Coil: Seamless copper tubes expanded into aluminum fins with modulating control valve.
   a. Cooling Medium: Water **OR** Glycol solution, **as directed**.
   b. Mount coil assembly over stainless-steel drain pan complying with ASHRAE 62.1, **as directed**, and having a condensate pump unit with integral float switch, pump-motor assembly, and condensate reservoir, **as directed**.

   OR
   Remote, Air-Cooled, Glycol-Solution Cooler: Corrosion-resistant cabinet, copper-tube aluminum-fin coil, direct-drive propeller fan with fan guards, and single-phase motor with internal overload protection.
6. Glycol-Solution Pump Package: Weatherproof and vented enclosure of enameled, galvanized steel on structural base frame containing centrifugal pump with mechanical seal.
   a. Piping: Interconnecting piping, to and from remote, air-cooled, glycol-solution cooler, with shutoff valves, flow switches, unions, and pressurized expansion tank with air purge vent and system-charging connection.
   b. Glycol: Inhibited ethylene glycol and water solution mixed 50:50, suitable for operating temperature of minus 40 deg F (minus 40 deg C).
7. Electric-Resistance Heating Coil: Finned-tube electric elements with contactor and high-temperature-limit switches.
8. Filter: Cleanable.
   OR
   Filter: 1-inch- (25-mm-) thick, disposable, glass-fiber media.
   a. Initial Resistance: as directed by the Owner.
   b. Recommended Final Resistance: as directed by the Owner.
   c. Arrestance (ASHRAE 52.1): 90 percent.
   d. Merv (ASHRAE 52.2): 7.
9. Electrode Steam Humidifier: Self-contained and microprocessor controlled; with replaceable cylinder.
10. Disconnect Switch: Nonautomatic, molded-case circuit breaker with handle accessible when panel is closed and capable of preventing access until switched to off position.
11. Control System: Unit-mounted panel with contactors, control transformer with circuit breaker, and solid-state temperature- and humidity-, **as directed**,control modules. Provide solid-state, unit-mounted control panel with start-stop switch, adjustable humidity set point, **as directed**, and adjustable temperature set point.

E. Fan Motors
1. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements for motors specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
   b. Controllers, Electrical Devices, and Wiring: Comply with requirements for electrical devices and connections specified in Division 22.

1.3 EXECUTION

A. Installation

1. Install computer-room air conditioners level and plumb, maintaining manufacturer's recommended clearances. Install according to ARI Guideline B, **as directed**.
2. Computer-Room Air-Conditioner Mounting: Install using elastomeric pads **OR** elastomeric mounts **OR** restrained spring isolators, **as directed**. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   a. Minimum Deflection: 1/4 inch (6 mm) **OR** 1 inch (25 mm), **as directed**.
3. Suspended Computer-Room Air Conditioners: Install using continuous-thread hanger rods and elastomeric hangers **OR** spring hangers **OR** spring hangers with vertical-limit stop, **as directed**, of size required to support weight of computer-room air conditioner.
   a. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment". Fabricate brackets or supports as required.
   b. Comply with requirements for hangers and supports specified in Division 23 Section "Hangers And Supports For Hvac Piping And Equipment".
4. Air-Cooled Refrigerant Condenser Mounting: Install using elastomeric pads **OR** elastomeric mounts **OR** restrained spring isolators, **as directed**. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   a. Minimum Deflection: 1/4 inch (6 mm) **OR** 1 inch (25 mm), **as directed**.
5. Remote, Air-Cooled, Glycol-Solution Cooler Mounting: Install using elastomeric pads **OR** elastomeric mounts **OR** restrained spring isolators, **as directed**. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
   a. Minimum Deflection: 1/4 inch (6 mm) **OR** 1 inch (25 mm), **as directed**.
6. Glycol-Solution Pump Package Mounting: Install using elastomeric pads **OR** elastomeric mounts, **as directed**. Comply with requirements for vibration isolation devices specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".

B. Connections
1. Piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
2. Install piping adjacent to machine to allow service and maintenance.
3. Water and Drainage Connections: Comply with applicable requirements in Division 22 Section "Domestic Water Piping". Provide adequate connections for water-cooled units, condensate drain, and humidifier flushing system.
4. Hot-Water Heating Piping: Comply with applicable requirements in Division 23 Section "Hydronic Piping". Provide shutoff valves in inlet and outlet piping to heating coils.
5. Steam and Condensate Piping: Comply with applicable requirements in Division 23 Section "Steam And Condensate Heating Piping". Provide shutoff valves in steam inlet and steam trap in condensate outlet piping to heating coils.
6. Condenser-Water Piping: Comply with applicable requirements in Division 23 Section "Hydronic Piping". Provide shutoff valves in water inlet and outlet piping on water-cooled units.
7. Refrigerant Piping: Comply with applicable requirements in Division 23 Section "Refrigerant Piping". Provide shutoff valves and piping.

C. Field Quality Control
1. Perform tests and inspections.
2. Tests and Inspections:
   a. Inspect for and remove shipping bolts, blocks, and tie-down straps.
   b. After installing computer-room air conditioners and after electrical circuitry has been energized, test for compliance with requirements.
   c. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

d. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

3. Computer-room air conditioners will be considered defective if they do not pass tests and inspections.
4. Prepare test and inspection reports.
5. After startup service and performance test, change filters and flush humidifier.

D. Adjusting

1. Adjust initial temperature and humidity, **as directed**, set points.
2. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
3. Occupancy Adjustments: When requested within 12 months of date of Final Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.

E. Demonstration

1. Train Owner's maintenance personnel to adjust, operate, and maintain computer-room air conditioners.

END OF SECTION 23 81 23 00

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Task	Specification	Specification Description
23 81 43 00	23 81 13 00	Packaged Terminal Air Conditioners
23 81 49 00	23 63 13 00a	Split-System Air-Conditioning Units

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SECTION 23 82 16 00 - AIR COILS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for air coils. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following types of air coils that are not an integral part of air-handling units:
a. Hot-water.
b. Chilled-water.
c. Steam.
d. Refrigerant.
e. Electric.

C. Submittals
1. Product Data: For each type of product indicated. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for each air coil. Include rated capacity and pressure drop for each air coil.
2. Shop Drawings: Diagram power, signal, and control wiring.
3. Field quality-control test reports.
4. Operation and maintenance data.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. ASHRAE Compliance:
a. Comply with ASHRAE 15 for refrigeration system safety.
b. Comply with ASHRAE 33 for methods of testing cooling and heating coils.
c. Comply with applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup."

1.2 PRODUCTS

A. Water Coils
1. Performance Ratings: Tested and rated according to ARI 410 and ASHRAE 33.
2. Minimum Working-Pressure/Temperature Ratings: 200 psig (1380 kPa), 325 deg F (163 deg C).
3. Source Quality Control: Factory tested to 300 psig (2070 kPa).
4. Tubes: ASTM B 743 copper, minimum 0.020 inch (0.508 mm) **OR** 0.035 inch (0.889 mm) **OR** 0.049 inch (1.245 mm), **as directed**, thick.
5. Fins: Aluminum **OR** Copper, **as directed**, minimum 0.006 inch (0.152 mm) **OR** 0.010 inch (0.254 mm), **as directed**, thick.
6. Headers: Cast iron with drain and air vent tappings **OR** Cast iron with cleaning plugs, and drain and air vent tappings **OR** Seamless copper tube with brazed joints, prime coated **OR** Steel with brazed joints, prime coated, **as directed**.
7. Frames: Galvanized-steel channel frame, minimum 0.052 inch (1.3 mm) **OR** 0.064 inch (1.6 mm) **OR** 0.079 inch (2.0 mm) **OR** 0.0625 inch (1.6 mm), **as directed**, thick for slip-in **OR** flanged, **as directed**, mounting.

OR
Frames: ASTM A 666, Type 304 **OR** 316, **as directed**, stainless steel, minimum 0.0625 inch (1.6 mm) thick for slip-in **OR** flanged, **as directed**, mounting.

8. Hot-Water Coil and Steam Coil, Face-and-Bypass Dampers: Alternating arrangement of coil segments and dampers.
   a. Coil Configuration: Horizontal **OR** Vertical, **as directed**, tubes.
   b. Dampers: Extruded-aluminum **OR** Galvanized-steel, **as directed**, blades with edge and end seals; full-length drive rod and mount for actuator in **OR** outside, **as directed**, the airstream.

B. Steam Coils
1. Performance Ratings: Tested and rated according to ARI 410 and ASHRAE 33.
2. Minimum Working-Pressure/Temperature Ratings: 100 psig (690 kPa), 400 deg F (204 deg C).
3. Source Quality Control: Factory tested to 300 psig (2070 kPa).
4. Tubes: ASTM B 743 copper, minimum 0.025 inch (0.635 mm) **OR** 0.035 inch (0.889 mm) **OR** 0.049 inch (1.245 mm), **as directed**, thick.
5. Fins: Aluminum **OR** Copper, **as directed**, minimum 0.006 inch (0.152 mm) **OR** 0.010 inch (0.254 mm), **as directed**, thick.
6. Headers: Cast iron with drain and air vent tappings **OR** Cast iron with cleaning plugs, and drain and air vent tappings **OR** Seamless copper tube with brazed joints, prime coated **OR** Steel with brazed joints, prime coated, **as directed**.
7. Tube Type: Single or distributing as indicated.
8. Frames: Galvanized-steel channel frame, minimum 0.052 inch (1.3 mm) **OR** 0.064 inch (1.6 mm) **OR** 0.079 inch (2.0 mm) **OR** 0.0625 inch (1.6 mm), **as directed**, thick for slip-in **OR** flanged, **as directed**, mounting.
   OR
   Frames: ASTM A 666, Type 304 **OR** 316, **as directed**, stainless steel, minimum 0.0625 inch (1.6 mm) thick for slip-in **OR** flanged, **as directed**, mounting.
9. Face-and-Bypass Dampers: Alternating arrangement of coil segments and dampers.
   a. Coil Configuration: Horizontal **OR** Vertical, **as directed**, tubes.
   b. Dampers: Extruded-aluminum **OR** Galvanized-steel, **as directed**, blades with edge and end seals; full-length drive rod and mount for actuator in **OR** outside, **as directed**, the airstream.

C. Refrigerant Coils
1. Performance Ratings: Tested and rated according to ARI 410 and ASHRAE 33.
2. Minimum Working-Pressure Rating: 300 psig (2070 kPa).
3. Source Quality Control: Factory tested to 450 psig (3105 kPa).
4. Tubes: ASTM B 743 copper, minimum 0.020 inch (0.508 mm) **OR** 0.035 inch (0.889 mm) **OR** 0.049 inch (1.245 mm), **as directed**, thick.
5. Fins: Aluminum **OR** Copper, **as directed**, minimum 0.006 inch (0.152 mm) **OR** 0.010 inch (0.254 mm), **as directed**, thick.
6. Suction and Distributor Piping: ASTM B 88, Type L (ASTM B 88M, Type B) copper tube with brazed joints.
7. Frames: Galvanized-steel channel frame, minimum 0.052 inch (1.3 mm) **OR** 0.064 inch (1.6 mm) **OR** 0.079 inch (2.0 mm) **OR** 0.0625 inch (1.6 mm), **as directed**, thick for slip-in **OR** flanged, **as directed**, mounting.
   OR
   Frames: ASTM A 666, Type 304 **OR** 316, **as directed**, stainless steel, minimum 0.0625 inch (1.6 mm) thick for slip-in **OR** flanged, **as directed**, mounting.

D. Electric Coils
1. Coil Assembly: Comply with UL 1995.

2. Heating Elements: Coiled resistance wire of 80 percent nickel and 20 percent chromium; surrounded by compacted magnesium-oxide powder in tubular-steel sheath; with spiral-wound, copper-plated, steel fins continuously brazed to sheath.
   OR
   Heating Elements: Open-coil resistance wire of 80 percent nickel and 20 percent chromium, supported and insulated by floating ceramic bushings recessed into casing openings, and fastened to supporting brackets.
3. High-Temperature Coil Protection: Disk-type, automatically reset, thermal-cutout, safety device; serviceable through terminal box without removing heater from duct or casing.
   a. Secondary Protection: Load-carrying, manually reset or manually replaceable, thermal cutouts; factory wired in series with each heater stage.
4. Frames: Galvanized-steel channel frame, minimum 0.052 inch (1.3 mm) **OR** 0.064 inch (1.6 mm) **OR** 0.079 inch (2.0 mm) **OR** 0.0625 inch (1.6 mm), **as directed**, thick for slip-in **OR** flanged, **as directed**, mounting.
5. Control Panel: Unit **OR** Remote, **as directed**, mounted with disconnecting means and overcurrent protection. Include the following controls:
   a. Magnetic contactor.
   b. Mercury contactor.
   c. Toggle switches; one per step.
   d. Step controller.
   e. Time-delay relay.
   f. Pilot lights; one per step.
   g. Airflow proving switch.
6. Refer to Division 23 Section "Instrumentation And Control For Hvac" for thermostat.
   OR
   Thermostats: Wall-mounted thermostats, with temperature range from 50 to 90 deg F (10 to plus 32 deg C), and 2.5 deg F (1.4 deg C) throttling range.

1.3 EXECUTION

A. Installation
   1. Install coils level and plumb.
   2. Install coils in metal ducts and casings constructed according to SMACNA's "HVAC Duct Construction Standards, Metal and Flexible."
   3. Install galvanized-steel **OR** stainless-steel, **as directed**, drain pan under each cooling coil.
      a. Construct drain pans with connection for drain; insulated and complying with ASHRAE 62.1, **as directed**.
      b. Construct drain pans to extend beyond coil length and width and to connect to condensate trap and drainage.
      c. Extend drain pan upstream and downstream from coil face.
      d. Extend drain pan under coil headers and exposed supply piping.
   4. Install moisture eliminators for cooling coils. Extend drain pan under moisture eliminator.
   5. Straighten bent fins on air coils.
   6. Clean coils using materials and methods recommended in writing by manufacturers, and clean inside of casings and enclosures to remove dust and debris.

B. Connections
   1. Piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
   2. Install piping adjacent to coils to allow service and maintenance.
   3. Connect water piping with unions and shutoff valves to allow coils to be disconnected without draining piping. Control valves are specified in Division 23 Section "Instrumentation And Control For Hvac", and other piping specialties are specified in Division 23 Section "Hydronic Piping".
   4. Connect steam piping with gate valve and union and steam condensate piping with union, strainer, trap, and gate valve to allow coils to be disconnected without draining piping. Control

valves are specified in Division 23 Section "Instrumentation And Control For Hvac", and other piping specialties are specified in Division 23 Section "Steam And Condensate Heating Piping".

5. Connect refrigerant piping according to Division 23 Section "Refrigerant Piping".
6. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
7. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

C. Field Quality Control

1. Perform the following field tests and inspections and prepare test reports:
   a. Operational Test: After electrical circuitry has been energized, operate electric coils to confirm proper unit operation.
   b. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

END OF SECTION 23 82 16 00

Task	Specification	Specification Description
23 82 19 00	23 64 16 16	Fan-Coil Units
23 82 39 13	01 22 16 00	No Specification Required
23 82 39 13	23 55 33 00a	Unit Heaters
23 82 39 16	01 22 16 00	No Specification Required
23 82 39 16	23 55 33 00a	Unit Heaters
23 82 39 19	23 55 33 00a	Unit Heaters

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SECTION 23 84 13 00 - HUMIDIFIERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for humidifiers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following humidifiers:
a. Atomizing.
b. Steam injection.
c. Self-contained.
d. Heated pan.
e. Heat exchanger.

C. Definition
1. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.

D. Submittals
1. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories.
2. Shop Drawings: Detail fabrication and installation of humidifiers. Include piping details, plans, elevations, sections, details of components, manifolds, and attachments to other work.
a. Wiring Diagrams: Power, signal, and control wiring.
3. Field quality-control test reports.
4. Operation and maintenance data.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Comply with ARI 640, "Commercial and Industrial Humidifiers."

1.2 Products

A. Water-Pressure Atomizing Humidifiers
1. Nozzles: ASTM A 666, Type 304 **OR** 316, **as directed**, stainless steel.
2. Manifold: ASTM A 269, Type 304 **OR** 316, **as directed**, stainless-steel piping.
3. Droplet Filter: Biocide-treated polyethylene with maximum 0.30-inch wg (75-Pa) resistance.
4. Piping and Fittings: ASTM A 269, Type 304 **OR** 316, **as directed**, stainless-steel pipe and fittings.
OR
Piping and Fittings: ASTM B 88 (ASTM B 88M), Type L copper pipe and wrought-copper fittings with brazed joints.
5. Water Pump: Enclosed belt-drive ceramic plunger pump with stainless-steel **OR** bronze, **as directed**, heads, and single **OR** variable, **as directed**,-speed, totally enclosed, fan-cooled motor.
6. Final Water-Filter Efficiency: Minimum 98 percent retention of suspended particles 10 **OR** 20, **as directed**, microns and larger from makeup water.

7. Final Water-Filter Pressure Drop: Maximum 2 psig (14 kPa) at design flow when clean, and <**Insert value**> when dirty, **as directed**.
8. Pump Controls:
   a. Cycle **OR** Vary speed of, **as directed**, motor to satisfy humidistat.
   b. High-pressure solenoid valve for each control zone shown on Drawings.
   c. Building automation system interface for each control zone for start/stop and status indication and control at central workstation.
9. Dispersion Fan:
   a. Aluminum blade propeller fan with finger guard and single-speed motor interlocked to operate with humidifier.
   b. Fan Mounting: Above and behind manifold on bracket integral to wall-mounting manifold.
10. Accessories:
   a. Humidistat: Wall **OR** Return-duct, **as directed**,-mounting, solid-state, electronic-sensor controller capable of full-modulation or cycling control.
   b. Duct-mounting, high-limit humidistat.
   c. Airflow switch for preventing humidifier operation without airflow.

B. Compressed-Air Atomizing Humidifiers
1. Nozzles: ASTM A 666, Type 304 **OR** 316, **as directed**, stainless steel.
2. Manifold: ASTM A 269, Type 304 **OR** 316, **as directed**, stainless-steel piping.
3. Droplet Filter: Biocide-treated polyethylene with maximum 0.30-inch wg (75-Pa) resistance.
4. Piping and Fittings: ASTM A 269, Type 304 **OR** 316, **as directed**, stainless-steel pipe and fittings.
5. Compressed-Air and Water, **as directed**, Piping and Fittings: ASTM B 88 (ASTM B 88M), Type L copper pipe and wrought-copper fittings with soldered joints.
6. Final Water-Filter Efficiency: Minimum 98 percent retention of suspended particles 10 **OR** 20, **as directed**, microns and larger from makeup water.
7. Final Water-Filter Pressure Drop: Maximum 2 psig (14 kPa) at design flow when clean, and <**Insert value**> when dirty, **as directed**.
8. Air and Water Solenoid Controls:
   a. Cycle valves to satisfy humidistat.
   b. Solenoid valves for each control zone shown on Drawings.
   c. Building automation system interface for each control zone for start/stop and status indication and control at central workstation.
9. Dispersion Fan:
   a. Aluminum blade propeller fan with finger guard and single-speed motor interlocked to operate with humidifier.
   b. Fan Mounting: Above and behind manifold on bracket integral to wall-mounting manifold.
10. Accessories:
   a. Humidistat: Wall **OR** Return-duct, **as directed**,-mounting, solid-state, electronic-sensor controller capable of full-modulation or cycling control.
   b. Duct-mounting, high-limit humidistat.
   c. Airflow switch for preventing humidifier operation without airflow.

C. Steam-Injection Humidifiers
1. Manifold: ASTM A 666, Type 304 stainless steel, steam jacketed, **as directed**; insulated with 1/2-inch (13-mm) fiberglass and stainless-steel jacket; and , **as directed**,extending the full width of duct or plenum with mounting brackets at ends.
2. Discharge Nozzle and Dispersion Fan:
   a. Steam-jacketed discharge nozzle, aluminum blade propeller fan with finger guard, and single-speed motor interlocked to operate with humidifier.
   b. Fan Mounting: Above and behind discharge outlet on bracket integral to discharge outlet.
3. Steam Separator: Cast iron **OR** ASTM A 666, Type 304 stainless steel, **as directed**, with separate, **as directed**, humidifier control valve.
4. Humidifier Control Valve:

a. Actuator: Pneumatic **OR** Electric, **as directed**, modulating with spring return.
OR
Actuator: As specified in Division 23 Section "Instrumentation And Control For Hvac".

5. Steam Trap: Inverted-bucket type, sized for a minimum of 3 times the maximum rated condensate flow of humidifier at 1/2-psig (3.4-kPa) inlet pressure.
6. Accessories:
   a. Wall **OR** Return-duct, **as directed**,-mounting humidistat.
   b. Duct-mounting, high-limit humidistat.
   c. Aquastat mounted on steam condensate return piping to prevent cold operation of humidifier.
   d. In-line strainer.
   e. Airflow switch for preventing humidifier operation without airflow.

D. Self-Contained Humidifiers
1. Electric-Resistance Heater Container: Cleanable, ASTM A 666, Type 304 **OR** 316, **as directed**, stainless steel. Comply with UL 499.
2. Electrode Cylinder: Replaceable plastic assembly with disposable ionic bed inserts, **as directed**. Comply with UL 499.
3. Gas-Fired Steam Generator: Factory assembled and tested.
   a. Standard: Fabricate and label steam generator to comply with CSA.
   b. Maximum Steam Pressure: 10 inches wg (2488 Pa).
   c. Burner Type: Natural-gas **OR** Propane, **as directed**, fired with modulating, low NOx infrared burner, minimum 82 percent efficient.
   d. Gas Train: Safety shutoff valves, gas cock, strainer, pressure-regulating valve.
   e. Ignition: Hot-surface ignition with flame safety system.
   f. Combustion Chamber: Sealed with outdoor-air and flue-vent connections.
   g. Heat-Exchanger Tank: Cleanable, ASTM A 666, Type 304 **OR** 316, **as directed**, stainless steel with corrosion-resistant coating and disposable ionic bed inserts, **as directed**.
4. Manifold: Stainless-steel tube with integral fan to discharge vapor directly into occupied space.
   OR
   Manifold: ASTM A 666, Type 304 **OR** 316, **as directed**, stainless-steel tube extending across entire width of duct or plenum and equipped with mounting brackets on ends.
5. Cabinet: Sheet metal enclosure for housing heater cylinder, electrical wiring, components, controls, and control panel. Enclosure shall include baked-enamel finish, hinged or removable access door, and threaded outlet in bottom of cabinet for drain piping.
6. Control Panel:
   a. Factory-wired disconnect switch.
   b. Liquid-crystal display.
   c. Programmable keyboard.
   d. Set-point adjustment.
   e. Warning signal indicating end of replaceable cylinder or ionic bed insert, **as directed**, life.
   f. Low-voltage, control circuit.
   g. Diagnostic, maintenance, alarm, and status features.
   h. High-water sensor **OR** float, **as directed**, to prevent overfilling.
7. Controls:
   a. Microprocessor-based control system for modulating or cycling control, and start/stop and status monitoring for interface to central HVAC instrumentation and controls.
   b. Solenoid-fill and automatic drain valves to maintain water level and temper hot drain water.
   c. Field-adjustable timer to control drain cycle for flush duration and interval.
   d. Controls shall drain tanks if no demand for humidification for more than 72 hours.
   e. Conductivity **OR** Float, **as directed**,-type level controls.
8. Accessories:
   a. Humidistat: Wall **OR** Return-duct, **as directed**,-mounting, solid-state, electronic-sensor controller capable of full modulation or cycling control.
   b. Duct-mounting, high-limit humidistat.
   c. Airflow switch for preventing humidifier operation without airflow.

E. Heated-Pan Humidifiers
1. Heat Source: Hot water **OR** Steam **OR** Electric resistance, **as directed**.
2. Comply with UL 499.
3. Pan and Heat-Exchange Piping: ASTM A 666, Type 304 **OR** 316, **as directed**, stainless steel with corrosion-resistant coating, overflow, and drain fittings. Include disposable ionic bed inserts, **as directed**.
4. Manifold: ASTM A 666, Type 304 **OR** 316, **as directed**, stainless-steel, duct-mounting, single- or manifold-grid connected to heated-pan housing with flexible hose and extending across width of duct or plenum. Manifold shall have mounting brackets at both ends.
   OR
   Manifold: Inverted, ASTM A 666, Type 304 **OR** 316, **as directed**, stainless-steel U-tube with humidifier mounted directly under the duct.
   OR
   Manifold: ASTM A 666, Type 304 **OR** 316, **as directed**, stainless-steel tube with flexible hose to connect to humidifier, integral fan to discharge vapor directly into occupied space, and wall- or ceiling-mounting brackets.
5. Controls:
   a. Solenoid-fill and automatic drain valves to maintain water level and temper hot drain water.
   b. Field-adjustable timer to control drain cycle for flush duration and interval.
   c. Conductivity **OR** Float, **as directed**,-type level controls.
6. Piping Specialties: Inlet strainer, control valve, and steam trap.
7. Piping Specialties: Inlet strainer and control valve.
8. Accessories:
   a. Humidistat: Wall **OR** Return-duct, **as directed**,-mounting, solid-state, electronic-sensor controller capable of full modulation or cycling control.
   b. Duct-mounting, high-limit humidistat.
   c. Airflow switch for preventing humidifier operation without airflow.

F. Heat-Exchanger Humidifiers
1. Fabricate and label steam generator to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
2. Heat Exchanger: ASTM A 666, Type 304 **OR** 316, **as directed**, stainless steel with corrosion-resistant coating, overflow, and drain fittings. Include disposable ionic bed inserts, **as directed**.
3. Manifold: ASTM A 666, Type 304 **OR** 316, **as directed**, stainless-steel, steam-jacketed, **as directed**, duct-mounting, single- or manifold-grid connected to steam generator with flexible hose and extending across width of duct or plenum. Manifold shall have mounting brackets for both ends. Insulate with 1/2-inch (13-mm) fiberglass and stainless-steel jacket extending full width of duct or plenum with mounting brackets at ends, **as directed**.
   OR
   Manifold: ASTM A 666, Type 304 **OR** 316, **as directed**, stainless-steel tube with flexible hose to connect to humidifier and integral fan to discharge vapor directly into occupied space. Manifold shall have wall- or ceiling-mounting brackets.
4. Controls:
   a. Solenoid-fill and automatic drain valves to maintain water level and temper hot drain water.
   b. Field-adjustable timer to control drain cycle for flush duration and interval.
   c. Conductivity **OR** Float, **as directed**,-type level controls.
5. Accessories:
   a. Humidistat: Wall **OR** Return-duct, **as directed**,-mounting, solid-state, electronic-sensor controller capable of full modulation.
   b. Duct-mounting, high-limit humidistat.
   c. Airflow switch for preventing humidifier operation without airflow.

1.3 EXECUTION

A. Installation
1. Install humidifiers with required clearance for service and maintenance. Maintain path, downstream from humidifiers, clear of obstructions as required by ASHRAE 62.1, **as directed**.
2. Seal humidifier manifold duct or plenum penetrations with flange.
3. Install humidifier manifolds in metal ducts and casings constructed according to SMACNA's "HVAC Duct Construction Standards, Metal and Flexible."
4. Install galvanized **OR** stainless, **as directed**,-steel drain pan under each manifold mounted in duct.
   a. Construct drain pans with connection for drain; insulated and complying with ASHRAE 62.1, **as directed**.
   b. Connect to condensate trap and drainage piping.
   c. Extend drain pan upstream and downstream from manifold a minimum distance recommended by manufacturer but not less than required by ASHRAE 62.1.
5. Install manifold supply piping pitched to drain condensate back to humidifier.
6. Install drip leg upstream from steam trap a minimum of 12 inches (300 mm) tall for proper operation of trap.
7. Install steam generator level on concrete base. Concrete base is specified in Division 23 Section "Common Work Results For Hvac".
8. Concrete Bases: Anchor steam generator to concrete base.
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around full perimeter of base.
   b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   d. Install anchor bolts to elevations required for proper attachment to supported equipment.
   e. Cast-in-place concrete materials and placement requirements are specified in Division 31.
9. Install seismic restraints on humidifiers. Seismic restraints are specified in Division 23 Section "Vibration And Seismic Controls For Hvac Piping And Equipment".
10. Install gas-fired steam generators according to NFPA 54.

B. Connections
1. Piping installation requirements are specified in other Division 21. Drawings indicate general arrangement of piping, fittings, and specialties.
   a. Install piping adjacent to humidifiers to allow service and maintenance.
   b. Install shutoff valve, strainer, backflow preventer, and union in humidifier makeup line.
2. Install electrical devices and piping specialties furnished by manufacturer but not factory mounted.
3. Install piping from safety relief valves to nearest floor drain.
4. Connect gas piping full size to steam-generator, gas-train inlet with union. Gas piping materials and specialties are specified in Division 23 Section(s) "Facility Natural-gas Piping" OR "Facility Liquefied-petroleum Gas Piping", **as directed**.
5. Connect breeching full size to steam-generator outlet. Venting materials are specified in Division 23 Section "Breechings, Chimneys, And Stacks".
6. Connect combustion-air inlet to intake terminal using PVC piping with solvent-cemented joints. Run from boiler connection to outside and terminate adjacent to flue termination.
7. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
8. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

C. Field Quality Control
1. Perform tests and inspections and prepare test reports.
2. Tests and Inspections:

a. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
b. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
c. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

3. Remove and replace malfunctioning units and retest as specified above.

D. Demonstration

1. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain humidifiers.

END OF SECTION 23 84 13 00

Task	Specification	Specification Description
26 01 30 00	01 22 16 00	No Specification Required
26 01 50 51	01 22 16 00	No Specification Required
26 01 50 51	02 84 16 00	Removal of Fluorescent Light Ballasts/Capacitors and Fluorescent Light Tubes
26 01 50 51	02 84 16 00a	Interior Lighting
26 01 50 51	02 84 16 00b	Exterior Lighting
26 01 50 52	02 84 16 00	Removal of Fluorescent Light Ballasts/Capacitors and Fluorescent Light Tubes
26 01 50 52	02 84 16 00a	Interior Lighting
26 01 50 52	02 84 16 00b	Exterior Lighting
26 01 50 53	02 84 16 00	Removal of Fluorescent Light Ballasts/Capacitors and Fluorescent Light Tubes
26 01 50 53	02 84 16 00a	Interior Lighting
26 01 50 53	02 84 16 00b	Exterior Lighting

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SECTION 26 05 13 00 - CONDUCTORS AND CABLES

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of conductors and cables. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following:
a. Building wires and cables rated 600 V and less.
b. Connectors, splices, and terminations rated 600 V and less.
c. Sleeves and sleeve seals for cables.

C. Definitions
1. EPDM: Ethylene-propylene-diene terpolymer rubber.
2. NBR: Acrylonitrile-butadiene rubber.

D. Submittals
1. Product Data: For each type of product indicated.
2. Field quality-control test reports.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Comply with NFPA 70.

1.2 PRODUCTS

A. Conductors And Cables
1. Copper, or **as directed**, Conductors: Comply with NEMA WC 70.
2. Conductor Insulation: Comply with NEMA WC 70 for Types THW **OR** THHN-THWN **OR** XHHW **OR** UF **OR** USE **OR** SO, **as directed**.
3. Multiconductor Cable: Comply with NEMA WC 70 for armored cable, metal-clad cable, mineral-insulated, metal-sheathed cable, Type MI **OR** nonmetallic-sheathed cable, Type SO **OR** Type USE, **as directed**, with ground wire.
a. The following are not to be installed without the Owner approval:
1) Type AC
2) Type MC
3) Type NM

B. Connectors And Splices
1. Description: Factory-fabricated connectors and splices of size, ampacity rating, material, type, and class for application and service indicated.

C. Sleeves For Cables
1. Steel Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, galvanized steel, plain ends.
2. Cast-Iron Pipe Sleeves: Cast or fabricated "wall pipe," equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop, unless otherwise indicated.

3. Sleeves for Rectangular Openings: Galvanized sheet steel with minimum 0.052- or 0.138-inch (1.3- or 3.5-mm) thickness as indicated and of length to suit application.
4. Coordinate sleeve selection and application with selection and application of firestopping specified in Division 07 Section "Penetration Firestopping".

D. Sleeve Seals
1. Description: Modular sealing device, designed for field assembly, to fill annular space between sleeve and cable.
   a. Sealing Elements: EPDM **OR** NBR, **as directed**, interlocking links shaped to fit surface of cable or conduit. Include type and number required for material and size of raceway or cable.
   b. Pressure Plates: Plastic **OR** Carbon steel **OR** Stainless steel, **as directed**. Include two for each sealing element.
   c. Connecting Bolts and Nuts: Carbon steel with corrosion-resistant coating **OR** Stainless steel, **as directed**, of length required to secure pressure plates to sealing elements. Include one for each sealing element.

1.3 EXECUTION

A. Conductor Material Applications
1. Feeders: Copper for feeders **as directed**. Solid for No. 10 AWG and smaller; stranded for No. 8 AWG and larger.
2. Branch Circuits: Copper. Solid for No. 10 AWG and smaller; stranded for No. 8 AWG and larger.

B. Conductor Insulation And Multiconductor Cable Applications And Wiring Methods
1. Service Entrance: Type THHN-THWN, single conductors in raceway **OR** Type XHHW, single conductors in raceway **OR** Mineral-insulated, metal-sheathed cable, Type MI **OR** Type SE or USE multiconductor cable, **as directed**.
2. Exposed Feeders: Type THHN-THWN, single conductors in raceway **OR** Armored cable, Type AC **OR** Metal-clad cable, Type MC **OR** Mineral-insulated, metal-sheathed cable, Type MI **OR** Nonmetallic-sheathed cable, Type NM, **as directed**.
3. Feeders Concealed in Ceilings, Walls, Partitions, and Crawlspaces: Type THHN-THWN, single conductors in raceway **OR** Armored cable, Type AC **OR** Metal-clad cable, Type MC **OR** Mineral-insulated, metal-sheathed cable, Type MI **OR** Nonmetallic-sheathed cable, Type NM, **as directed**.
4. Feeders Concealed in Concrete, below Slabs-on-Grade, and Underground: Type THHN-THWN, single conductors in raceway **OR** Underground feeder cable, Type UF, **as directed**.
5. Feeders Installed below Raised Flooring: Type THHN-THWN, single conductors in raceway **OR** Armored cable, Type AC **OR** Metal-clad cable, Type MC **OR** Mineral-insulated, metal-sheathed cable, Type MI, **as directed**.
6. Feeders in Cable Tray: Type THHN-THWN, single conductors in raceway **OR** Armored cable, Type AC **OR** Metal-clad cable, Type MC **OR** Mineral-insulated, metal-sheathed cable, Type MI **OR** Nonmetallic-sheathed cable, Type NM, **as directed**.
7. Exposed Branch Circuits, Including in Crawlspaces: Type THHN-THWN, single conductors in raceway **OR** Armored cable, Type AC **OR** Metal-clad cable, Type MC **OR** Mineral-insulated, metal-sheathed cable, Type MI **OR** Nonmetallic-sheathed cable, Type NM, **as directed**.
8. Branch Circuits Concealed in Ceilings, Walls, and Partitions: Type THHN-THWN, single conductors in raceway **OR** Armored cable, Type AC **OR** Metal-clad cable, Type MC **OR** Mineral-insulated, metal-sheathed cable, Type MI **OR** Nonmetallic-sheathed cable, Type NM, **as directed**.
9. Branch Circuits Concealed in Concrete, below Slabs-on-Grade, and Underground: Type THHN-THWN, single conductors in raceway **OR** Underground branch-circuit cable, Type UF, **as directed**.

10. Branch Circuits Installed below Raised Flooring: Type THHN-THWN, single conductors in raceway **OR** Armored cable, Type AC **OR** Metal-clad cable, Type MC **OR** Mineral-insulated, metal-sheathed cable, Type MI, **as directed**.
11. Branch Circuits in Cable Tray: Type THHN-THWN, single conductors in raceway **OR** Armored cable, Type AC **OR** Metal-clad cable, Type MC **OR** Mineral-insulated, metal-sheathed cable, Type MI, **as directed**.
12. Cord Drops and Portable Appliance Connections: Type SO, hard service cord with stainless-steel, wire-mesh, strain relief device at terminations to suit application.
13. Class 1 Control Circuits: Type THHN-THWN, in raceway.
14. Class 2 Control Circuits: Type THHN-THWN, in raceway **OR** Power-limited cable, concealed in building finishes **OR** Power-limited tray cable, in cable tray, **as directed**.

C. Installation Of Conductors And Cables
1. Conceal cables in finished walls, ceilings, and floors, unless otherwise indicated.
2. Use manufacturer-approved pulling compound or lubricant where necessary; compound used must not deteriorate conductor or insulation. Do not exceed manufacturer's recommended maximum pulling tensions and sidewall pressure values.
3. Use pulling means, including fish tape, cable, rope, and basket-weave wire/cable grips, that will not damage cables or raceway.
4. Install exposed cables parallel and perpendicular to surfaces of exposed structural members, and follow surface contours where possible.
5. Support cables according to Division 26 Section "Hangers And Supports For Electrical Systems".
6. Identify and color-code conductors and cables according to Division 26 Section "Identification For Electrical Systems".
7. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.
8. Make splices and taps that are compatible with conductor material and that possess equivalent or better mechanical strength and insulation ratings than unspliced conductors.
   a. Use oxide inhibitor in each splice and tap conductor for aluminum conductors.
9. Wiring at Outlets: Install conductor at each outlet, with at least 6 inches (150 mm) **OR** 12 inches (300 mm), **as directed**, of slack.

D. Sleeve Installation For Electrical Penetrations
1. Coordinate sleeve selection and application with selection and application of firestopping specified in Division 07 Section "Penetration Firestopping".
2. Concrete Slabs and Walls: Install sleeves for penetrations unless core-drilled holes or formed openings are used. Install sleeves during erection of slabs and walls.
3. Use pipe sleeves unless penetration arrangement requires rectangular sleeved opening.
4. Rectangular Sleeve Minimum Metal Thickness:
   a. For sleeve rectangle perimeter less than 50 inches (1270 mm) and no side greater than 16 inches (400 mm), thickness shall be 0.052 inch (1.3 mm).
   b. For sleeve rectangle perimeter equal to, or greater than, 50 inches (1270 mm) and 1 or more sides equal to, or greater than, 16 inches (400 mm), thickness shall be 0.138 inch (3.5 mm).
5. Fire-Rated Assemblies: Install sleeves for penetrations of fire-rated floor and wall assemblies unless openings compatible with firestop system used are fabricated during construction of floor or wall.
6. Cut sleeves to length for mounting flush with both wall surfaces.
7. Extend sleeves installed in floors 2 inches (50 mm) above finished floor level.
8. Size pipe sleeves to provide 1/4-inch (6.4-mm) annular clear space between sleeve and cable unless sleeve seal is to be installed or unless seismic criteria require different clearance, **as directed**.
9. Seal space outside of sleeves with grout for penetrations of concrete and masonry and with approved joint compound for gypsum board assemblies, **as directed**.

10. Interior Penetrations of Non-Fire-Rated Walls and Floors: Seal annular space between sleeve and cable, using joint sealant appropriate for size, depth, and location of joint according to Division 07 Section "Joint Sealants".
11. Fire-Rated-Assembly Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at cable penetrations. Install sleeves and seal with firestop materials according to Division 07 Section "Penetration Firestopping".
12. Roof-Penetration Sleeves: Seal penetration of individual cables with flexible boot-type flashing units applied in coordination with roofing work.
13. Aboveground Exterior-Wall Penetrations: Seal penetrations using sleeves and mechanical sleeve seals. Size sleeves to allow for 1-inch (25-mm) annular clear space between pipe and sleeve for installing mechanical sleeve seals.
14. Underground Exterior-Wall Penetrations: Install cast-iron "wall pipes" for sleeves. Size sleeves to allow for 1-inch (25-mm) annular clear space between cable and sleeve for installing mechanical sleeve seals.

E. Sleeve-Seal Installation
1. Install to seal underground exterior-wall penetrations.
2. Use type and number of sealing elements recommended by manufacturer for cable material and size. Position cable in center of sleeve. Assemble mechanical sleeve seals and install in annular space between cable and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

F. Firestopping
1. Apply firestopping to electrical penetrations of fire-rated floor and wall assemblies to restore original fire-resistance rating of assembly according to Division 07 Section "Penetration Firestopping".

G. Field Quality Control
1. Perform tests and inspections and prepare test reports.
2. Tests and Inspections:
   a. After installing conductors and cables and before electrical circuitry has been energized, test service entrance and feeder conductors, and conductors feeding the following critical equipment and services, **as directed**, for compliance with requirements.
   b. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
   c. Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each splice in cables and conductors No. 3 AWG and larger. Remove box and equipment covers so splices are accessible to portable scanner.
      1) Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each splice 11 months after date of Substantial Completion.
      2) Instrument: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
      3) Record of Infrared Scanning: Prepare a certified report that identifies splices checked and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.
3. Test Reports: Prepare a written report to record the following:
   a. Test procedures used.
   b. Test results that comply with requirements.
   c. Test results that do not comply with requirements and corrective action taken to achieve compliance with requirements.
4. Remove and replace malfunctioning units and retest as specified above.

END OF SECTION 26 05 13 00

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SECTION 26 05 13 00a - UNDERCARPET CABLES

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of undercarpet cables. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following:
a. Undercarpet cable and service fittings for branch circuits.
b. Undercarpet cable and service fittings for communication and data transmission.

C. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings: Include plans, elevations, sections, details of components, and attachments to other work.
a. Indicate cable types, accessories, and transition boxes.
b. Indicate proposed layering of cables, cable dimensions, and installation requirements.
3. Field quality-control test reports.
4. Operation and maintenance data.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Comply with NEMA UC 2, "Undercarpet Power Distribution Systems" and with NFPA 70.

1.2 PRODUCTS

A. Power Distribution Cable
1. Cable: Factory laminated and complying with NEMA UC 2; three-piece assembly including bottom shield, conductor assembly, and top shield.
a. Bottom Shield: Abrasion resistant, nonmetallic **OR** Metallic, **as directed**.
b. Conductor Assembly: Two **OR** Three **OR** Four, **as directed**,-wire branch circuit with insulated ground, **as directed**.
c. Top Shield: Copper or copper alloy.
2. Current Rating: 20 **OR** 30 **OR** 20 and 30, **as directed**, A.

B. Communication And Data Cable
1. Category 5e Communication and Data Cable: Extruded-vinyl jacket over 4 unshielded, twisted pairs, No. 24 AWG, copper; complying with TIA/EIA 568-B; and tested to 300-lb (136-kg) rollover test.

C. Pedestals
1. Description: Manufacturer's standard low **OR** regular, **as directed**,-profile type, single **OR** two **OR** three, **as directed**, gang with single **OR** duplex, **as directed**, receptacles and Category 5e modular connectors, **as directed**.
a. Pedestal Colors: As selected from manufacturer's full range.

D. Power Cable Transition Unit

1. Description: Interface transition unit, with junction box, for connecting three-, four-, or five-conductor, flat-conductor cable to building wiring system.

E. Communication And Data Cable Transition Unit
1. Description: Category 5 transition termination circuit board in wall-mounted box to convert round incoming cable to outgoing flat-undercarpet cable.

1.3 EXECUTION

A. Installation
1. Do not begin installation until heavy construction is completed and wheeled traffic is no longer a threat.
2. Do not stack cables in circulation routes.
3. Limit total installed height to 0.09 inch (2.29 mm).
4. Install cables in proper order with power-transmission cable first, followed by telephone cable and then data cable. Cross cables at 90-degree angles.
5. Install undercarpet cables and accessories using special tools as recommended by undercarpet cable manufacturer.

B. Connections
1. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
2. Connect undercarpet cable and components to branch circuits and to ground as indicated and instructed by manufacturer.

C. Field Quality Control
1. Perform tests and inspections and prepare test reports.
2. Tests and Inspections:
   a. Branch-Circuit Cables: After cables have been installed and energized, perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
   b. Communication and Data Cables: After cables have been installed and connected between telecommunications outlet and system cross-connect panel, test each cable according to TIA/EIA TSB67. Certify compliance with test parameters.
3. Remove and replace malfunctioning units and retest as specified above.

END OF SECTION 26 05 13 00a

SECTION 26 05 13 00b - MEDIUM-VOLTAGE CABLES

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of medium-voltage cables. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes cables and related splices, terminations, and accessories for medium-voltage electrical distribution systems.

C. Definitions
1. NETA ATS: Acceptance Testing Specification.

D. Submittals
1. Product Data: For each type of cable indicated. Include splices and terminations for cables and cable accessories.
2. Field quality-control test reports.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Comply with IEEE C2 and NFPA 70.

1.2 PRODUCTS

A. Cables
1. Cable Type: MV90 **OR** MV105, **as directed**.
2. Comply with UL 1072, AEIC CS 8, ICEA S-93-639, and ICEA S-97-682, **OR** ICEA S-94-649, **as directed**.
3. Conductor: Copper **OR** Aluminum, **as directed**.
4. Conductor Stranding: Compact round, concentric lay, Class B) **OR** Concentric lay, Class B, **as directed**.
5. Strand Filling: Conductor interstices are filled with impermeable compound.
6. Conductor Insulation: Crosslinked polyethylene **OR** Ethylene-propylene rubber, **as directed**.
   a. Voltage Rating: 5 **OR** 8 **OR** 15 **OR** 25 **OR** 35, **as directed,** kV.
   b. Insulation Thickness: 100 **OR** 133, **as directed,** percent insulation level.
7. Shielding: Copper tape **OR** Solid copper wires, **as directed**, helically applied over semiconducting insulation shield.
8. Shielding and Jacket: Corrugated copper drain wires embedded in extruded, chlorinated, polyethylene jacket.
9. Three-Conductor Cable Assembly: Three insulated, shielded conductors cabled together with ground conductors, **as directed**.
   a. Circuit Identification: Color-coded tape (black, red, blue) under the metallic shielding.
10. Cable Armor: Interlocked aluminum **OR** Interlocked galvanized steel **OR** Corrugated aluminum tube, **as directed,** applied over cable.
11. Cable Jacket: Sunlight-resistant PVC **OR** Chlorosulfonated polyethylene, CPE, **as directed**.

B. Splice Kits

1. Connectors and Splice Kits: Comply with IEEE 404; type as recommended by cable or splicing kit manufacturer for the application.
2. Splicing Products: As recommended, in writing, by splicing kit manufacturer for specific sizes, ratings, and configurations of cable conductors. Include all components required for complete splice, with detailed instructions.
   a. Combination tape and cold-shrink-rubber sleeve kit with rejacketing by cast-epoxy-resin encasement or other waterproof, abrasion-resistant material.
   b. Heat-shrink splicing kit of uniform, cross-section, polymeric construction with outer heat-shrink jacket.
   c. Premolded, cold-shrink-rubber, in-line splicing kit.
   d. Premolded EPDM splicing body kit with cable joint sealed by interference fit of mating parts and cable.

C. Solid Terminations
1. Multiconductor Cable Sheath Seals: Type recommended by seal manufacturer for type of cable and installation conditions, including orientation.
   a. Compound-filled, cast-metal body, metal-clad cable terminator for metal-clad cable with **OR** without, **as directed,** external plastic jacket.
   b. Cold-shrink sheath seal kit with preformed sleeve openings sized for cable and insulated conductors.
   c. Heat-shrink sheath seal kit with phase- and ground-conductor rejacketing tubes, cable-end sealing boot, and sealing plugs for unused ground-wire openings in boot.
   d. Cast-epoxy-resin sheath seal kit with wraparound mold and packaged, two-part, epoxy-resin casting material.
2. Shielded-Cable Terminations: Comply with the following classes of IEEE 48. Insulation class is equivalent to that of cable. Include shield ground strap for shielded cable terminations.
   a. Class 1 Terminations: Modular type, furnished as a kit, with stress-relief tube; multiple, molded-silicone rubber, insulator modules; shield ground strap; and compression-type connector.
   b. Class 1 Terminations: Heat-shrink type with heat-shrink inner stress control and outer nontracking tubes; multiple, molded, nontracking skirt modules; and compression-type connector.
   c. Class 1 Terminations: Modular type, furnished as a kit, with stress-relief shield terminator; multiple-wet-process, porcelain, insulator modules; shield ground strap; and compression-type connector.
   d. Class 1 Terminations, Indoors: Kit with stress-relief tube, nontracking insulator tube, shield ground strap, compression-type connector, and end seal.
   e. Class 2 Terminations, Indoors: Kit with stress-relief tube, nontracking insulator tube, shield ground strap, and compression-type connector. Include silicone-rubber tape, cold-shrink-rubber sleeve, or heat-shrink plastic-sleeve moisture seal for end of insulation whether or not supplied with kits.
   f. Class 3 Terminations: Kit with stress cone and compression-type connector.
3. Nonshielded-Cable Terminations: Kit with compression-type connector. Include silicone-rubber tape, cold-shrink-rubber sleeve, or heat-shrink plastic-sleeve moisture seal for end of insulation whether or not supplied with kits.

D. Separable Insulated Connectors
1. Description: Modular system, complying with IEEE 386, with disconnecting, single-pole, cable terminators and with matching, stationary, plug-in, dead-front terminals designed for cable voltage and for sealing against moisture.
2. Terminations at Distribution Points: Modular type, consisting of terminators installed on cables and modular, dead-front, terminal junctions for interconnecting cables.
3. Load-Break Cable Terminators: Elbow-type units with 200-A load make/break and continuous-current rating; coordinated with insulation diameter, conductor size, and material of cable being terminated. Include test point on terminator body that is capacitance coupled.

4. Dead-Break Cable Terminators: Elbow-type unit with 600-A continuous-current rating; designed for de-energized disconnecting and connecting; coordinated with insulation diameter, conductor size, and material of cable being terminated. Include test point on terminator body that is capacitance coupled.
5. Dead-Front Terminal Junctions: Modular bracket-mounted groups of dead-front stationary terminals that mate and match with above cable terminators. Two-, three-, or four-terminal units as indicated, with fully rated, insulated, watertight conductor connection between terminals and complete with grounding lug, manufacturer's standard accessory stands, stainless-steel mounting brackets, and attaching hardware.
   a. Protective Cap: Insulating, electrostatic-shielding, water-sealing cap with drain wire.
   b. Portable Feed-Through Accessory: Two-terminal, dead-front junction arranged for removable mounting on accessory stand of stationary terminal junction.
   c. Grounding Kit: Jumpered elbows, portable feed-through accessory units, protective caps, test rods suitable for concurrently grounding three phases of feeders, and carrying case.
   d. Standoff Insulator: Portable, single dead-front terminal for removable mounting on accessory stand of stationary terminal junction. Insulators suitable for fully insulated isolation of energized cable-elbow terminator.
6. Test-Point Fault Indicators: Applicable current-trip ratings and arranged for installation in test points of load-break separable connectors, and complete with self-resetting indicators capable of being installed with shotgun hot stick and tested with test tool.
7. Tool Set: Shotgun hot stick with energized terminal indicator, fault-indicator test tool, and carrying case.

E. Arc-Proofing Materials
1. Tape for First Course on Metal Objects: 10-mil- (250-micrometer-) thick, corrosion-protective, moisture-resistant, PVC pipe-wrapping tape.
2. Arc-Proofing Tape: Fireproof tape, flexible, conformable, intumescent to 0.3 inch (8 mm) thick, compatible with cable jacket.
3. Glass-Cloth Tape: Pressure-sensitive adhesive type, 1/2 inch (13 mm) wide.

F. Fault Indicators
1. Indicators: Automatically **OR** Manually, **as directed,** reset fault indicator with inrush restraint feature, arranged to clamp to cable sheath and provide a display after a fault has occurred in cable. Instrument shall not be affected by heat, moisture, and corrosive conditions and shall be recommended by manufacturer for installation conditions.
2. Resetting Tool: Designed for use with fault indicators, with moisture-resistant storage and carrying case.

G. Source Quality Control
1. Test and inspect cables according to ICEA S-97-682 **OR** ICEA S-94-649, **as directed,** before shipping.
2. Test strand-filled cables for water-penetration resistance according to ICEA T-31-610, using a test pressure of 5 psig (35 kPa).

1.3 EXECUTION

A. Installation
1. Install cables according to IEEE 576.
2. Pull Conductors: Do not exceed manufacturer's recommended maximum pulling tensions and sidewall pressure values.
   a. Where necessary, use manufacturer-approved pulling compound or lubricant that will not deteriorate conductor or insulation.
   b. Use pulling means, including fish tape, cable, rope, and basket-weave cable grips that will not damage cables and raceways. Do not use rope hitches for pulling attachment to cable.

3. Install exposed cables parallel and perpendicular to surfaces of exposed structural members and follow surface contours where possible.
4. Support cables according to Division 26 Section "Common Work Results For Electrical".
5. Install direct-buried cables on leveled and tamped bed of 3-inch- (75-mm-) thick, clean sand. Separate cables crossing other cables or piping by a minimum of 4 inches (100 mm) of tamped earth. Install permanent markers at ends of cable runs, changes in direction, and buried splices.
6. Install "buried-cable" warning tape 12 inches (305 mm) above cables.
7. In manholes, handholes, pull boxes, junction boxes, and cable vaults, train cables around walls by the longest route from entry to exit and support cables at intervals adequate to prevent sag.
8. Install cable splices at pull points and elsewhere as indicated; use standard kits.
9. Install terminations at ends of conductors and seal multiconductor cable ends with standard kits.
10. Install separable insulated-connector components as follows:
    a. Protective Cap: At each terminal junction, with one on each terminal to which no feeder is indicated to be connected.
    b. Portable Feed-Through Accessory: Three.
    c. Standoff Insulator: Three.
11. Arc Proofing: Unless otherwise indicated, arc proof medium-voltage cable at locations not protected by conduit, cable tray, direct burial, or termination materials. In addition to arc-proofing tape manufacturer's written instructions, apply arc proofing as follows:
    a. Clean cable sheath.
    b. Wrap metallic cable components with 10-mil (250-micrometer) pipe-wrapping tape.
    c. Smooth surface contours with electrical insulation putty.
    d. Apply arc-proofing tape in one half-lapped layer with coated side toward cable.
    e. Band arc-proofing tape with 1-inch- (25-mm-) wide bands of half-lapped, adhesive, glass-cloth tape 2 inches (50 mm) o.c.
12. Seal around cables passing through fire-rated elements according to Division 07 Section "Penetration Firestopping".
13. Install fault indicators on each phase where indicated.
14. Ground shields of shielded cable at terminations, splices, and separable insulated connectors. Ground metal bodies of terminators, splices, cable and separable insulated-connector fittings, and hardware.
15. Identify cables according to Division 26 Section "Identification For Electrical Systems".

B. Field Quality Control
1. Perform the following field tests and inspections and prepare test reports:
    a. Perform each visual and mechanical inspection and electrical test stated in NETA ATS. Certify compliance with test parameters.
    b. After installing medium-voltage cables and before electrical circuitry has been energized, test for compliance with requirements.
2. Remove and replace malfunctioning units and retest as specified above.

END OF SECTION 26 05 13 00b

SECTION 26 05 19 16 - COMMON WORK RESULTS FOR ELECTRICAL

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for common work results for electrical. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Electrical equipment coordination and installation.
b. Sleeves for raceways and cables.
c. Sleeve seals.
d. Grout.
e. Common electrical installation requirements.

C. Definitions
1. EPDM: Ethylene-propylene-diene terpolymer rubber.
2. NBR: Acrylonitrile-butadiene rubber.

D. Submittals
1. Product Data: For sleeve seals.

1.2 PRODUCTS

A. Sleeves For Raceways And Cables
1. Steel Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, galvanized steel, plain ends.
2. Cast-Iron Pipe Sleeves: Cast or fabricated "wall pipe," equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop, unless otherwise indicated.
3. Sleeves for Rectangular Openings: Galvanized sheet steel.
a. Minimum Metal Thickness:
1) For sleeve cross-section rectangle perimeter less than 50 inches (1270 mm) and no side more than 16 inches (400 mm), thickness shall be 0.052 inch (1.3 mm).
2) For sleeve cross-section rectangle perimeter equal to, or more than, 50 inches (1270 mm) and 1 or more sides equal to, or more than, 16 inches (400 mm), thickness shall be 0.138 inch (3.5 mm).

B. Sleeve Seals
1. Description: Modular sealing device, designed for field assembly, to fill annular space between sleeve and raceway or cable.
a. Sealing Elements: EPDM **OR** NBR, **as directed**, interlocking links shaped to fit surface of cable or conduit. Include type and number required for material and size of raceway or cable.
b. Pressure Plates: Plastic **OR** Carbon steel **OR** Stainless steel, **as directed**. Include two for each sealing element.
c. Connecting Bolts and Nuts: Carbon steel with corrosion-resistant coating **OR** Stainless steel, **as directed**, of length required to secure pressure plates to sealing elements. Include one for each sealing element.

C. Grout

1. Nonmetallic, Shrinkage-Resistant Grout: ASTM C 1107, factory-packaged, nonmetallic aggregate grout, noncorrosive, nonstaining, mixed with water to consistency suitable for application and a 30-minute working time.

1.3 EXECUTION

A. Common Requirements For Electrical Installation
1. Comply with NECA 1.
2. Measure indicated mounting heights to bottom of unit for suspended items and to center of unit for wall-mounting items.
3. Headroom Maintenance: If mounting heights or other location criteria are not indicated, arrange and install components and equipment to provide maximum possible headroom consistent with these requirements.
4. Equipment: Install to facilitate service, maintenance, and repair or replacement of components of both electrical equipment and other nearby installations. Connect in such a way as to facilitate future disconnecting with minimum interference with other items in the vicinity.
5. Right of Way: Give to piping systems installed at a required slope.

B. Sleeve Installation For Electrical Penetrations
1. Electrical penetrations occur when raceways, cables, wireways, cable trays, or busways penetrate concrete slabs, concrete or masonry walls, or fire-rated floor and wall assemblies.
2. Concrete Slabs and Walls: Install sleeves for penetrations unless core-drilled holes or formed openings are used. Install sleeves during erection of slabs and walls.
3. Use pipe sleeves unless penetration arrangement requires rectangular sleeved opening.
4. Fire-Rated Assemblies: Install sleeves for penetrations of fire-rated floor and wall assemblies unless openings compatible with firestop system used are fabricated during construction of floor or wall.
5. Cut sleeves to length for mounting flush with both surfaces of walls.
6. Extend sleeves installed in floors 2 inches (50 mm) above finished floor level.
7. Size pipe sleeves to provide 1/4-inch (6.4-mm) annular clear space between sleeve and raceway or cable, unless indicated otherwise.
8. Seal space outside of sleeves with grout for penetrations of concrete and masonry
   a. Promptly pack grout solidly between sleeve and wall so no voids remain. Tool exposed surfaces smooth; protect grout while curing.
9. Interior Penetrations of Non-Fire-Rated Walls and Floors: Seal annular space between sleeve and raceway or cable, using joint sealant appropriate for size, depth, and location of joint. Comply with requirements in Division 07 Section "Joint Sealants".
10. Fire-Rated-Assembly Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at raceway and cable penetrations. Install sleeves and seal raceway and cable penetration sleeves with firestop materials. Comply with requirements in Division 07 Section "Penetration Firestopping".
11. Roof-Penetration Sleeves: Seal penetration of individual raceways and cables with flexible boot-type flashing units applied in coordination with roofing work.
12. Aboveground, Exterior-Wall Penetrations: Seal penetrations using steel **OR** cast-iron, **as directed**, pipe sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch (25-mm) annular clear space between pipe and sleeve for installing mechanical sleeve seals.
13. Underground, Exterior-Wall Penetrations: Install cast-iron pipe sleeves. Size sleeves to allow for 1-inch (25-mm) annular clear space between raceway or cable and sleeve for installing mechanical sleeve seals.

C. Sleeve-Seal Installation
1. Install to seal exterior wall penetrations.
2. Use type and number of sealing elements recommended by manufacturer for raceway or cable material and size. Position raceway or cable in center of sleeve. Assemble mechanical sleeve

seals and install in annular space between raceway or cable and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

D. Firestopping

1. Apply firestopping to penetrations of fire-rated floor and wall assemblies for electrical installations to restore original fire-resistance rating of assembly. Firestopping materials and installation requirements are specified in Division 07 Section "Penetration Firestopping".

END OF SECTION 26 05 19 16

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SECTION 26 05 19 16a - COMMON WORK RESULTS FOR COMMUNICATIONS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for common work results for communications. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Communications equipment coordination and installation.
b. Sleeves for pathways and cables.
c. Sleeve seals.
d. Grout.
e. Common communications installation requirements.

C. Definitions
1. EPDM: Ethylene-propylene-diene terpolymer rubber.
2. NBR: Acrylonitrile-butadiene rubber.

D. Submittals
1. Product Data: For sleeve seals.

1.2 PRODUCTS

A. Sleeves For Pathways And Cables
1. Steel Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, galvanized steel, plain ends.
2. Cast-Iron Pipe Sleeves: Cast or fabricated "wall pipe," equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop, unless otherwise indicated.
3. Sleeves for Rectangular Openings: Galvanized sheet steel.
a. Minimum Metal Thickness:
1) For sleeve cross-section rectangle perimeter less than 50 inches (1270 mm) and no side more than 16 inches (400 mm), thickness shall be 0.052 inch (1.3 mm).
2) For sleeve cross-section rectangle perimeter equal to, or more than, 50 inches (1270 mm) and 1 or more sides equal to, or more than, 16 inches (400 mm), thickness shall be 0.138 inch (3.5 mm).

B. Sleeve Seals
1. Description: Modular sealing device, designed for field assembly, to fill annular space between sleeve and pathway or cable.
a. Sealing Elements: EPDM **OR** NBR, **as directed**, interlocking links shaped to fit surface of cable or conduit. Include type and number required for material and size of pathway or cable.
b. Pressure Plates: Plastic **OR** Carbon steel **OR** Stainless steel, **as directed**. Include two for each sealing element.
c. Connecting Bolts and Nuts: Carbon steel with corrosion-resistant coating **OR** Stainless steel, **as directed**, of length required to secure pressure plates to sealing elements. Include one for each sealing element.

C. Grout

1. Nonmetallic, Shrinkage-Resistant Grout: ASTM C 1107, factory-packaged, nonmetallic aggregate grout, noncorrosive, nonstaining, mixed with water to consistency suitable for application and a 30-minute working time.

1.3 EXECUTION

A. Common Requirements For Communications Installation
1. Comply with NECA 1.
2. Measure indicated mounting heights to bottom of unit for suspended items and to center of unit for wall-mounting items.
3. Headroom Maintenance: If mounting heights or other location criteria are not indicated, arrange and install components and equipment to provide maximum possible headroom consistent with these requirements.
4. Equipment: Install to facilitate service, maintenance, and repair or replacement of components of both communications equipment and other nearby installations. Connect in such a way as to facilitate future disconnecting with minimum interference with other items in the vicinity.
5. Right of Way: Give to piping systems installed at a required slope.

B. Sleeve Installation For Communications Penetrations
1. Communications penetrations occur when pathways, cables, wireways, or cable trays penetrate concrete slabs, concrete or masonry walls, or fire-rated floor and wall assemblies.
2. Concrete Slabs and Walls: Install sleeves for penetrations unless core-drilled holes or formed openings are used. Install sleeves during erection of slabs and walls.
3. Use pipe sleeves unless penetration arrangement requires rectangular sleeved opening.
4. Fire-Rated Assemblies: Install sleeves for penetrations of fire-rated floor and wall assemblies unless openings compatible with firestop system used are fabricated during construction of floor or wall.
5. Cut sleeves to length for mounting flush with both surfaces of walls.
6. Extend sleeves installed in floors 2 inches (50 mm) above finished floor level.
7. Size pipe sleeves to provide 1/4-inch (6.4-mm) annular clear space between sleeve and pathway or cable, unless indicated otherwise.
8. Seal space outside of sleeves with grout for penetrations of concrete and masonry
   a. Promptly pack grout solidly between sleeve and wall so no voids remain. Tool exposed surfaces smooth; protect grout while curing.
9. Interior Penetrations of Non-Fire-Rated Walls and Floors: Seal annular space between sleeve and pathway or cable, using joint sealant appropriate for size, depth, and location of joint. Comply with requirements in Division 07 Section "Joint Sealants".
10. Fire-Rated-Assembly Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pathway and cable penetrations. Install sleeves and seal pathway and cable penetration sleeves with firestop materials. Comply with requirements in Division 07 Section "Penetration Firestopping".
11. Roof-Penetration Sleeves: Seal penetration of individual pathways and cables with flexible boot-type flashing units applied in coordination with roofing work.
12. Aboveground, Exterior-Wall Penetrations: Seal penetrations using steel **OR** cast-iron, **as directed**, pipe sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch (25-mm) annular clear space between pipe and sleeve for installing mechanical sleeve seals.
13. Underground, Exterior-Wall Penetrations: Install cast-iron pipe sleeves. Size sleeves to allow for 1-inch (25-mm) annular clear space between pathway or cable and sleeve for installing mechanical sleeve seals.

C. Sleeve-Seal Installation
1. Install to seal exterior wall penetrations.
2. Use type and number of sealing elements recommended by manufacturer for pathway or cable material and size. Position pathway or cable in center of sleeve. Assemble mechanical sleeve

seals and install in annular space between pathway or cable and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

D. Firestopping

1. Apply firestopping to penetrations of fire-rated floor and wall assemblies for communications installations to restore original fire-resistance rating of assembly. Firestopping materials and installation requirements are specified in Division 07 Section "Penetration Firestopping".

END OF SECTION 26 05 19 16a

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SECTION 26 05 19 16b - COMMON WORK RESULTS FOR ELECTRONIC SAFETY AND SECURITY

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for common work results for electronic safety and security. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Electronic safety and security equipment coordination and installation.
b. Sleeves for raceways and cables.
c. Sleeve seals.
d. Grout.
e. Common electronic safety and security installation requirements.

C. Definitions
1. EPDM: Ethylene-propylene-diene terpolymer rubber.
2. NBR: Acrylonitrile-butadiene rubber.

D. Submittals
1. Product Data: For sleeve seals.

1.2 PRODUCTS

A. Sleeves For Raceways And Cables
1. Steel Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, galvanized steel, plain ends.
2. Cast-Iron Pipe Sleeves: Cast or fabricated "wall pipe," equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop, unless otherwise indicated.
3. Sleeves for Rectangular Openings: Galvanized sheet steel.
a. Minimum Metal Thickness:
1) For sleeve cross-section rectangle perimeter less than 50 inches (1270 mm) and no side more than 16 inches (400 mm), thickness shall be 0.052 inch (1.3 mm).
2) For sleeve cross-section rectangle perimeter equal to, or more than, 50 inches (1270 mm) and 1 or more sides equal to, or more than, 16 inches (400 mm), thickness shall be 0.138 inch (3.5 mm).

B. Sleeve Seals
1. Description: Modular sealing device, designed for field assembly, to fill annular space between sleeve and raceway or cable.
a. Sealing Elements: EPDM **OR** NBR, **as directed**, interlocking links shaped to fit surface of cable or conduit. Include type and number required for material and size of raceway or cable.
b. Pressure Plates: Plastic **OR** Carbon steel **OR** Stainless steel, **as directed**. Include two for each sealing element.
c. Connecting Bolts and Nuts: Carbon steel with corrosion-resistant coating **OR** Stainless steel, **as directed**, of length required to secure pressure plates to sealing elements. Include one for each sealing element.

C. Grout

1. Nonmetallic, Shrinkage-Resistant Grout: ASTM C 1107, factory-packaged, nonmetallic aggregate grout, noncorrosive, nonstaining, mixed with water to consistency suitable for application and a 30-minute working time.

1.3 EXECUTION

A. Common Requirements For Electronic Safety And Security Installation
1. Comply with NECA 1.
2. Measure indicated mounting heights to bottom of unit for suspended items and to center of unit for wall-mounting items.
3. Headroom Maintenance: If mounting heights or other location criteria are not indicated, arrange and install components and equipment to provide maximum possible headroom consistent with these requirements.
4. Equipment: Install to facilitate service, maintenance, and repair or replacement of components of both electronic safety and security equipment and other nearby installations. Connect in such a way as to facilitate future disconnecting with minimum interference with other items in the vicinity.
5. Right of Way: Give to piping systems installed at a required slope.

B. Sleeve Installation For Electronic Safety And Security Penetrations
1. Electronic safety and security penetrations occur when raceways, pathways, cables, wireways, or cable trays penetrate concrete slabs, concrete or masonry walls, or fire-rated floor and wall assemblies.
2. Concrete Slabs and Walls: Install sleeves for penetrations unless core-drilled holes or formed openings are used. Install sleeves during erection of slabs and walls.
3. Use pipe sleeves unless penetration arrangement requires rectangular sleeved opening.
4. Fire-Rated Assemblies: Install sleeves for penetrations of fire-rated floor and wall assemblies unless openings compatible with firestop system used are fabricated during construction of floor or wall.
5. Cut sleeves to length for mounting flush with both surfaces of walls.
6. Extend sleeves installed in floors 2 inches (50 mm) above finished floor level.
7. Size pipe sleeves to provide 1/4-inch (6.4-mm) annular clear space between sleeve and raceway or cable, unless indicated otherwise.
8. Seal space outside of sleeves with grout for penetrations of concrete and masonry
   a. Promptly pack grout solidly between sleeve and wall so no voids remain. Tool exposed surfaces smooth; protect grout while curing.
9. Interior Penetrations of Non-Fire-Rated Walls and Floors: Seal annular space between sleeve and raceway or cable, using joint sealant appropriate for size, depth, and location of joint. Comply with requirements in Division 07 Section "Joint Sealants".
10. Fire-Rated-Assembly Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at raceway and cable penetrations. Install sleeves and seal raceway and cable penetration sleeves with firestop materials. Comply with requirements in Division 07 Section "Penetration Firestopping".
11. Roof-Penetration Sleeves: Seal penetration of individual raceways and cables with flexible boot-type flashing units applied in coordination with roofing work.
12. Aboveground, Exterior-Wall Penetrations: Seal penetrations using steel **OR** cast-iron, **as directed**, pipe sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch (25-mm) annular clear space between pipe and sleeve for installing mechanical sleeve seals.
13. Underground, Exterior-Wall Penetrations: Install cast-iron pipe sleeves. Size sleeves to allow for 1-inch (25-mm) annular clear space between raceway or cable and sleeve for installing mechanical sleeve seals.

C. Sleeve-Seal Installation
1. Install to seal exterior wall penetrations.

2. Use type and number of sealing elements recommended by manufacturer for raceway or cable material and size. Position raceway or cable in center of sleeve. Assemble mechanical sleeve seals and install in annular space between raceway or cable and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

D. Firestopping

1. Apply firestopping to penetrations of fire-rated floor and wall assemblies for electronic safety and security installations to restore original fire-resistance rating of assembly. Firestopping materials and installation requirements are specified in Division 07 Section "Penetration Firestopping".

END OF SECTION 26 05 19 16b

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SECTION 26 05 19 16c - ELECTRICAL RENOVATION

DESCRIPTION OF WORK

This specification covers the furnishing and installation of materials for electrical renovation. Products shall be as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

GENERAL

Quality Assurance

1. Regulatory Requirements: Comply with following:
   a. Electrical: National Fire Protection Association (NFPA): NFPA 70 - National Electrical Code (NEC).
   b. Accessibility:
      1) Architectural Barriers Act of 1968 as amended (42 USC 4152-4157) and HUD implementing regulations (24 CFR Part 40).
         a) Uniform Federal Accessibility Standards (UFAS).
      2) Section 504 of the Rehabilitation Act of 1973 as amended (29 USC 794) and HUD implementing regulations 24 CFR Part 8.
      3) Fair Housing Accessibility Guidelines (24 CFR Chapter 1).
      4) Americans with Disabilities Act of 1990 (ADA) (28 CFR Part 35).

Project Conditions

2. Existing Conditions: Buildings will be occupied during construction. See Division 1 Section “Summary of Work.” Do not interfere with use of occupied portions of building. Maintain free and safe passage to and from occupied areas.

Scheduling And Sequencing

3. Scheduling and Completion: Comply with requirements of Detailed Scope of Work.

Alterations, Cutting And Protection

4. Protection: Protect existing finishes, equipment, utilities and adjacent work, which is scheduled to remain, from damage.
5. Existing Operating Facilities: Confine operations to immediate vicinity of new work and do not interfere with or obstruct ingress or egress to and from adjacent facilities.

PRODUCTS

Materials

6. Electrical Materials and Devices: Comply with NFPA 70 (NEC):
   a. Boxes: Galvanized steel, not less than 1.6 mm (0.0625 inch) thickness (NEC 370-20) grounded in accordance with NEC, Article 250, suitable for recess mounting.
      1) Provide boxes of appropriate shape and size for intended purpose.
   b. Devices:
      1) Duplex Receptacles: 15 A or 20 A 115 V, UL Listed with screw side connections and corrugated bearing pads.
         a) GFIC Outlets: 115 V, 60 Hz, 15/20 A rating, UL Listed.
      2) Switches: 15 A. 115 V, single pole, single throw switch, UL Listed, with side screw connections and corrugated bearing pads.

a) Garbage Disposal: Heavy duty, 120/277 VAC, 60 Hz, single pole, single throw, 20 A rate, UL listed and CSA certified.

3) Cover Plates: Smooth plastic in color to match existing.

c. Wiring: Insulated wire, Type NM 600 V with ground wire, sized as appropriate for intended purpose and in accordance with NEC.

1) Aluminum Wire: Not allowed unless existing wiring is aluminum.

2) Provide necessary fittings in accordance with NEC.

EXECUTION

Examination

7. Units, Spaces and Areas to be Renovated: Inspect to become familiar with existing conditions and to take measurements which are necessary for renovation work to be completed in accordance with contract requirements.

a. Carefully inspect condition of existing spaces including, but not limited to walls, floors, plumbing, electrical, etc. as essential to successful completion of renovation work.

b. Survey each space and verify dimensions for work.

Preparation

8. Building Occupation: Carry out renovation work to cause as little inconvenience to occupants as possible. See Division 1 Section “Summary of Work.”

9. Protection: Protect and be responsible for existing buildings, facilities, utilities, and improvements within areas of construction operations.

a. Tenant's Property: Be responsible for any damage or loss to residents' property and to other work. Replace any material, which, in opinion of the Owner, has become damaged to extent that it could not be restored to its original condition.

b. Take precautions to protect residents and public from injury from construction operations.

Laying Out Work

10. Discrepancies: Verify dimensions and elevations indicated in layout of existing work.

a. Prior to commencing work, carefully compare and check Drawings (if any), for discrepancies in locations or elevations of work to be executed.

b. Refer discrepancies among Drawings (if any), Specifications and existing conditions to the Owner for adjustment before work affected is performed.

1) Failure to make such notification shall place responsibility on Contractor to carry out work in satisfactory, workmanlike manner.

11. Contractor: Responsible for location and elevation of construction contemplated by Construction Documents.

Location Of Equipment And Piping

12. Drawings (if any) indicating location of equipment, piping, ductwork, etc. are diagrammatic and job conditions shall not always permit their installation in location shown. When this situation occurs, bring condition to the Owner's attention immediately. Relocation will be determined in joint conference.

13. Contractor: Do not relocate any items without first obtaining the Owner's acceptance. Remove and relocate such relocated items at own expense if so directed.

Electrical Work

14. General: Install boxes, wiring, and devices as indicated and required to connect and control electrical devices in accordance with NFPA 70 (NEC).

a. Boxes: Solidly anchor to framing or blocking.

15. Removing Electrical Switch or Duplex Outlet (Non-Hazardous Locations):

a. Box to Remain:

1) Remove electrical device; cap hot and neutral with set-screw wire connectors.

2) Attach ground wire to remaining box with solid screw attachment.
3) Provide and install natural finish aluminum blank cover plate with screw fasteners integral to match size of box remaining.

b. Box to be removed:
1) Remove electrical device and box and pull wire out of wall back to first circuit panel, disconnecting from circuit panel.
2) Patch and repair hole in partition to match existing.

16. Garbage Disposal Electrical Hook-up: See Section “Plumbing.” Comply with NFPA 70 (NEC):
a. Wiring: Install from disposal through concealed spaces to house panel, anchoring wire, and providing necessary fittings.
b. Switch: Install above counter top backsplash.

17. Range Hood Electrical Hook-up: See Section “Residential Appliances.” Comply with NFPA 70 (NEC):
a. Electric service: Install insulated wire from range hood through concealed spaces to house panel, anchoring wire, and providing necessary fittings.

18. Water Heater Electrical Hook-up: See Division 15 Section “Domestic Water Heaters.” Comply with NFPA 70 (NEC).

19. Furnace Electrical Hook-up: See Section “Furnaces.” Comply with NFPA 70 (NEC).

20. Smoke Detector Electrical Hook-up: See “Fire Alarm.” Comply with NFPA 70 (NEC).

Integrating Existing Work

21. Protection: Protect existing improvements from damage.
a. Where new work is to be connected to existing work, exercise special care not to disturb or damage existing work more than necessary.
b. Damaged Work: Replace, repair and restored to its original condition at no cost to the Owner.

END OF SECTION 26 05 19 16c

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SECTION 26 05 19 16d - CONTROL-VOLTAGE ELECTRICAL POWER CABLES

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of control-voltage electrical power cables. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. UTP cabling.
b. 50/125 **OR** 62.5/125, **as directed**,-micrometer, multimode optical fiber cabling.
c. RS-232 cabling.
d. RS-485 cabling.
e. Low-voltage control cabling.
f. Control-circuit conductors.
g. Identification products.

C. Definitions
1. Basket Cable Tray: A fabricated structure consisting of wire mesh bottom and side rails.
2. Channel Cable Tray: A fabricated structure consisting of a one-piece, ventilated-bottom or solid-bottom channel section.
3. EMI: Electromagnetic interference.
4. IDC: Insulation displacement connector.
5. Ladder Cable Tray: A fabricated structure consisting of two longitudinal side rails connected by individual transverse members (rungs).
6. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control and signaling power-limited circuits.
7. Open Cabling: Passing telecommunications cabling through open space (e.g., between the studs of a wall cavity).
8. RCDD: Registered Communications Distribution Designer.
9. Solid-Bottom or Nonventilated Cable Tray: A fabricated structure consisting of integral or separate longitudinal side rails, and a bottom without ventilation openings.
10. Trough or Ventilated Cable Tray: A fabricated structure consisting of integral or separate longitudinal rails and a bottom having openings sufficient for the passage of air and using 75 percent or less of the plan area of the surface to support cables.
11. UTP: Unshielded twisted pair.

D. Submittals
1. Product Data: For each type of product indicated.
2. Field quality-control reports.
3. Maintenance data.

E. Quality Assurance
1. Testing Agency Qualifications: Member company of an NRTL.
a. Testing Agency's Field Supervisor: Currently certified by BICSI as an RCDD to supervise on-site testing.
2. Surface-Burning Characteristics: As determined by testing identical products according to ASTM E 84 by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
a. Flame-Spread Index: 25 or less.
b. Smoke-Developed Index: 50 **OR** 450, **as directed**, or less.

3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

F. Delivery, Storage, And Handling
1. Test cables upon receipt at Project site.
   a. Test optical fiber cable to determine the continuity of the strand end to end. Use optical fiber flashlight **OR** optical loss test set, **as directed**.
   b. Test optical fiber cable on reels. Use an optical time domain reflectometer to verify the cable length and locate cable defects, splices, and connector; include the loss value of each. Retain test data and include the record in maintenance data.
   c. Test each pair of UTP cable for open and short circuits.

1.2 PRODUCTS

A. Pathways
1. Support of Open Cabling: NRTL labeled for support of Category 5e **OR** Category 6, **as directed**, cabling, designed to prevent degradation of cable performance and pinch points that could damage cable.
   a. Support brackets with cable tie slots for fastening cable ties to brackets.
   b. Lacing bars, spools, J-hooks, and D-rings.
   c. Straps and other devices.
2. Cable Trays:
   a. Cable Tray Materials: Metal, suitable for indoors and protected against corrosion by electroplated zinc galvanizing, complying with ASTM B 633, Type 1, not less than 0.000472 inch (0.012 mm) thick **OR** hot-dip galvanizing, complying with ASTM A 123/A 123M, Grade 0.55, not less than 0.002165 inch (0.055 mm) thick, **as directed**.
      1) Basket Cable Trays: 6 inches (150 mm) wide and 2 inches (50 mm) deep. Wire mesh spacing shall not exceed 2 by 4 inches (50 by 100 mm).
      2) Trough or Ventilated Cable Trays: Nominally 6 inches (150 mm) wide.
      3) Ladder Cable Trays: Nominally 18 inches (455 mm) wide, and a rung spacing of 12 inches (305 mm).
      4) Channel Cable Trays: One-piece construction, nominally 4 inches (100 mm) wide. Slot spacing shall not exceed 4-1/2 inches (115 mm) o.c.
      5) Solid-Bottom or Nonventilated Cable Trays: One-piece construction, nominally 12 inches (305 mm) wide. Provide with **OR** without, **as directed**, solid covers.
3. Conduit and Boxes: Comply with requirements in Division 26 Section "Raceway And Boxes For Electrical Systems". Flexible metal conduit shall not be used, **as directed**.
   a. Outlet boxes shall be no smaller than 2 inches (50 mm) wide, 3 inches (75 mm) high, and 2-1/2 inches (64 mm) deep.

B. Backboards
1. Description: Plywood, fire-retardant treated, **as directed**, 3/4 by 48 by 96 inches (19 by 1220 by 2440 mm). Comply with requirements for plywood backing panels in Division 06 Section "Rough Carpentry".

C. UTP Cable
1. Description: 100-ohm, four-pair UTP, formed into 25-pair binder groups covered with a blue thermoplastic jacket, **as directed**.
   a. Comply with ICEA S-90-661 for mechanical properties.
   b. Comply with TIA/EIA-568-B.1 for performance specifications.
   c. Comply with TIA/EIA-568-B.2, Category 5e **OR** Category 6, **as directed**.
   d. Listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 444 and NFPA 70 for the following types:

1) Communications, General Purpose: Type CM or Type CMG; or Type MPP, Type CMP, Type MPR, Type CMR, Type MP, or Type MPG, **as directed**.
2) Communications, Plenum Rated: Type CMP or Type MPP, **as directed**, complying with NFPA 262.
3) Communications, Riser Rated: Type CMR; or Type MPP, Type CMP, or Type MPR, **as directed**; complying with UL 1666.
4) Communications, Limited Purpose: Type CMX; or Type MPP, Type CMP, Type MPR, Type CMR, Type MP, Type MPG, Type CM, or Type CMG, **as directed**.
5) Multipurpose: Type MP or Type MPG; or Type MPP or Type MPR, **as directed**.
6) Multipurpose, Plenum Rated: Type MPP, complying with NFPA 262.
7) Multipurpose, Riser Rated: Type MPR or Type MPP, **as directed**, complying with UL 1666.

D. UTP Cable Hardware
1. UTP Cable Connecting Hardware: IDC type, using modules designed for punch-down caps or tools. Cables shall be terminated with connecting hardware of the same category or higher.
2. Connecting Blocks: 110 style for Category 5e **OR** 110 style for Category 6 **OR** 66 style for Category 5e, **as directed**. Provide blocks for the number of cables terminated on the block, plus 25 percent spare; integral with connector bodies, including plugs and jacks where indicated.

E. Optical Fiber Cable
1. Description: Multimode, 50/125 **OR** 62.5/125, **as directed**,-micrometer, 24-fiber, nonconductive, **as directed**, tight buffer, optical fiber cable.
   a. Comply with ICEA S-83-596 for mechanical properties.
   b. Comply with TIA/EIA-568-B.3 for performance specifications.
   c. Comply with TIA/EIA-492AAAA-B **OR** TIA/EIA-492AAAA-A, **as directed**, for detailed specifications.
   d. Listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 444, UL 1651, and NFPA 70 for the following types:
      1) General Purpose, Nonconductive: Type OFN or OFNG, or Type OFNR or Type OFNP, **as directed**.
      2) Plenum Rated, Nonconductive: Type OFNP, complying with NFPA 262.
      3) Riser Rated, Nonconductive: Type OFNR or Type OFNP, **as directed**, complying with UL 1666.
      4) General Purpose, Conductive: Type OFC or Type OFCG; or Type OFNG, Type OFN, Type OFCR, Type OFNR, Type OFCP, or Type OFNP, **as directed**.
      5) Plenum Rated, Conductive: Type OFCP or Type OFNP, **as directed**, complying with NFPA 262.
      6) Riser Rated, Conductive: Type OFCR; or Type OFNR, Type OFCP, or Type OFNP, **as directed**; complying with UL 1666.
   e. Conductive cable shall be steel **OR** aluminum, **as directed**,-armored type.
   f. Maximum Attenuation: 3.5 dB/km at 850 nm; 1.5 dB/km at 1300 nm.
   g. Minimum Modal Bandwidth: 160 MHz-km at 850 nm; 500 MHz-km at 1300 nm.
2. Jacket:
   a. Jacket Color: Aqua for 50/125 **OR** Orange for 62.5/125, **as directed**,-micrometer cable.
   b. Cable cordage jacket, fiber, unit, and group color shall be according to TIA/EIA-598-B.
   c. Imprinted with fiber count, fiber type, and aggregate length at regular intervals not to exceed 40 inches (1000 mm).

F. Optical Fiber Cable Hardware
1. Cable Connecting Hardware: Comply with the Fiber Optic Connector Intermateability Standards (FOCIS) specifications of TIA/EIA-604-2, TIA/EIA-604-3-A, and TIA/EIA-604-12. Comply with TIA/EIA-568-B.3.
   a. Quick-connect, simplex and duplex, Type SC **OR** Type ST **OR** Type LC **OR** Type MT-RJ, **as directed**, connectors. Insertion loss not more than 0.75 dB.
   b. Type SFF connectors may be used in termination racks, panels, and equipment packages.

G. RS-232 Cable
1. Standard Cable: NFPA 70, Type CM.
   a. Paired, two pairs, No. 22 AWG, stranded (7x30) tinned-copper conductors.
   b. Polypropylene insulation.
   c. Individual aluminum foil-polyester tape shielded pairs with 100 percent shield coverage.
   d. PVC jacket.
   e. Pairs are cabled on common axis with No. 24 AWG, stranded (7x32) tinned-copper drain wire.
   f. Flame Resistance: Comply with UL 1581.
2. Plenum-Rated Cable: NFPA 70, Type CMP.
   a. Paired, two pairs, No. 22 AWG, stranded (7x30) tinned-copper conductors.
   b. Plastic insulation.
   c. Individual aluminum foil-polyester tape shielded pairs with 100 percent shield coverage.
   d. Plastic jacket.
   e. Pairs are cabled on common axis with No. 24 AWG, stranded (7x32) tinned-copper drain wire.
   f. Flame Resistance: Comply with NFPA 262.

H. RS-485 Cable
1. Standard Cable: NFPA 70, Type CM or Type CMG, **as directed**.
   a. Paired, two pairs, twisted, No. 22 AWG, stranded (7x30) tinned-copper conductors.
   b. PVC insulation.
   c. Unshielded.
   d. PVC jacket.
   e. Flame Resistance: Comply with UL 1581.
2. Plenum-Rated Cable: NFPA 70, Type CMP.
   a. Paired, two pairs, No. 22 AWG, stranded (7x30) tinned-copper conductors.
   b. Fluorinated ethylene propylene insulation.
   c. Unshielded.
   d. Fluorinated ethylene propylene jacket.
   e. Flame Resistance: NFPA 262, Flame Test.

I. Low-Voltage Control Cable
1. Paired Cable: NFPA 70, Type CMG.
   a. One pair, twisted, No. 16 AWG, stranded (19x29) tinned-copper conductors.
   b. PVC insulation.
   c. Unshielded.
   d. PVC jacket.
   e. Flame Resistance: Comply with UL 1581.
2. Plenum-Rated, Paired Cable: NFPA 70, Type CMP.
   a. One pair, twisted, No. 16 AWG, stranded (19x29) tinned-copper conductors.
   b. PVC insulation.
   c. Unshielded.
   d. PVC jacket.
   e. Flame Resistance: Comply with NFPA 262.
3. Paired Cable: NFPA 70, Type CMG.
   a. One pair, twisted, No. 18 AWG, stranded (19x30) tinned-copper conductors.
   b. PVC insulation.
   c. Unshielded.
   d. PVC jacket.
   e. Flame Resistance: Comply with UL 1581.
4. Plenum-Rated, Paired Cable: NFPA 70, Type CMP.
   a. One pair, twisted, No. 18 AWG, stranded (19x30) tinned-copper conductors.
   b. Fluorinated ethylene propylene insulation.
   c. Unshielded.

d. Plastic jacket.
e. Flame Resistance: NFPA 262, Flame Test.

J. Control-Circuit Conductors
1. Class 1 Control Circuits: Stranded copper, Type THHN-THWN **OR** Type XHHN, **as directed**, in raceway, complying with UL 83 **OR** UL 44, **as directed**.
2. Class 2 Control Circuits: Stranded copper, Type THHN-THWN, in raceway **OR** Type XHHN, in raceway **OR** power-limited cable, concealed in building finishes **OR** power-limited tray cable, in cable tray, **as directed**, complying with UL 83 **OR** UL 44, **as directed**.
3. Class 3 Remote-Control and Signal Circuits: Stranded copper, Type TW or Type TF, complying with UL 83.

K. Identification Products
1. Comply with UL 969 for a system of labeling materials, including label stocks, laminating adhesives, and inks used by label printers.
2. Comply with requirements in Division 26 Section "Identification For Electrical Systems".

L. Source Quality Control
1. Testing Agency: Engage a qualified testing agency to evaluate cables.
2. Factory test UTP and optical fiber cables on reels according to TIA/EIA-568-B.1.
3. Factory test UTP cables according to TIA/EIA-568-B.2.
4. Factory test multimode optical fiber cables according to TIA/EIA-526-14-A and TIA/EIA-568-B.3.
5. Cable will be considered defective if it does not pass tests and inspections.
6. Prepare test and inspection reports.

1.3 EXECUTION

A. Installation Of Pathways
1. Cable Trays: Comply with NEMA VE 2 and TIA/EIA-569-A-7.
2. Comply with TIA/EIA-569-A for pull-box sizing and length of conduit and number of bends between pull points.
3. Comply with requirements in Division 26 Section "Raceway And Boxes For Electrical Systems" for installation of conduits and wireways.
4. Install manufactured conduit sweeps and long-radius elbows if possible.
5. Pathway Installation in Equipment Rooms:
   a. Position conduit ends adjacent to a corner on backboard if a single piece of plywood is installed or in the corner of room if multiple sheets of plywood are installed around perimeter walls of room.
   b. Install cable trays to route cables if conduits cannot be located in these positions.
   c. Secure conduits to backboard if entering room from overhead.
   d. Extend conduits 3 inches (75 mm) above finished floor.
   e. Install metal conduits with grounding bushings and connect with grounding conductor to grounding system.
6. Backboards: Install backboards with 96-inch (2440-mm) dimension vertical. Butt adjacent sheets tightly and form smooth gap-free corners and joints.

B. Installation Of Conductors And Cables
1. Comply with NECA 1.
2. General Requirements for Cabling:
   a. Comply with TIA/EIA-568-B.1.
   b. Comply with BICSI ITSIM, Ch. 6, "Cable Termination Practices."
   c. Terminate all conductors; no cable shall contain unterminated elements. Make terminations only at indicated outlets, terminals, and cross-connect and patch panels.

d. Cables may not be spliced. Secure and support cables at intervals not exceeding 30 inches (760 mm) and not more than 6 inches (150 mm) from cabinets, boxes, fittings, outlets, racks, frames, and terminals.
e. Bundle, lace, and train conductors to terminal points without exceeding manufacturer's limitations on bending radii, but not less than radii specified in BICSI ITSIM, "Cabling Termination Practices" Chapter. Install lacing bars and distribution spools.
f. Do not install bruised, kinked, scored, deformed, or abraded cable. Do not splice cable between termination, tap, or junction points. Remove and discard cable if damaged during installation and replace it with new cable.
g. Cold-Weather Installation: Bring cable to room temperature before dereeling. Heat lamps shall not be used for heating.
h. Pulling Cable: Comply with BICSI ITSIM, Ch. 4, "Pulling Cable." Monitor cable pull tensions.

3. UTP Cable Installation:
   a. Comply with TIA/EIA-568-B.2.
   b. Install 110-style IDC termination hardware unless otherwise indicated.
   c. Do not untwist UTP cables more than 1/2 inch (12 mm) from the point of termination to maintain cable geometry.
4. Installation of Control-Circuit Conductors:
   a. Install wiring in raceways. Comply with requirements specified in Division 26 Section "Raceway And Boxes For Electrical Systems".
5. Optical Fiber Cable Installation:
   a. Comply with TIA/EIA-568-B.3.
   b. Cable shall be terminated on connecting hardware that is rack or cabinet mounted.
6. Open-Cable Installation:
   a. Install cabling with horizontal and vertical cable guides in telecommunications spaces with terminating hardware and interconnection equipment.
   b. Suspend copper cable not in a wireway or pathway a minimum of 8 inches (200 mm) above ceilings by cable supports not more than 60 inches (1525 mm) apart.
   c. Cable shall not be run through structural members or in contact with pipes, ducts, or other potentially damaging items.
7. Installation of Cable Routed Exposed under Raised Floors:
   a. Install plenum-rated cable only.
   b. Install cabling after the flooring system has been installed in raised floor areas.
   c. Coil cable 72 inches (1830 mm) long shall be neatly coiled not less than 12 inches (305 mm) in diameter below each feed point.
8. Separation from EMI Sources:
   a. Comply with BICSI TDMM and TIA/EIA-569-A recommendations for separating unshielded copper voice and data communication cable from potential EMI sources, including electrical power lines and equipment.
   b. Separation between open communications cables or cables in nonmetallic raceways and unshielded power conductors and electrical equipment shall be as follows:
      1) Electrical Equipment Rating Less Than 2 kVA: A minimum of 5 inches (127 mm).
      2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of 12 inches (305 mm).
      3) Electrical Equipment Rating More Than 5 kVA: A minimum of 24 inches (600 mm).
   c. Separation between communications cables in grounded metallic raceways and unshielded power lines or electrical equipment shall be as follows:
      1) Electrical Equipment Rating Less Than 2 kVA: A minimum of 2-1/2 inches (64 mm).
      2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of 6 inches (150 mm).
      3) Electrical Equipment Rating More Than 5 kVA: A minimum of 12 inches (305 mm).
   d. Separation between communications cables in grounded metallic raceways and power lines and electrical equipment located in grounded metallic conduits or enclosures shall be as follows:

1) Electrical Equipment Rating Less Than 2 kVA: No requirement.
2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of 3 inches (75 mm).
3) Electrical Equipment Rating More Than 5 kVA: A minimum of 6 inches (150 mm).

e. Separation between Cables and Electrical Motors and Transformers, 5 kVA or HP and Larger: A minimum of 48 inches (1200 mm).

f. Separation between Cables and Fluorescent Fixtures: A minimum of 5 inches (127 mm).

C. Removal Of Conductors And Cables

1. Remove abandoned conductors and cables.

D. Control-Circuit Conductors

1. Minimum Conductor Sizes:
   a. Class 1 remote-control and signal circuits, No 14 AWG.
   b. Class 2 low-energy, remote-control, and signal circuits, No. 16 AWG.
   c. Class 3 low-energy, remote-control, alarm, and signal circuits, No 12 AWG.

E. Firestopping

1. Comply with requirements in Division 07 Section "Penetration Firestopping".
2. Comply with TIA/EIA-569-A, Annex A, "Firestopping."
3. Comply with BICSI TDMM, "Firestopping Systems" Article.

F. Grounding

1. For data communication wiring, comply with ANSI-J-STD-607-A and with BICSI TDMM, "Grounding, Bonding, and Electrical Protection" Chapter.
2. For low-voltage wiring and cabling, comply with requirements in Division 26 Section "Grounding And Bonding For Electrical Systems".

G. Identification

H. Identify system components, wiring, and cabling according to TIA/EIA-606-A. Comply with requirements for identification specified in Division 26 Section "Identification For Electrical Systems".

I. Field Quality Control

1. Perform tests and inspections.
2. Tests and Inspections:
   a. Visually inspect UTP and optical fiber cable jacket materials for UL or third-party certification markings. Inspect cabling terminations to confirm color-coding for pin assignments, and inspect cabling connections to confirm compliance with TIA/EIA-568-B.1.
   b. Visually inspect cable placement, cable termination, grounding and bonding, equipment and patch cords, and labeling of all components.
   c. Test UTP cabling for DC loop resistance, shorts, opens, intermittent faults, and polarity between conductors. Test operation of shorting bars in connection blocks. Test cables after termination but not after cross connection.
      1) Test instruments shall meet or exceed applicable requirements in TIA/EIA-568-B.2. Perform tests with a tester that complies with performance requirements in "Test Instruments (Normative)" Annex, complying with measurement accuracy specified in "Measurement Accuracy (Informative)" Annex. Use only test cords and adapters that are qualified by test equipment manufacturer for channel or link test configuration.
   d. Optical Fiber Cable Tests:
      1) Test instruments shall meet or exceed applicable requirements in TIA/EIA-568-B.1. Use only test cords and adapters that are qualified by test equipment manufacturer for channel or link test configuration.
      2) Link End-to-End Attenuation Tests:
         a) Multimode Link Measurements: Test at 850 or 1300 nm in one direction according to TIA/EIA-526-14-A, Method B, One Reference Jumper.

b) Attenuation test results for links shall be less than 2.0 dB. Attenuation test results shall be less than that calculated according to equation in TIA/EIA-568-B.1.

3. Document data for each measurement. Print data for submittals in a summary report that is formatted using Table 10.1 in BICSI TDMM as a guide, or transfer the data from the instrument to the computer, save as text files, print, and submit.
4. End-to-end cabling will be considered defective if it does not pass tests and inspections.
5. Prepare test and inspection reports.

END OF SECTION 26 05 19 16d

SECTION 26 05 19 16e - COMMUNICATIONS EQUIPMENT ROOM FITTINGS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for communications equipment room fittings. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Telecommunications mounting elements.
b. Backboards.
c. Telecommunications equipment racks and cabinets.
d. Telecommunications service entrance pathways.
e. Grounding.

C. Definitions
1. Basket Cable Tray: A fabricated structure consisting of wire mesh bottom and side rails.
2. BICSI: Building Industry Consulting Service International.
3. Channel Cable Tray: A fabricated structure consisting of a one-piece, ventilated-bottom or solid-bottom channel not exceeding 6 inches (152 mm) in width.
4. Ladder Cable Tray: A fabricated structure consisting of two longitudinal side rails connected by individual transverse members (rungs).
5. LAN: Local area network.
6. RCDD: Registered Communications Distribution Designer.
7. Solid-Bottom or Nonventilated Cable Tray: A fabricated structure consisting of a bottom without ventilation openings within integral or separate longitudinal side rails.
8. Trough or Ventilated Cable Tray: A fabricated structure consisting of integral or separate longitudinal rails and a bottom having openings sufficient for the passage of air and using 75 percent or less of the plan area of the surface to support cables.

D. Performance Requirements
1. Seismic Performance: Floor-mounted cabinets and cable pathways shall withstand the effects of earthquake motions determined according to SEI/ASCE 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

E. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings: For communications equipment room fittings. Include plans, elevations, sections, details, and attachments to other work.
a. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
b. Equipment Racks and Cabinets: Include workspace requirements and access for cable connections.
c. Grounding: Indicate location of grounding bus bar and its mounting detail showing standoff insulators and wall mounting brackets.
3. Qualification Data: For Installer, qualified layout technician, installation supervisor, and field inspector.
4. Seismic Qualification Certificates: For floor-mounted cabinets, accessories, and components, from manufacturer.

a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions. Base certification on the maximum number of components capable of being mounted in each rack type. Identify components on which certification is based.
c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

F. Quality Assurance
1. Installer Qualifications: Cabling Installer must have personnel certified by BICSI on staff.
a. Layout Responsibility: Preparation of Shop Drawings shall be under the direct supervision of RCDD **OR** RCDD/NTS **OR** Commercial Installer, Level 2, **as directed**.
b. Installation Supervision: Installation shall be under the direct supervision of Registered Technician **OR** Level 2 Installer, **as directed**, who shall be present at all times when Work of this Section is performed at Project site.
c. Field Inspector: Currently registered by BICSI as RCDD **OR** Commercial Installer, Level 2, **as directed**, to perform the on-site inspection.
2. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
3. Telecommunications Pathways and Spaces: Comply with TIA/EIA-569-A.
4. Grounding: Comply with ANSI-J-STD-607-A.

G. Project Conditions
1. Environmental Limitations: Do not deliver or install equipment frames and cable trays until spaces are enclosed and weathertight, wet work in spaces is complete and dry, and work above ceilings is complete.

H. Coordination
1. Coordinate layout and installation of communications equipment with Owner's telecommunications and LAN equipment and service suppliers. Coordinate service entrance arrangement with local exchange carrier.
a. Meet jointly with telecommunications and LAN equipment suppliers, local exchange carrier representatives, and Owner to exchange information and agree on details of equipment arrangements and installation interfaces.
b. Record agreements reached in meetings and distribute them to other participants.
c. Adjust arrangements and locations of distribution frames, cross-connects, and patch panels in equipment rooms to accommodate and optimize arrangement and space requirements of telephone switch and LAN equipment.
d. Adjust arrangements and locations of equipment with distribution frames, cross-connects, and patch panels of cabling systems of other communications, electronic safety and security, and related systems that share space in the equipment room.
2. Coordinate location of power raceways and receptacles with locations of communications equipment requiring electrical power to operate.

1.2 PRODUCTS

A. Pathways
1. General Requirements: Comply with TIA/EIA-569-A.
2. Cable Support: NRTL labeled. Cable support brackets shall be designed to prevent degradation of cable performance and pinch points that could damage cable. Cable tie slots fasten cable ties to brackets.
a. Comply with NFPA 70 and UL 2043 for fire-resistant and low-smoke-producing characteristics.

b. Support brackets with cable tie slots for fastening cable ties to brackets.
c. Lacing bars, spools, J-hooks, and D-rings.
d. Straps and other devices.

3. Cable Trays:
   a. Cable Tray Materials: Metal, suitable for indoors and protected against corrosion by electroplated zinc galvanizing, complying with ASTM B 633, Type 1, not less than 0.000472 inch (0.012 mm) thick **OR** hot-dip galvanizing, complying with ASTM A 123/A 123M, Grade 0.55, not less than 0.002165 inch (0.055 mm) thick, **as directed**.
      1) Basket Cable Trays: 6 inches (150 mm) wide and 2 inches (50 mm) deep. Wire mesh spacing shall not exceed 2 by 4 inches (50 by 100 mm).
      2) Trough Cable Trays: Nominally 6 inches (150 mm) wide.
      3) Ladder Cable Trays: Nominally 18 inches (455 mm) wide, and a rung spacing of 12 inches (305 mm).
      4) Channel Cable Trays: One-piece construction, nominally 4 inches (100 mm) wide. Slot spacing shall not exceed 4-1/2 inches (115 mm) o.c.
      5) Solid-Bottom Cable Trays: One-piece construction, nominally 12 inches (305 mm) wide. Provide with **OR** without, **as directed**, solid covers.
4. Conduit and Boxes: Comply with requirements in Division 26 Section "Raceway And Boxes For Electrical Systems". Flexible metal conduit shall not be used.
   a. Outlet boxes shall be no smaller than 2 inches (50 mm) wide, 3 inches (75 mm) high, and 2-1/2 inches (64 mm) deep.

B. Backboards
1. Backboards: Plywood, fire-retardant treated, **as directed**, 3/4 by 48 by 96 inches (19 by 1220 by 2440 mm). Comply with requirements for plywood backing panels specified in Division 06 Section "Rough Carpentry".

C. Equipment Frames
1. General Frame Requirements:
   a. Distribution Frames: Freestanding and wall-mounting, modular-steel units designed for telecommunications terminal support and coordinated with dimensions of units to be supported.
   b. Module Dimension: Width compatible with EIA 310 standard, 19-inch (480-mm) panel mounting.
   c. Finish: Manufacturer's standard, baked-polyester powder coat.
2. Floor-Mounted Racks: Modular-type, steel **OR** aluminum, **as directed**, construction.
   a. Vertical and horizontal cable management channels, top and bottom cable troughs, grounding lug, and a power strip, **as directed**.
   b. Baked-polyester powder coat finish.
3. Modular Freestanding Cabinets:
   a. Removable and lockable side panels.
   b. Hinged and lockable front and rear doors.
   c. Adjustable feet for leveling.
   d. Screened ventilation openings in the roof and rear door.
   e. Cable access provisions in the roof and base.
   f. Grounding bus bar.
   g. Rack **OR** Roof, **as directed**,-mounted, 550-cfm (260-L/s) fan with filter.
   h. Power strip.
   i. Baked-polyester powder coat finish.
   j. All cabinets keyed alike.
4. Modular Wall Cabinets:
   a. Wall mounting.
   b. Steel **OR** Aluminum, **as directed**, construction.
   c. Treated to resist corrosion.
   d. Lockable front and rear doors.

e. Louvered side panels.
f. Cable access provisions top and bottom.
g. Grounding lug.
h. Rack **OR** Roof, **as directed**,-mounted, 250-cfm (118-L/s) fan.
i. Power strip.
j. All cabinets keyed alike.

5. Cable Management for Equipment Frames:
   a. Metal, with integral wire retaining fingers.
   b. Baked-polyester powder coat finish.
   c. Vertical cable management panels shall have front and rear channels, with covers.
   d. Provide horizontal crossover cable manager at the top of each relay rack, with a minimum height of two rack units each.

D. Power Strips
1. Power Strips: Comply with UL 1363.
   a. Rack mounting.
   b. Six, 15-A, 120-V ac, NEMA WD 6, Configuration 5-15R **OR** 20-A, 120-V ac, NEMA WD 6, Configuration 5-20R, **as directed**, receptacles.
   c. LED indicator lights for power and protection status.
   d. LED indicator lights for reverse polarity and open outlet ground.
   e. Circuit Breaker and Thermal Fusing:
      1) When protection is lost, circuit opens and cannot be reset.
   f. Close-coupled, direct plug-in **OR** Cord connected with 15-foot (4.5-m), **as directed**, line cord.
   g. Rocker-type on-off switch, illuminated when in on position.
   h. Peak Single-Impulse Surge Current Rating: 33 **OR** 26 **OR** 13, **as directed**, kA per phase.
   i. Protection modes shall be line to neutral, line to ground, and neutral to ground. UL 1449 clamping voltage for all 3 modes shall be not more than 330 V.

E. Grounding
1. Comply with requirements in Division 26 Section "Grounding And Bonding For Electrical Systems" for grounding conductors and connectors.
2. Telecommunications Main Bus Bar:
   a. Connectors: Mechanical type, cast silicon bronze, solderless compression **OR** exothermic, **as directed**,-type wire terminals, and long-barrel, two-bolt connection to ground bus bar.
   b. Ground Bus Bar: Copper, minimum 1/4 inch thick by 4 inches wide (6 mm thick by 100 mm wide) with 9/32-inch (7.14-mm) holes spaced 1-1/8 inches (28 mm) apart.
   c. Stand-Off Insulators: Comply with UL 891 for use in switchboards, 600 V. Lexan or PVC, impulse tested at 5000 V.
3. Comply with ANSI-J-STD-607-A.

F. Labeling
1. Comply with TIA/EIA-606-A and UL 969 for a system of labeling materials, including label stocks, laminating adhesives, and inks used by label printers.

1.3 EXECUTION

A. Entrance Facilities
1. Contact telecommunications service provider and arrange for installation of demarcation point, protected entrance terminals, and a housing when so directed by service provider.
2. Install underground **OR** buried **OR** aerial, **as directed**, pathways complying with recommendations in TIA/EIA-569-A, "Entrance Facilities" Article.
   a. Install underground **OR** buried, **as directed**, entrance pathway complying with Division 26 Section "Raceway And Boxes For Electrical Systems".

B. Installation
   1. Comply with NECA 1.
   2. Comply with BICSI TDMM for layout and installation of communications equipment rooms.
   3. Cable Trays: Comply with NEMA VE 2 and TIA/EIA-569-A-7.
   4. Bundle, lace, and train conductors and cables to terminal points without exceeding manufacturer's limitations on bending radii. Install lacing bars and distribution spools.

C. Firestopping
   1. Comply with requirements in Division 07 Section "Penetration Firestopping".
   2. Comply with TIA/EIA-569-A, Annex A, "Firestopping."
   3. Comply with BICSI TDMM, "Firestopping Systems" Article.

D. Grounding
   1. Install grounding according to BICSI TDMM, "Grounding, Bonding, and Electrical Protection" Chapter.
   2. Comply with ANSI-J-STD-607-A.
   3. Locate grounding bus bar to minimize the length of bonding conductors. Fasten to wall allowing at least 2-inch (50-mm) clearance behind the grounding bus bar. Connect grounding bus bar with a minimum No. 4 AWG grounding electrode conductor from grounding bus bar to suitable electrical building ground.
   4. Bond metallic equipment to the grounding bus bar, using not smaller than No. 6 AWG equipment grounding conductor.
      a. Bond the shield of shielded cable to the grounding bus bar in communications rooms and spaces.

E. Identification
   1. Identify system components, wiring, and cabling complying with TIA/EIA-606-A. Comply with requirements in Division 26 Section "Identification For Electrical Systems".
   2. Comply with requirements in Division 09 Section "Interior Painting" for painting backboards. For fire-resistant plywood, do not paint over manufacturer's label.
   3. Paint and label colors for equipment identification shall comply with TIA/EIA-606-A for Class 2 **OR** Class 3 **OR** Class 4, **as directed**, level of administration including optional identification requirements of this standard, **as directed**.
   4. Labels shall be preprinted or computer-printed type.

END OF SECTION 26 05 19 16e

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SECTION 26 05 19 16f - COMMUNICATIONS BACKBONE CABLING

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for communications backbone cabling. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Pathways.
b. UTP cable.
c. 50/125 and 62.5/125-micrometer, optical fiber cabling.
d. Coaxial cable.
e. Cable connecting hardware, patch panels, and cross-connects.
f. Cabling identification products.

C. Definitions
1. BICSI: Building Industry Consulting Service International.
2. Cross-Connect: A facility enabling the termination of cable elements and their interconnection or cross-connection.
3. EMI: Electromagnetic interference.
4. IDC: Insulation displacement connector.
5. LAN: Local area network.
6. RCDD: Registered Communications Distribution Designer.
7. UTP: Unshielded twisted pair.

D. Backbone Cabling Description
1. Backbone cabling system shall provide interconnections between communications equipment rooms, main terminal space, and entrance facilities in the telecommunications cabling system structure. Cabling system consists of backbone cables, intermediate and main cross-connects, mechanical terminations, and patch cords or jumpers used for backbone-to-backbone cross-connection.
2. Backbone cabling cross-connects may be located in communications equipment rooms or at entrance facilities. Bridged taps and splitters shall not be used as part of backbone cabling.

E. Performance Requirements
1. General Performance: Backbone cabling system shall comply with transmission standards in TIA/EIA-568-B.1, when tested according to test procedures of this standard.

F. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings:
a. System Labeling Schedules: Electronic copy of labeling schedules, in software and format selected by the Owner.
b. System Labeling Schedules: Electronic copy of labeling schedules that are part of the cabling and asset identification system of the software.
c. Cabling administration drawings and printouts.
d. Wiring diagrams to show typical wiring schematics including the following:
1) Cross-connects.
2) Patch panels.
3) Patch cords.

e. Cross-connects and patch panels. Detail mounting assemblies, and show elevations and physical relationship between the installed components.
f. Cable tray layout, showing cable tray route to scale, with relationship between the tray and adjacent structural, electrical, and mechanical elements.

3. Qualification Data: For Installer, **as directed**, qualified layout technician, installation supervisor, and field inspector.
4. Source quality-control reports.
5. Field quality-control reports.
6. Maintenance Data.
7. Software and Firmware Operational Documentation:
   a. Software operating and upgrade manuals.
   b. Program Software Backup: On magnetic media or compact disk, complete with data files.
   c. Device address list.
   d. Printout of software application and graphic screens.

G. Quality Assurance
1. Installer Qualifications: Cabling Installer must have personnel certified by BICSI on staff.
   a. Layout Responsibility: Preparation of Shop Drawings, Cabling Administration Drawings, and field testing program development by an RCDD.
   b. Installation Supervision: Installation shall be under the direct supervision of Registered Technician **OR** Level 2 Installer, **as directed**, who shall be present at all times when Work of this Section is performed at Project site.
2. Surface-Burning Characteristics: As determined by testing identical products according to ASTM E 84 by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
   a. Flame-Spread Index: 25 or less.
   b. Smoke-Developed Index: 50 **OR** 450, **as directed**, or less.
3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
4. Telecommunications Pathways and Spaces: Comply with TIA/EIA-569-A.
5. Grounding: Comply with ANSI-J-STD-607-A.

H. Delivery, Storage, And Handling
1. Test cables upon receipt at Project site.
   a. Test optical fiber cable to determine the continuity of the strand end to end. Use optical fiber flashlight or optical loss test set.
   b. Test optical fiber cable while on reels. Use an optical time domain reflectometer to verify the cable length and locate cable defects, splices, and connector, including the loss value of each. Retain test data and include the record in maintenance data.
   c. Test each pair of UTP cable for open and short circuits.

I. Software Service Agreement
1. Technical Support: Beginning with Final Completion, provide software support for two years.
2. Upgrade Service: Update software to latest version at Project completion. Install and program software upgrades that become available within two years from date of Final Completion. Upgrading software shall include operating system. Upgrade shall include new or revised licenses for use of software.
   a. Provide 30 days' notice to the Owner to allow scheduling and access to system and to allow the Owner to upgrade computer equipment if necessary.

1.2 PRODUCTS

A. Pathways
1. General Requirements: Comply with TIA/EIA-569-A.

2. Cable Support: NRTL labeled for support of Category 6 cabling, designed to prevent degradation of cable performance and pinch points that could damage cable.
   a. Support brackets with cable tie slots for fastening cable ties to brackets.
   b. Lacing bars, spools, J-hooks, and D-rings.
   c. Straps and other devices.
3. Cable Trays:
   a. Cable Tray Material: Metal, suitable for indoors, and protected against corrosion by electroplated zinc galvanizing, complying with ASTM B 633, Type 1, not less than 0.000472 inches (0.012 mm) thick **OR** hot-dip galvanizing, complying with ASTM A 123/A 123M, Grade 0.55, not less than 0.002165 inches (0.055 mm) thick, **as directed**.
      1) Basket Cable Trays: 6 inches (150 mm) wide and 2 inches (50 mm) deep. Wire mesh spacing shall not exceed 2 by 4 inches (50 by 100 mm).
      2) Trough Cable Trays: Nominally 6 inches (150 mm) wide.
      3) Ladder Cable Trays: Nominally 18 inches (455 mm) wide, and a rung spacing of 12 inches (305 mm).
      4) Channel Cable Trays: One-piece construction, nominally 4 inches (100 mm) wide. Slot spacing shall not exceed 4-1/2 inches (115 mm) o.c.
      5) Solid-Bottom Cable Trays: One-piece construction, nominally 12 inches (305 mm) wide. Provide with **OR** without, **as directed**, solid covers.
4. Conduit and Boxes: Comply with requirements in Division 26 Section "Raceway And Boxes For Electrical Systems". Flexible metal conduit shall not be used.
   a. Outlet boxes shall be no smaller than 2 inches (50 mm) wide, 3 inches (75 mm) high, and 2-1/2 inches (64 mm) deep.

B. Backboards
1. Backboards: Plywood, fire-retardant treated, **as directed**, 3/4 by 48 by 96 inches (19 by 1220 by 2440 mm). Comply with requirements in Division 06 Section "Rough Carpentry" for plywood backing panels.

C. UTP Cable
1. Description: 100-ohm, 100-pair UTP, formed into 25-pair binder groups covered with a gray thermoplastic jacket and overall metallic shield.
   a. Comply with ICEA S-90-661 for mechanical properties.
   b. Comply with TIA/EIA-568-B.1 for performance specifications.
   c. Comply with TIA/EIA-568-B.2, Category 5e **OR** Category 6, **OR** Category 6e **as directed**.
   d. Listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 444 and NFPA 70 for the following types:
      1) Communications, General Purpose: Type CM or CMG; or MPP, CMP, MPR, CMR, MP, or MPG, **as directed**.
      2) Communications, Plenum Rated: Type CMP or MPP, **as directed**, complying with NFPA 262.
      3) Communications, Riser Rated: Type CMR; or MPP, CMP, or MPR, **as directed**, complying with UL 1666.
      4) Communications, Limited Purpose: Type CMX; or MPP, CMP, MPR, CMR, MP, MPG, CM, or CMG, **as directed**.
      5) Multipurpose: Type MP or MPG; or MPP or MPR, **as directed**.
      6) Multipurpose, Plenum Rated: Type MPP, complying with NFPA 262.
      7) Multipurpose, Riser Rated: Type MPR or MPP, **as directed**, complying with UL 1666.

D. UTP Cable Hardware
1. General Requirements for Cable Connecting Hardware: Comply with TIA/EIA-568-B.2, IDC type, with modules designed for punch-down caps or tools. Cables shall be terminated with connecting hardware of same category or higher.

2. Connecting Blocks: 110-style IDC for Category 5e **OR** 110-style IDC for Category 6 **OR** 66-style IDC for Category 5e, **OR** 110-style IDC for Category 6e **as directed**. Provide blocks for the number of cables terminated on the block, plus 25 percent spare. Integral with connector bodies, including plugs and jacks where indicated.
3. Cross-Connect: Modular array of connecting blocks arranged to terminate building cables and permit interconnection between cables.
   a. Number of Terminals per Field: One for each conductor in assigned cables.
4. Patch Panel: Modular panels housing multiple-numbered jack units with IDC-type connectors at each jack for permanent termination of pair groups of installed cables.
   a. Number of Jacks per Field: One for each four-pair UTP cable indicated **OR** conductor group of indicated cables, plus spares and blank positions adequate to suit specified expansion criteria, **as directed**.
5. Jacks and Jack Assemblies: Modular, color-coded, eight-position modular receptacle units with integral IDC-type terminals.
6. Patch Cords: Factory-made, 4-pair cables in 36-inch (900-mm) **OR** 48-inch (1200-mm), **as directed**, lengths; terminated with 8-position modular plug at each end.
   a. Patch cords shall have bend-relief-compliant boots and color-coded icons to ensure Category 6 performance. Patch cords shall have latch guards to protect against snagging.
   b. Patch cords shall have color-coded boots for circuit identification.

E. Optical Fiber Cable
1. Description: Multimode, 50/125 **OR** 62.5/125, **as directed**,-micrometer, 24-fiber, nonconductive, **as directed**, tight buffer, optical fiber cable.
   a. Comply with ICEA S-83-596 for mechanical properties.
   b. Comply with TIA/EIA-568-B.3 for performance specifications.
   c. Comply with TIA/EIA-492AAAA-B **OR** TIA/EIA-492AAAA-A, **as directed**, for detailed specifications.
   d. Listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 444, UL 1651, and NFPA 70 for the following types:
      1) General Purpose, Nonconductive: Type OFN or OFNG, or OFNR, OFNP, **as directed**.
      2) Plenum Rated, Nonconductive: Type OFNP, complying with NFPA 262.
      3) Riser Rated, Nonconductive: Type OFNR or OFNP, **as directed**, complying with UL 1666.
      4) General Purpose, Conductive: Type OFC or OFCG; or OFNG, OFN, OFCR, OFNR, OFCP, or OFNP, **as directed**.
      5) Plenum Rated, Conductive: Type OFCP or OFNP, **as directed**, complying with NFPA 262.
      6) Riser Rated, Conductive: Type OFCR; or OFNR, OFCP, or OFNP, **as directed**, complying with UL 1666.
   e. Conductive cable shall be steel **OR** aluminum, **as directed**, armored type.
   f. Maximum Attenuation: 3.50 dB/km at 850 nm; 1.5 dB/km at 1300 nm.
   g. Minimum Modal Bandwidth: 160 MHz-km at 850 nm; 500 MHz-km at 1300 nm.
2. Jacket:
   a. Jacket Color: Aqua for 50/125-micrometer cable **OR** Orange for 62.5/125-micrometer cable, **as directed**.
   b. Cable cordage jacket, fiber, unit, and group color shall be according to TIA/EIA-598-B.
   c. Imprinted with fiber count, fiber type, and aggregate length at regular intervals not to exceed 40 inches (1000 mm).

F. Optical Fiber Cable Hardware
1. Cross-Connects and Patch Panels: Modular panels housing multiple-numbered, duplex cable connectors.
   a. Number of Connectors per Field: One for each fiber of cable or cables assigned to field, plus spares and blank positions adequate to suit specified expansion criteria.

2. Patch Cords: Factory-made, dual-fiber cables in 36-inch (900-mm) lengths.
3. Cable Connecting Hardware:
   a. Comply with Optical Fiber Connector Intermateability Standards (FOCIS) specifications of TIA/EIA-604-2, TIA/EIA-604-3-A, and TIA/EIA-604-12. Comply with TIA/EIA-568-B.3.
   b. Quick-connect, simplex and duplex, Type SC **OR** Type ST **OR** Type LC **OR** Type MT-RJ, **as directed**, connectors. Insertion loss not more than 0.75 dB.
   c. Type SFF connectors may be used in termination racks, panels, and equipment packages.

G. Coaxial Cable
1. General Coaxial Cable Requirements: Broadband type, recommended by cable manufacturer specifically for broadband data transmission applications. Coaxial cable and accessories shall have 75-ohm nominal impedance with a return loss of 20 dB maximum from 7 to 806 MHz.
2. RG-11/U: NFPA 70, Type CATV.
   a. No. 14 AWG, solid, copper-covered steel conductor.
   b. Gas-injected, foam-PE insulation.
   c. Double shielded with 100 percent aluminum polyester tape and 60 percent aluminum braid.
   d. Jacketed with sunlight-resistant, black PVC or PE.
   e. Suitable for outdoor installations in ambient temperatures ranging from minus 40 to plus 85 deg C.
3. RG59/U: NFPA 70, Type CATVR.
   a. No. 20 AWG, solid, silver-plated, copper-covered steel conductor.
   b. Gas-injected, foam-PE insulation.
   c. Triple shielded with 100 percent aluminum polyester tape and 95 percent aluminum braid; covered by aluminum foil with grounding strip.
   d. Color-coded PVC jacket.
4. RG-6/U: NFPA 70, Type CATV or CM.
   a. No. 16 AWG, solid, copper-covered steel conductor; gas-injected, foam-PE insulation.
   b. Double shielded with 100 percent aluminum-foil shield and 60 percent aluminum braid.
   c. Jacketed with black PVC or PE.
   d. Suitable for indoor installations.
5. RG59/U: NFPA 70, Type CATV.
   a. No. 20 AWG, solid, copper-covered steel conductor; gas-injected, foam-PE insulation.
   b. Double shielded with 100 percent aluminum polyester tape and 40 percent aluminum braid.
   c. PVC jacket.
6. RG59/U (Plenum Rated): NFPA 70, Type CMP.
   a. No. 20 AWG, solid, copper-covered steel conductor; foam fluorinated ethylene propylene insulation.
   b. Double shielded with 100 percent aluminum-foil shield and 65 percent aluminum braid.
   c. Copolymer jacket.
7. NFPA and UL compliance, listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 1655 and with NFPA 70, "Radio and Television Equipment" and "Community Antenna Television and Radio Distribution" Articles. Types are as follows:
   a. CATV Cable: Type CATV, or CATVP or CATVR, **as directed**.
   b. CATV Plenum Rated: Type CATVP, complying with NFPA 262.
   c. CATV Riser Rated: Type CATVR; or CATVP, CATVR, or CATV, **as directed**, complying with UL 1666.
   d. CATV Limited Rating: Type CATVX.

H. Coaxial Cable Hardware
1. Coaxial-Cable Connectors: Type BNC, 75 ohms.

I. Grounding
1. Comply with requirements in Division 26 Section "Grounding And Bonding For Electrical Systems" for grounding conductors and connectors.
2. Comply with ANSI-J-STD-607-A.

J. Identification Products
1. Comply with TIA/EIA-606-A and UL 969 for a system of labeling materials, including label stocks, laminating adhesives, and inks used by label printers.

K. Source Quality Control
1. Testing Agency: Engage a qualified testing agency to evaluate cables.
2. Factory test cables on reels according to TIA/EIA-568-B.1.
3. Factory test UTP cables according to TIA/EIA-568-B.2.
4. Factory test multimode optical fiber cables according to TIA/EIA-526-14-A and TIA/EIA-568-B.3.
5. Cable will be considered defective if it does not pass tests and inspections.
6. Prepare test and inspection reports.

1.3 EXECUTION

A. Entrance Facilities
1. Coordinate backbone cabling with the protectors and demarcation point provided by communications service provider.

B. Wiring Methods
1. Wiring Method: Install cables in raceways and cable trays except within consoles, cabinets, desks, and counters and except in accessible ceiling spaces, in attics, and in gypsum board partitions where unenclosed wiring method may be used. Conceal raceway and cables except in unfinished spaces.
   a. Install plenum cable in environmental air spaces, including plenum ceilings.
   b. Comply with requirements for raceways and boxes specified in Division 26 Section "Raceway And Boxes For Electrical Systems".
2. Wiring Method: Conceal conductors and cables in accessible ceilings, walls, and floors where possible.
3. Wiring within Enclosures: Bundle, lace, and train cables within enclosures. Connect to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Provide and use lacing bars and distribution spools.

C. Installation Of Pathways
1. Cable Trays: Comply with NEMA VE 2 and TIA/EIA-569-A.
2. Comply with requirements for demarcation point, pathways, cabinets, and racks specified in Division 27 Section "Communications Equipment Room Fittings". Drawings indicate general arrangement of pathways and fittings.
3. Comply with TIA/EIA-569-A for pull-box sizing and length of conduit and number of bends between pull points.
4. Comply with requirements in Division 26 Section "Raceway And Boxes For Electrical Systems" for installation of conduits and wireways.
5. Install manufactured conduit sweeps and long-radius elbows whenever possible.
6. Pathway Installation in Communications Equipment Rooms:
   a. Position conduit ends adjacent to a corner on backboard where a single piece of plywood is installed, or in the corner of room where multiple sheets of plywood are installed around perimeter walls of room.
   b. Install cable trays to route cables if conduits cannot be located in these positions.
   c. Secure conduits to backboard when entering room from overhead.
   d. Extend conduits 3 inches (76 mm) above finished floor.
   e. Install metal conduits with grounding bushings and connect with grounding conductor to grounding system.
7. Backboards: Install backboards with 96-inch (2440-mm) dimension vertical. Butt adjacent sheets tightly, and form smooth gap-free corners and joints.

D. Installation Of Cables
1. Comply with NECA 1.
2. General Requirements for Cabling:
   a. Comply with TIA/EIA-568-B.1.
   b. Comply with BICSI ITSIM, Ch. 6, "Cable Termination Practices."
   c. Install 110-style IDC termination hardware unless otherwise indicated.
   d. Terminate all conductors; no cable shall contain unterminated elements. Make terminations only at indicated outlets, terminals, cross-connects, and patch panels.
   e. Cables may not be spliced. Secure and support cables at intervals not exceeding 30 inches (760 mm) and not more than 6 inches (150 mm) from cabinets, boxes, fittings, outlets, racks, frames, and terminals.
   f. Install lacing bars to restrain cables, to prevent straining connections, and to prevent bending cables to smaller radii than minimums recommended by manufacturer.
   g. Bundle, lace, and train conductors to terminal points without exceeding manufacturer's limitations on bending radii, but not less than radii specified in BICSI ITSIM, "Cabling Termination Practices" Chapter. Use lacing bars and distribution spools.
   h. Do not install bruised, kinked, scored, deformed, or abraded cable. Do not splice cable between termination, tap, or junction points. Remove and discard cable if damaged during installation and replace it with new cable.
   i. Cold-Weather Installation: Bring cable to room temperature before dereeling. Heat lamps shall not be used for heating.
   j. In the communications equipment room, install a 10-foot- (3-m-) long service loop on each end of cable.
   k. Pulling Cable: Comply with BICSI ITSIM, Ch. 4, "Pulling Cable." Monitor cable pull tensions.
3. UTP Cable Installation:
   a. Comply with TIA/EIA-568-B.2.
   b. Do not untwist UTP cables more than 1/2 inch (12 mm) from the point of termination to maintain cable geometry.
4. Optical Fiber Cable Installation:
   a. Comply with TIA/EIA-568-B.3.
   b. Cable may be terminated on connecting hardware that is rack or cabinet mounted.
5. Open-Cable Installation:
   a. Install cabling with horizontal and vertical cable guides in telecommunications spaces with terminating hardware and interconnection equipment.
   b. Suspend UTP cable not in a wireway or pathway, a minimum of 8 inches (200 mm) above ceilings by cable supports not more than 60 inches (1524 mm) apart.
   c. Cable shall not be run through structural members or in contact with pipes, ducts, or other potentially damaging items.
6. Installation of Cable Routed Exposed under Raised Floors:
   a. Install plenum-rated cable only.
   b. Install cabling after the flooring system has been installed in raised floor areas.
   c. Coil cable 6 feet (1800 mm) long not less than 12 inches (300 mm) in diameter below each feed point.
7. Outdoor Coaxial Cable Installation:
   a. Install outdoor connections in enclosures complying with NEMA 250, Type 4X. Install corrosion-resistant connectors with properly designed O-rings to keep out moisture.
   b. Attach antenna lead-in cable to support structure at intervals not exceeding 36 inches (915 mm).
8. Group connecting hardware for cables into separate logical fields.
9. Separation from EMI Sources:
   a. Comply with BICSI TDMM and TIA/EIA-569-A recommendations for separating unshielded copper voice and data communication cable from potential EMI sources, including electrical power lines and equipment.
   b. Separation between open communications cables or cables in nonmetallic raceways and unshielded power conductors and electrical equipment shall be as follows:

1) Electrical Equipment Rating Less Than 2 kVA: A minimum of 5 inches (127 mm).
2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of 12 inches (300 mm).
3) Electrical Equipment Rating More Than 5 kVA: A minimum of 24 inches (610 mm).

c. Separation between communications cables in grounded metallic raceways and unshielded power lines or electrical equipment shall be as follows:
1) Electrical Equipment Rating Less Than 2 kVA: A minimum of 2-1/2 inches (64 mm).
2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of 6 inches (150 mm).
3) Electrical Equipment Rating More Than 5 kVA: A minimum of 12 inches (300 mm).

d. Separation between communications cables in grounded metallic raceways and power lines and electrical equipment located in grounded metallic conduits or enclosures shall be as follows:
1) Electrical Equipment Rating Less Than 2 kVA: No requirement.
2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of 3 inches (76 mm).
3) Electrical Equipment Rating More Than 5 kVA: A minimum of 6 inches (150 mm).

e. Separation between Communications Cables and Electrical Motors and Transformers, 5 kVA or HP and Larger: A minimum of 48 inches (1200 mm).

f. Separation between Communications Cables and Fluorescent Fixtures: A minimum of 5 inches (127 mm).

E. Firestopping
1. Comply with requirements in Division 07 Section "Penetration Firestopping".
2. Comply with TIA/EIA-569-A, Annex A, "Firestopping."
3. Comply with BICSI TDMM, "Firestopping Systems" Article.

F. Grounding
1. Install grounding according to BICSI TDMM, "Grounding, Bonding, and Electrical Protection" Chapter.
2. Comply with ANSI-J-STD-607-A.
3. Locate grounding bus bar to minimize the length of bonding conductors. Fasten to wall allowing at least 2-inch (50-mm) clearance behind the grounding bus bar. Connect grounding bus bar with a minimum No. 4 AWG grounding electrode conductor from grounding bus bar to suitable electrical building ground.
4. Bond metallic equipment to the grounding bus bar, using not smaller than No. 6 AWG equipment grounding conductor.

G. Identification
1. Identify system components, wiring, and cabling complying with TIA/EIA-606-A. Comply with requirements for identification specified in Division 26 Section "Identification For Electrical Systems".
a. Administration Class: 1 **OR** 2 **OR** 3 **OR** 4, **as directed**.
b. Color-code cross-connect fields and apply colors to voice and data service backboards, connections, covers, and labels.
2. Comply with requirements in Division 09 Section "Interior Painting" for painting backboards. For fire-resistant plywood, do not paint over manufacturer's label.
3. Paint and label colors for equipment identification shall comply with TIA/EIA-606-A for Class 2 **OR** Class 3 **OR** Class 4, **as directed**, level of administration including optional identification requirements of this standard.
4. Comply with requirements in Division 27 Section "Communications Horizontal Cabling" for cable and asset management software.
5. Cable Schedule: Install in a prominent location in each equipment room and wiring closet. List incoming and outgoing cables and their designations, origins, and destinations. Protect with rigid frame and clear plastic cover. Furnish an electronic copy of final comprehensive schedules for Project.

6. Cabling Administration Drawings: Show building floor plans with cabling administration-point labeling. Identify labeling convention and show labels for telecommunications closets, backbone pathways and cables, entrance pathways and cables, terminal hardware and positions, horizontal cables, work areas and workstation terminal positions, grounding buses and pathways, and equipment grounding conductors.
7. Cable and Wire Identification:
   a. Label each cable within 4 inches (100 mm) of each termination and tap, where it is accessible in a cabinet or junction or outlet box, and elsewhere as indicated.
   b. Each wire connected to building-mounted devices is not required to be numbered at device if color of wire is consistent with associated wire connected and numbered within panel or cabinet.
   c. Exposed Cables and Cables in Cable Trays and Wire Troughs: Label each cable at intervals not exceeding 15 feet (4.5 m).
   d. Label each terminal strip and screw terminal in each cabinet, rack, or panel.
      1) Individually number wiring conductors connected to terminal strips and identify each cable or wiring group being extended from a panel or cabinet to a building-mounted device with name and number of particular device as shown.
      2) Label each unit and field within distribution racks and frames.
   e. Identification within Connector Fields in Equipment Rooms and Wiring Closets: Label each connector and each discrete unit of cable-terminating and connecting hardware. Where similar jacks and plugs are used for both voice and data communication cabling, use a different color for jacks and plugs of each service.
8. Labels shall be preprinted or computer-printed type with printing area and font color that contrasts with cable jacket color but still complies with requirements in TIA/EIA 606-A, for the following:
   a. Cables use flexible vinyl or polyester that flexes as cables are bent.

H. Field Quality Control
1. Tests and Inspections:
   a. Visually inspect UTP and optical fiber jacket materials for NRTL certification markings. Inspect cabling terminations in communications equipment rooms for compliance with color-coding for pin assignments, and inspect cabling connections for compliance with TIA/EIA-568-B.1.
   b. Visually inspect cable placement, cable termination, grounding and bonding, equipment and patch cords, and labeling of all components.
   c. Test UTP copper cabling for DC loop resistance, shorts, opens, intermittent faults, and polarity between conductors. Test operation of shorting bars in connection blocks. Test cables after termination but not cross-connection.
      1) Test instruments shall meet or exceed applicable requirements in TIA/EIA-568-B.2. Perform tests with a tester that complies with performance requirements in "Test Instruments (Normative)" Annex, complying with measurement accuracy specified in "Measurement Accuracy (Informative)" Annex. Use only test cords and adapters that are qualified by test equipment manufacturer for channel or link test configuration.
   d. Optical Fiber Cable Tests:
      1) Test instruments shall meet or exceed applicable requirements in TIA/EIA-568-B.1. Use only test cords and adapters that are qualified by test equipment manufacturer for channel or link test configuration.
      2) Link End-to-End Attenuation Tests:
         a) Horizontal and multimode backbone link measurements: Test at 850 or 1300 nm in 1 direction according to TIA/EIA-526-14-A, Method B, One Reference Jumper.
         b) Attenuation test results for backbone links shall be less than 2.0 dB. Attenuation test results shall be less than that calculated according to equation in TIA/EIA-568-B.1.

2. Data for each measurement shall be documented. Data for submittals shall be printed in a summary report that is formatted similar to Table 10.1 in BICSI TDMM, or transferred from the instrument to the computer, saved as text files, and printed and submitted.
3. Remove and replace cabling where test results indicate that they do not comply with specified requirements.
4. End-to-end cabling will be considered defective if it does not pass tests and inspections.
5. Prepare test and inspection reports.

END OF SECTION 26 05 19 16f

SECTION 26 05 19 16g - COMMUNICATIONS HORIZONTAL CABLING

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for communications horizontal cabling. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Pathways.
b. UTP cabling.
c. 50/125 and 62.5/125-micrometer, optical fiber cabling.
d. Coaxial cable.
e. Multiuser telecommunications outlet assemblies.
f. Cable connecting hardware, patch panels, and cross-connects.
g. Telecommunications outlet/connectors.
h. Cabling system identification products.
i. Cable management system.

C. Definitions
1. Basket Cable Tray: A fabricated structure consisting of wire mesh bottom and side rails.
2. BICSI: Building Industry Consulting Service International.
3. Channel Cable Tray: A fabricated structure consisting of a one-piece, ventilated-bottom or solid-bottom channel.
4. Consolidation Point: A location for interconnection between horizontal cables extending from building pathways and horizontal cables extending into furniture pathways.
5. Cross-Connect: A facility enabling the termination of cable elements and their interconnection or cross-connection.
6. EMI: Electromagnetic interference.
7. IDC: Insulation displacement connector.
8. Ladder Cable Tray: A fabricated structure consisting of two longitudinal side rails connected by individual transverse members (rungs).
9. LAN: Local area network.
10. MUTOA: Multiuser telecommunications outlet assembly, a grouping in one location of several telecommunications outlet/connectors.
11. Outlet/Connectors: A connecting device in the work area on which horizontal cable or outlet cable terminates.
12. RCDD: Registered Communications Distribution Designer.
13. Solid-Bottom or Nonventilated Cable Tray: A fabricated structure consisting of longitudinal side rails and a bottom without ventilation openings.
14. Trough or Ventilated Cable Tray: A fabricated structure consisting of longitudinal side rails and a bottom having openings for the passage of air.
15. UTP: Unshielded twisted pair.

D. Horizontal Cabling Description
1. Horizontal cable and its connecting hardware provide the means of transporting signals between the telecommunications outlet/connector and the horizontal cross-connect located in the communications equipment room. This cabling and its connecting hardware are called "permanent link," a term that is used in the testing protocols.
a. TIA/EIA-568-B.1 requires that a minimum of two telecommunications outlet/connectors be installed for each work area.

b. Horizontal cabling shall contain no more that one transition point or consolidation point between the horizontal cross-connect and the telecommunications outlet/connector.
c. Bridged taps and splices shall not be installed in the horizontal cabling.
d. Splitters shall not be installed as part of the optical fiber cabling.

2. A work area is approximately 100 sq. ft. (9.3 sq. m), and includes the components that extend from the telecommunications outlet/connectors to the station equipment.
3. The maximum allowable horizontal cable length is 295 feet (90 m). This maximum allowable length does not include an allowance for the length of 16 feet (4.9 m) to the workstation equipment. The maximum allowable length does not include an allowance for the length of 16 feet (4.9 m) in the horizontal cross-connect.

E. Performance Requirements
1. General Performance: Horizontal cabling system shall comply with transmission standards in TIA/EIA-568-B.1, when tested according to test procedures of this standard.

F. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings:
a. System Labeling Schedules: Electronic copy of labeling schedules, in software and format selected by the Owner.
b. System Labeling Schedules: Electronic copy of labeling schedules that are part of the cabling and asset identification system of the software.
c. Cabling administration drawings and printouts.
d. Wiring diagrams to show typical wiring schematics, including the following:
1) Cross-connects.
2) Patch panels.
3) Patch cords.
e. Cross-connects and patch panels. Detail mounting assemblies, and show elevations and physical relationship between the installed components.
f. Cable tray layout, showing cable tray route to scale, with relationship between the tray and adjacent structural, electrical, and mechanical elements.
3. Samples: For workstation outlets, jacks, jack assemblies, in specified finish, one for each size and outlet configuration and faceplates for color selection and evaluation of technical features.
4. Qualification Data: For Installer, **as directed**, qualified layout technician, installation supervisor, and field inspector.
5. Source quality-control reports.
6. Field quality-control reports.
7. Maintenance Data.
8. Software and Firmware Operational Documentation:
a. Software operating and upgrade manuals.
b. Program Software Backup: On magnetic media or compact disk, complete with data files.
c. Device address list.
d. Printout of software application and graphic screens.

G. Quality Assurance
1. Installer Qualifications: Cabling Installer must have personnel certified by BICSI on staff.
a. Layout Responsibility: Preparation of Shop Drawings, Cabling Administration Drawings, and field testing program development by an RCDD.
b. Installation Supervision: Installation shall be under the direct supervision of Registered Technician **OR** Level 2 Installer, **as directed**, who shall be present at all times when Work of this Section is performed at Project site.
2. Surface-Burning Characteristics: As determined by testing identical products according to ASTM E 84 by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
a. Flame-Spread Index: 25 or less.

b. Smoke-Developed Index: 50 **OR** 450, **as directions**, or less.

3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
4. Telecommunications Pathways and Spaces: Comply with TIA/EIA-569-A.
5. Grounding: Comply with ANSI-J-STD-607-A.

H. Delivery, Storage, And Handling

1. Test cables upon receipt at Project site.
   a. Test optical fiber cables to determine the continuity of the strand end to end. Use optical fiber flashlight or optical loss test set.
   b. Test optical fiber cables while on reels. Use an optical time domain reflectometer to verify the cable length and locate cable defects, splices, and connector; including the loss value of each. Retain test data and include the record in maintenance data.
   c. Test each pair of UTP cable for open and short circuits.

I. Software Service Agreement

1. Technical Support: Beginning with Final Completion, provide software support for two years.
2. Upgrade Service: Update software to latest version at Project completion. Install and program software upgrades that become available within two years from date of Final Completion. Upgrading software shall include operating system. Upgrade shall include new or revised licenses for use of software.
   a. Provide 30 days' notice to the Owner to allow scheduling and access to system and to allow the Owner to upgrade computer equipment if necessary.

1.2 PRODUCTS

A. Pathways

1. General Requirements: Comply with TIA/EIA-569-A.
2. Cable Support: NRTL labeled for support of Category 6 cabling, designed to prevent degradation of cable performance and pinch points that could damage cable.
   a. Support brackets with cable tie slots for fastening cable ties to brackets.
   b. Lacing bars, spools, J-hooks, and D-rings.
   c. Straps and other devices.
3. Cable Trays:
   a. Cable Tray Materials: Metal, suitable for indoors, and protected against corrosion by electroplated zinc galvanizing, complying with ASTM B 633, Type 1, not less than 0.000472 inch (0.012 mm) thick **OR** hot-dip galvanizing, complying with ASTM A 123/A 123M, Grade 0.55, not less than 0.002165 inch (0.055 mm) thick, **as directed**.
      1) Basket Cable Trays: 6 inches (150 mm) wide and 2 inches (50 mm) deep. Wire mesh spacing shall not exceed 2 by 4 inches (50 by 100 mm).
      2) Trough Cable Trays: Nominally 6 inches (150 mm) wide.
      3) Ladder Cable Trays: Nominally 18 inches (455 mm) wide, and a rung spacing of 12 inches (305 mm).
      4) Channel Cable Trays: One-piece construction, nominally 4 inches (100 mm) wide. Slot spacing shall not exceed 4-1/2 inches (115 mm) o.c.
      5) Solid-Bottom Cable Trays: One-piece construction, nominally 12 inches (305 mm) wide. Provide with **OR** without, **as directed**, solid covers.
4. Conduit and Boxes: Comply with requirements in Division 26 Section "Raceway And Boxes For Electrical Systems". Flexible metal conduit shall not be used.
   a. Outlet boxes shall be no smaller than 2 inches (50 mm) wide, 3 inches (75 mm) high, and 2-1/2 inches (64 mm) deep.

B. Backboards

1. Backboards: Plywood, fire-retardant treated, **as directed**, 3/4 by 48 by 96 inches (19 by 1220 by 2440 mm). Comply with requirements in Division 06 Section "Rough Carpentry" for plywood backing panels.

C. UTP Cable
1. Description: 100-ohm, 4-pair UTP, formed into 25-pair, binder groups covered with a blue thermoplastic jacket.
   a. Comply with ICEA S-90-661 for mechanical properties.
   b. Comply with TIA/EIA-568-B.1 for performance specifications.
   c. Comply with TIA/EIA-568-B.2, Category 5e **OR** Category 6, **OR** Category 6e **as directed**.
   d. Listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 444 and NFPA 70 for the following types:
      1) Communications, General Purpose: Type CM or CMG; or MPP, CMP, MPR, CMR, MP, or MPG, **as directed**.
      2) Communications, Plenum Rated: Type CMP or MPP, **as directed**, complying with NFPA 262.
      3) Communications, Riser Rated: Type CMR; or MPP, CMP, or MPR, **as directed**, complying with UL 1666.
      4) Communications, Limited Purpose: Type CMX; or MPP, CMP, MPR, CMR, MP, MPG, CM, or CMG, **as directed**.
      5) Multipurpose: Type MP or MPG; or MPP or MPR, **as directed**.
      6) Multipurpose, Plenum Rated: Type MPP, complying with NFPA 262.
      7) Multipurpose, Riser Rated: Type MPR or MPP, **as directed**, complying with UL 1666.

D. UTP Cable Hardware
1. General Requirements for Cable Connecting Hardware: Comply with TIA/EIA-568-B.2, IDC type, with modules designed for punch-down caps or tools. Cables shall be terminated with connecting hardware of same category or higher.
2. Connecting Blocks: 110-style IDC for Category 5e **OR** 110-style IDC for Category 6 **OR** 66-style IDC for Category 5e, OR 110-style IDC for Category 6e **as directed**. Provide blocks for the number of cables terminated on the block, plus 25 percent spare. Integral with connector bodies, including plugs and jacks where indicated.
3. Cross-Connect: Modular array of connecting blocks arranged to terminate building cables and permit interconnection between cables.
   a. Number of Terminals per Field: One for each conductor in assigned cables.
4. Patch Panel: Modular panels housing multiple-numbered jack units with IDC-type connectors at each jack for permanent termination of pair groups of installed cables.
   a. Number of Jacks per Field: One for each four-pair UTP cable indicated **OR** conductor group of indicated cables, plus spares and blank positions adequate to suit specified expansion criteria, **as directed**.
5. Jacks and Jack Assemblies: Modular, color-coded, eight-position modular receptacle units with integral IDC-type terminals.
6. Patch Cords: Factory-made, four-pair cables in 36-inch (900 mm) **OR** 48-inch (1200-mm), **as directed**, lengths; terminated with eight-position modular plug at each end.
   a. Patch cords shall have bend-relief-compliant boots and color-coded icons to ensure Category 6 performance. Patch cords shall have latch guards to protect against snagging.
   b. Patch cords shall have color-coded boots for circuit identification.

E. Optical Fiber Cable
1. Description: Multimode, 50/125 **OR** 62.5/125, **as directed**,-micrometer, 24-fiber, nonconductive, **as directed**, tight buffer, optical fiber cable.
   a. Comply with ICEA S-83-596 for mechanical properties.
   b. Comply with TIA/EIA-568-B.3 for performance specifications.

c. Comply with TIA/EIA-492AAAA-B **OR** TIA/EIA-492AAAA-A, **as directed**, for detailed specifications.
d. Listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 444, UL 1651, and NFPA 70 for the following types:
1) General Purpose, Nonconductive: Type OFN or OFNG, or OFNR, OFNP, **as directed**.
2) Plenum Rated, Nonconductive: Type OFNP, complying with NFPA 262.
3) Riser Rated, Nonconductive: Type OFNR or OFNP, **as directed**, complying with UL 1666.
4) General Purpose, Conductive: Type OFC or OFCG; or OFNG, OFN, OFCR, OFNR, OFCP, or OFNP, **as directed**.
5) Plenum Rated, Conductive: Type OFCP or OFNP, **as directed**, complying with NFPA 262.
6) Riser Rated, Conductive: Type OFCR; or OFNR, OFCP, or OFNP, **as directed**, complying with UL 1666.
e. Conductive cable shall be steel **OR** aluminum, **as directed**, armored type.
f. Maximum Attenuation: 3.50 dB/km at 850 nm; 1.5 dB/km at 1300 nm.
g. Minimum Modal Bandwidth: 160 MHz-km at 850 nm; 500 MHz-km at 1300 nm.

2. Jacket:
a. Jacket Color: Aqua for 50/125-micrometer cable **OR** Orange for 62.5/125-micrometer cable, **as directed**.
b. Cable cordage jacket, fiber, unit, and group color shall be according to TIA/EIA-598-B.
c. Imprinted with fiber count, fiber type, and aggregate length at regular intervals not to exceed 40 inches (1000 mm).

F. Optical Fiber Cable Hardware
1. Cross-Connects and Patch Panels: Modular panels housing multiple-numbered, duplex cable connectors.
a. Number of Connectors per Field: One for each fiber of cable or cables assigned to field, plus spares and blank positions adequate to suit specified expansion criteria.
2. Patch Cords: Factory-made, dual-fiber cables in 36-inch (900-mm) lengths.
3. Cable Connecting Hardware:
a. Comply with Optical Fiber Connector Intermateability Standards (FOCIS) specifications of TIA/EIA-604-2, TIA/EIA-604-3-A, and TIA/EIA-604-12. Comply with TIA/EIA-568-B.3.
b. Quick-connect, simplex and duplex, Type SC **OR** Type ST **OR** Type LC **OR** Type MT-RJ, **as directed**, connectors. Insertion loss not more than 0.75 dB.
c. Type SFF connectors may be used in termination racks, panels, and equipment packages.

G. Coaxial Cable
1. Cable Characteristics: Broadband type, recommended by cable manufacturer specifically for broadband data transmission applications. Coaxial cable and accessories shall have 75-ohm nominal impedance with a return loss of 20 dB maximum from 7 to 806 MHz.
2. RG-11/U: NFPA 70, Type CATV.
a. No. 14 AWG, solid, copper-covered steel conductor.
b. Gas-injected, foam-PE insulation.
c. Double shielded with 100 percent aluminum polyester tape and 60 percent aluminum braid.
d. Jacketed with sunlight-resistant, black PVC or PE.
e. Suitable for outdoor installations in ambient temperatures ranging from minus 40 to plus 85 deg C.
3. RG59/U: NFPA 70, Type CATVR.
a. No. 20 AWG, solid, silver-plated, copper-covered steel conductor.
b. Gas-injected, foam-PE insulation.
c. Triple shielded with 100 percent aluminum polyester tape and 95 percent aluminum braid; covered by aluminum foil with grounding strip.
d. Color-coded PVC jacket.
4. RG-6/U: NFPA 70, Type CATV or CM.

a. No. 16 AWG, solid, copper-covered steel conductor; gas-injected, foam-PE insulation.
b. Double shielded with 100 percent aluminum-foil shield and 60 percent aluminum braid.
c. Jacketed with black PVC or PE.
d. Suitable for indoor installations.

5. RG59/U: NFPA 70, Type CATV.
   a. No. 20 AWG, solid, copper-covered steel conductor; gas-injected, foam-PE insulation.
   b. Double shielded with 100 percent aluminum polyester tape and 40 percent aluminum braid.
   c. PVC jacket.
6. RG59/U (Plenum Rated): NFPA 70, Type CMP.
   a. No. 20 AWG, solid, copper-covered steel conductor; foam fluorinated ethylene propylene insulation.
   b. Double shielded with 100 percent aluminum-foil shield and 65 percent aluminum braid.
   c. Copolymer jacket.
7. NFPA and UL compliance, listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 1655 and with NFPA 70 "Radio and Television Equipment" and "Community Antenna Television and Radio Distribution" Articles. Types are as follows:
   a. CATV Cable: Type CATV or CATVP or CATVR, **as directed**.
   b. CATV Plenum Rated: Type CATVP, complying with NFPA 262.
   c. CATV Riser Rated: Type CATVR; or CATVP, CATVR, or CATV, **as directed**, complying with UL 1666.
   d. CATV Limited Rating: Type CATVX.

H. Coaxial Cable Hardware
1. Coaxial-Cable Connectors: Type BNC, 75 ohms.

I. Consolidation Points
1. Description: Consolidation points shall comply with requirements for cable connecting hardware.
   a. Number of Terminals per Field: One for each conductor in assigned cables.
   b. Number of Connectors per Field:
      1) One for each four-pair UTP cable indicated.
      2) One for each four-pair conductor group of indicated cables, plus 25 percent spare positions.
   c. Mounting: Recessed in ceiling **OR** Wall **OR** Desk **OR** Furniture, **as directed**.
   d. NRTL listed as complying with UL 50 and UL 1863.
   e. When installed in plenums used for environmental air, NRTL listed as complying with UL 2043.

J. Multiuser Telecommunications Outlet Assembly (MUTOA)
1. Description: MUTOAs shall meet the requirements for cable connecting hardware.
   a. Number of Terminals per Field: One for each conductor in assigned cables.
   b. Number of Connectors per Field:
      1) One for each four-pair UTP cable indicated.
      2) One for each four-pair conductor group of indicated cables, plus 25 percent spare positions.
   c. Mounting: Recessed in ceiling **OR** Wall **OR** Desk **OR** Furniture, **as directed**.
   d. NRTL listed as complying with UL 50 and UL 1863.
   e. Label shall include maximum length of work area cords, based on TIA/EIA-568-B.1.
   f. When installed in plenums used for environmental air, NRTL listed as complying with UL 2043.

K. Telecommunications Outlet/Connectors
1. Jacks: 100-ohm, balanced, twisted-pair connector; four-pair, eight-position modular. Comply with TIA/EIA-568-B.1.
2. Workstation Outlets: Two **OR** Four, **as directed**,-port-connector assemblies mounted in single or multigang faceplate.

a. Plastic Faceplate: High-impact plastic. Coordinate color with Division 26 Section "Wiring Devices".
b. Metal Faceplate: Stainless steel **OR** Brass, **as directed**, complying with requirements in Division 26 Section "Wiring Devices".
c. For use with snap-in jacks accommodating any combination of UTP, optical fiber, and coaxial work area cords.
   1) Flush mounting jacks, positioning the cord at a 45-degree angle.
d. Legend:
   1) Factory labeled by silk-screening or engraving for stainless steel **OR** brass, **as directed**, faceplates.
      OR
      Machine printed, in the field, using adhesive-tape label.
      OR
      Snap-in, clear-label covers and machine-printed paper inserts.

L. Grounding
1. Comply with requirements in Division 26 Section "Grounding And Bonding For Electrical Systems" for grounding conductors and connectors.
2. Comply with ANSI-J-STD-607-A.

M. Identification Products
1. Comply with TIA/EIA-606-A and UL 969 for labeling materials, including label stocks, laminating adhesives, and inks used by label printers.
2. Comply with requirements in Division 26 Section "Identification For Electrical Systems".

N. Cable Management System
1. Description: Computer-based cable management system, with integrated database and graphic, **as directed**, capabilities.
2. Document physical characteristics by recording the network, TIA/EIA details, and connections between equipment and cable.
3. Information shall be presented in database view, schematic plans, or technical drawings.
   a. Microsoft Visio Professional or AutoCAD drawing software shall be used as drawing and schematic plans software.
4. System shall interface with the following testing and recording devices:
   a. Direct upload tests from circuit testing instrument into the personal computer.
   b. Direct download circuit labeling into labeling printer.

O. Source Quality Control
1. Testing Agency: Engage a qualified testing agency to evaluate cables.
2. Factory test UTP and optical fiber cables on reels according to TIA/EIA-568-B.1.
3. Factory test UTP cables according to TIA/EIA-568-B.2.
4. Factory test multimode optical fiber cables according to TIA/EIA-526-14-A and TIA/EIA-568-B.3.
5. Factory-sweep test coaxial cables at frequencies from 5 MHz to 1 GHz. Sweep test shall test the frequency response, or attenuation over frequency, of a cable by generating a voltage whose frequency is varied through the specified frequency range and graphing the results.
6. Cable will be considered defective if it does not pass tests and inspections.
7. Prepare test and inspection reports.

1.3 EXECUTION

A. Entrance Facilities
1. Coordinate backbone cabling with the protectors and demarcation point provided by communications service provider.

B. Wiring Methods

1. Wiring Method: Install cables in raceways and cable trays except within consoles, cabinets, desks, and counters and except in accessible ceiling spaces, in attics, and in gypsum board partitions where unenclosed wiring method may be used. Conceal raceway and cables except in unfinished spaces.
   a. Install plenum cable in environmental air spaces, including plenum ceilings.
   b. Comply with requirements for raceways and boxes specified in Division 26 Section "Raceway And Boxes For Electrical Systems".
2. Wiring Method: Conceal conductors and cables in accessible ceilings, walls, and floors where possible.
3. Wiring within Enclosures: Bundle, lace, and train cables to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Provide and use lacing bars and distribution spools.

C. Installation Of Pathways
1. Cable Trays: Comply with NEMA VE 2 and TIA/EIA-569-A-7.
2. Comply with requirements for demarcation point, pathways, cabinets, and racks specified in Division 27 Section "Communications Equipment Room Fittings". Drawings indicate general arrangement of pathways and fittings.
3. Comply with TIA/EIA-569-A for pull-box sizing and length of conduit and number of bends between pull points.
4. Comply with requirements in Division 26 Section "Raceway And Boxes For Electrical Systems" for installation of conduits and wireways.
5. Install manufactured conduit sweeps and long-radius elbows whenever possible.
6. Pathway Installation in Communications Equipment Rooms:
   a. Position conduit ends adjacent to a corner on backboard where a single piece of plywood is installed, or in the corner of room where multiple sheets of plywood are installed around perimeter walls of room.
   b. Install cable trays to route cables if conduits cannot be located in these positions.
   c. Secure conduits to backboard when entering room from overhead.
   d. Extend conduits 3 inches (76 mm) above finished floor.
   e. Install metal conduits with grounding bushings and connect with grounding conductor to grounding system.
7. Backboards: Install backboards with 96-inch (2440-mm) dimension vertical. Butt adjacent sheets tightly, and form smooth gap-free corners and joints.

D. Installation Of Cables
1. Comply with NECA 1.
2. General Requirements for Cabling:
   a. Comply with TIA/EIA-568-B.1.
   b. Comply with BICSI ITSIM, Ch. 6, "Cable Termination Practices."
   c. Install 110-style IDC termination hardware unless otherwise indicated.
   d. MUTOA shall not be used as a cross-connect point.
   e. Consolidation points may be used only for making a direct connection to telecommunications outlet/connectors:
      1) Do not use consolidation point as a cross-connect point, as a patch connection, or for direct connection to workstation equipment.
      2) Locate consolidation points for UTP at least 49 feet (15 m) from communications equipment room.
   f. Terminate conductors; no cable shall contain unterminated elements. Make terminations only at indicated outlets, terminals, cross-connects, and patch panels.
   g. Cables may not be spliced. Secure and support cables at intervals not exceeding 30 inches (760 mm) and not more than 6 inches (150 mm) from cabinets, boxes, fittings, outlets, racks, frames, and terminals.
   h. Install lacing bars to restrain cables, to prevent straining connections, and to prevent bending cables to smaller radii than minimums recommended by manufacturer.

i. Bundle, lace, and train conductors to terminal points without exceeding manufacturer's limitations on bending radii, but not less than radii specified in BICSI ITSIM, "Cabling Termination Practices" Chapter. Install lacing bars and distribution spools.
j. Do not install bruised, kinked, scored, deformed, or abraded cable. Do not splice cable between termination, tap, or junction points. Remove and discard cable if damaged during installation and replace it with new cable.
k. Cold-Weather Installation: Bring cable to room temperature before dereeling. Heat lamps shall not be used for heating.
l. In the communications equipment room, install a 10-foot- (3-m-) long service loop on each end of cable.
m. Pulling Cable: Comply with BICSI ITSIM, Ch. 4, "Pulling Cable." Monitor cable pull tensions.

3. UTP Cable Installation:
   a. Comply with TIA/EIA-568-B.2.
   b. Do not untwist UTP cables more than 1/2 inch (12 mm) from the point of termination to maintain cable geometry.
4. Optical Fiber Cable Installation:
   a. Comply with TIA/EIA-568-B.3.
   b. Cable may be terminated on connecting hardware that is rack or cabinet mounted.
5. Open-Cable Installation:
   a. Install cabling with horizontal and vertical cable guides in telecommunications spaces with terminating hardware and interconnection equipment.
   b. Suspend UTP cable not in a wireway or pathway a minimum of 8 inches (200 mm) above ceilings by cable supports not more than 60 inches (1524 mm) apart.
   c. Cable shall not be run through structural members or in contact with pipes, ducts, or other potentially damaging items.
6. Installation of Cable Routed Exposed under Raised Floors:
   a. Install plenum-rated cable only.
   b. Install cabling after the flooring system has been installed in raised floor areas.
   c. Coil cable 6 feet (1800 mm) long not less than 12 inches (300 mm) in diameter below each feed point.
7. Outdoor Coaxial Cable Installation:
   a. Install outdoor connections in enclosures complying with NEMA 250, Type 4X. Install corrosion-resistant connectors with properly designed O-rings to keep out moisture.
   b. Attach antenna lead-in cable to support structure at intervals not exceeding 36 inches (915 mm).
8. Group connecting hardware for cables into separate logical fields.
9. Separation from EMI Sources:
   a. Comply with BICSI TDMM and TIA/EIA-569-A for separating unshielded copper voice and data communication cable from potential EMI sources, including electrical power lines and equipment.
   b. Separation between open communications cables or cables in nonmetallic raceways and unshielded power conductors and electrical equipment shall be as follows:
      1) Electrical Equipment Rating Less Than 2 kVA: A minimum of 5 inches (127 mm).
      2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of 12 inches (300 mm).
      3) Electrical Equipment Rating More Than 5 kVA: A minimum of 24 inches (610 mm).
   c. Separation between communications cables in grounded metallic raceways and unshielded power lines or electrical equipment shall be as follows:
      1) Electrical Equipment Rating Less Than 2 kVA: A minimum of 2-1/2 inches (64 mm).
      2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of 6 inches (150 mm).
      3) Electrical Equipment Rating More Than 5 kVA: A minimum of 12 inches (300 mm).
   d. Separation between communications cables in grounded metallic raceways and power lines and electrical equipment located in grounded metallic conduits or enclosures shall be as follows:

1) Electrical Equipment Rating Less Than 2 kVA: No requirement.
2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of 3 inches (76 mm).
3) Electrical Equipment Rating More Than 5 kVA: A minimum of 6 inches (150 mm).

e. Separation between Communications Cables and Electrical Motors and Transformers, 5 kVA or HP and Larger: A minimum of 48 inches (1200 mm).

f. Separation between Communications Cables and Fluorescent Fixtures: A minimum of 5 inches (127 mm).

E. Firestopping
1. Comply with requirements in Division 07 Section "Penetration Firestopping".
2. Comply with TIA/EIA-569-A, Annex A, "Firestopping."
3. Comply with BICSI TDMM, "Firestopping Systems" Article.

F. Grounding
1. Install grounding according to BICSI TDMM, "Grounding, Bonding, and Electrical Protection" Chapter.
2. Comply with ANSI-J-STD-607-A.
3. Locate grounding bus bar to minimize the length of bonding conductors. Fasten to wall allowing at least 2-inch (50-mm) clearance behind the grounding bus bar. Connect grounding bus bar with a minimum No. 4 AWG grounding electrode conductor from grounding bus bar to suitable electrical building ground.
4. Bond metallic equipment to the grounding bus bar, using not smaller than No. 6 AWG equipment grounding conductor.

G. Identification
1. Identify system components, wiring, and cabling complying with TIA/EIA-606-A. Comply with requirements for identification specified in Division 26 Section "Identification For Electrical Systems".
   a. Administration Class: 1 **OR** 2 **OR** 3 **OR** 4, **as directed**.
   b. Color-code cross-connect fields. Apply colors to voice and data service backboards, connections, covers, and labels.
2. Using cable management system software specified in Part 2, develop Cabling Administration Drawings for system identification, testing, and management. Use unique, alphanumeric designation for each cable and label cable, jacks, connectors, and terminals to which it connects with same designation. At completion, cable and asset management software shall reflect as-built conditions.
3. Comply with requirements in Division 09 Section "Interior Painting" for painting backboards. For fire-resistant plywood, do not paint over manufacturer's label.
4. Paint and label colors for equipment identification shall comply with TIA/EIA-606-A for Class 2 **OR** Class 3 **OR** Class 4, **as directed**, level of administration, including optional identification requirements of this standard.
5. Cable Schedule: Post in prominent location in each equipment room and wiring closet. List incoming and outgoing cables and their designations, origins, and destinations. Protect with rigid frame and clear plastic cover. Furnish an electronic copy of final comprehensive schedules for Project.
6. Cabling Administration Drawings: Show building floor plans with cabling administration-point labeling. Identify labeling convention and show labels for telecommunications closets, backbone pathways and cables, entrance pathways and cables, terminal hardware and positions, horizontal cables, work areas and workstation terminal positions, grounding buses and pathways, and equipment grounding conductors. Follow convention of TIA/EIA-606-A. Furnish electronic record of all drawings, in software and format selected by the Owner.
7. Cable and Wire Identification:
   a. Label each cable within 4 inches (100 mm) of each termination and tap, where it is accessible in a cabinet or junction or outlet box, and elsewhere as indicated.

b. Each wire connected to building-mounted devices is not required to be numbered at device if color of wire is consistent with associated wire connected and numbered within panel or cabinet.
c. Exposed Cables and Cables in Cable Trays and Wire Troughs: Label each cable at intervals not exceeding 15 feet (4.5 m).
d. Label each terminal strip and screw terminal in each cabinet, rack, or panel.
1) Individually number wiring conductors connected to terminal strips, and identify each cable or wiring group being extended from a panel or cabinet to a building-mounted device shall be identified with name and number of particular device as shown.
2) Label each unit and field within distribution racks and frames.
e. Identification within Connector Fields in Equipment Rooms and Wiring Closets: Label each connector and each discrete unit of cable-terminating and connecting hardware. Where similar jacks and plugs are used for both voice and data communication cabling, use a different color for jacks and plugs of each service.
f. Uniquely identify and label work area cables extending from the MUTOA to the work area. These cables may not exceed the length stated on the MUTOA label.
8. Labels shall be preprinted or computer-printed type with printing area and font color that contrasts with cable jacket color but still complies with requirements in TIA/EIA-606-A.
a. Cables use flexible vinyl or polyester that flex as cables are bent.

H. Field Quality Control
1. Tests and Inspections:
a. Visually inspect UTP and optical fiber cable jacket materials for NRTL certification markings. Inspect cabling terminations in communications equipment rooms for compliance with color-coding for pin assignments, and inspect cabling connections for compliance with TIA/EIA-568-B.1.
b. Visually confirm Category 5e **OR** Category 6, **OR** Category 6e **as directed**, marking of outlets, cover plates, outlet/connectors, and patch panels.
c. Visually inspect cable placement, cable termination, grounding and bonding, equipment and patch cords, and labeling of all components.
d. Test UTP backbone copper cabling for DC loop resistance, shorts, opens, intermittent faults, and polarity between conductors. Test operation of shorting bars in connection blocks. Test cables after termination but not cross-connection.
1) Test instruments shall meet or exceed applicable requirements in TIA/EIA-568-B.2. Perform tests with a tester that complies with performance requirements in "Test Instruments (Normative)" Annex, complying with measurement accuracy specified in "Measurement Accuracy (Informative)" Annex. Use only test cords and adapters that are qualified by test equipment manufacturer for channel or link test configuration.
e. Optical Fiber Cable Tests:
1) Test instruments shall meet or exceed applicable requirements in TIA/EIA-568-B.1. Use only test cords and adapters that are qualified by test equipment manufacturer for channel or link test configuration.
2) Link End-to-End Attenuation Tests:
a) Horizontal and multimode backbone link measurements: Test at 850 or 1300 nm in 1 direction according to TIA/EIA-526-14-A, Method B, One Reference Jumper.
b) Attenuation test results for backbone links shall be less than 2.0 dB. Attenuation test results shall be less than that calculated according to equation in TIA/EIA-568-B.1.
f. UTP Performance Tests:
1) Test for each outlet and MUTOA. Perform the following tests according to TIA/EIA-568-B.1 and TIA/EIA-568-B.2:
a) Wire map.
b) Length (physical vs. electrical, and length requirements).
c) Insertion loss.

d) Near-end crosstalk (NEXT) loss.
e) Power sum near-end crosstalk (PSNEXT) loss.
f) Equal-level far-end crosstalk (ELFEXT).
g) Power sum equal-level far-end crosstalk (PSELFEXT).
h) Return loss.
i) Propagation delay.
j) Delay skew.

g. Optical Fiber Cable Performance Tests: Perform optical fiber end-to-end link tests according to TIA/EIA-568-B.1 and TIA/EIA-568-B.3.

h. Coaxial Cable Tests: Conduct tests according to Division 27 Section "Master Antenna Television System".

i. Final Verification Tests: Perform verification tests for UTP and optical fiber systems after the complete communications cabling and workstation outlet/connectors are installed.

1) Voice Tests: These tests assume that dial tone service has been installed. Connect to the network interface device at the demarcation point. Go off-hook and listen and receive a dial tone. If a test number is available, make and receive a local, long distance, and digital subscription line telephone call.

2) Data Tests: These tests assume the Information Technology Staff has a network installed and is available to assist with testing. Connect to the network interface device at the demarcation point. Log onto the network to ensure proper connection to the network.

2. Document data for each measurement. Data for submittals shall be printed in a summary report that is formatted similar to Table 10.1 in BICSI TDMM, or transferred from the instrument to the computer, saved as text files, and printed and submitted.

3. End-to-end cabling will be considered defective if it does not pass tests and inspections.

4. Prepare test and inspection reports.

END OF SECTION 26 05 19 16g

SECTION 26 05 19 16h - CONDUCTORS AND CABLES FOR ELECTRONIC SAFETY AND SECURITY

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for conductors and cables for electronic safety and security. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. UTP cabling.
b. 50/125 and 62.5/125-micrometer, multimode optical fiber cabling.
c. Coaxial cabling.
d. RS-232 cabling.
e. RS-485 cabling.
f. Low-voltage control cabling.
g. Control-circuit conductors.
h. Fire alarm wire and cable.
i. Identification products.

C. Definitions
1. BICSI: Building Industry Consulting Service International.
2. EMI: Electromagnetic interference.
3. IDC: Insulation displacement connector.
4. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control and signaling power-limited circuits.
5. Open Cabling: Passing telecommunications cabling through open space (e.g., between the studs of a wall cavity).
6. RCDD: Registered Communications Distribution Designer.

D. Performance Requirements
1. Seismic Performance: Pathways shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

E. Submittals
1. Product Data: For each type of product indicated.
a. For coaxial cable, include the following installation data for each type used:
1) Nominal OD.
2) Minimum bending radius.
3) Maximum pulling tension.
2. Shop Drawings: Cable tray layout, showing cable tray route to scale, with relationship between the tray and adjacent structural, electrical, and mechanical elements. Include the following:
a. Vertical and horizontal offsets and transitions.
b. Clearances for access above and to side of cable trays.
c. Vertical elevation of cable trays above the floor or bottom of ceiling structure.
3. Qualification Data: For qualified layout technician, installation supervisor, and field inspector.
4. Seismic Qualification Certificates: For pathways, accessories, and components, from manufacturer.

a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

5. Source quality-control reports.
6. Field quality-control reports.
7. Operation and Maintenance Data: For wire and cable to include in operation and maintenance manuals. Include the following:
   a. Allowable pulling tension of cable.
   b. Cable connectors and terminations recommended by the manufacturer.

F. Quality Assurance
1. Testing Agency Qualifications: An NRTL.
   a. Testing Agency's Field Supervisor: Currently certified by BICSI as an RCDD to supervise on-site testing.
2. Surface-Burning Characteristics: As determined by testing identical products according to ASTM E 84 by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
   a. Flame-Spread Index: 25 or less.
   b. Smoke-Developed Index: 50 **OR** 450, **as directed**, or less.
3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

G. Delivery, Storage, And Handling
1. Test cables upon receipt at Project site.
   a. Test optical fiber cable to determine the continuity of the strand end to end. Use optical-fiber flashlight or optical loss test set.
   b. Test optical fiber cable on reels. Use an optical time domain reflectometer to verify the cable length and locate cable defects, splices, and connector; include the loss value of each. Retain test data and include the record in maintenance data.
   c. Test each pair of UTP cable for open and short circuits.

H. Project Conditions
1. Do not install conductors and cables that are wet, moisture damaged, or mold damaged.
   a. Indications that wire and cables are wet or moisture damaged include, but are not limited to, discoloration and sagging of factory packing materials.
2. Environmental Limitations: Do not deliver or install UTP, optical fiber, and coaxial cables and connecting materials until wet work in spaces is complete and dry, and temporary HVAC system is operating and maintaining ambient temperature and humidity conditions at occupancy levels during the remainder of the construction period.

1.2 PRODUCTS

A. Pathways
1. Support of Open Cabling: NRTL labeled for support of Category 5e **OR** Category 6, **OR** Category 6e **as directed**, cabling, designed to prevent degradation of cable performance and pinch points that could damage cable.
   a. Support brackets with cable tie slots for fastening cable ties to brackets.
   b. Lacing bars, spools, J-hooks, and D-rings.
   c. Straps and other devices.
2. Cable Trays:

a. Cable Tray Materials: Metal, suitable for indoors, and protected against corrosion by electroplated zinc galvanizing, complying with ASTM B 633, Type 1, not less than 0.000472 inch (0.012 mm) thick **OR** hot-dip galvanizing, complying with ASTM A 123/A 123M Grade 0.55, not less than 0.002165 inch (0.055 mm) thick, **as directed**.
   1) Basket Cable Trays: 6 inches (150 mm) wide and 2 inches (50 mm) deep, **as directed**. Wire mesh spacing shall not exceed 2 by 4 inches (50 by 100 mm).
   2) Trough Cable Trays: Nominally 6 inches (150 mm), **as directed**, wide.
   3) Ladder Cable Trays: Nominally 18 inches (455 mm), **as directed**, wide, and a rung spacing of 12 inches (305 mm), **as directed**.
   4) Channel Cable Trays: One-piece construction, nominally 4 inches (100 mm), **as directed**, wide. Slot spacing shall not exceed 4-1/2 inches (115 mm) o.c.
   5) Solid-Bottom Cable Trays: One-piece construction, nominally 12 inches (305 mm), **as directed**, wide. Provide with **OR** without, **as directed**, solid covers.

3. Conduit and Boxes: Comply with requirements in Division 16 Section "Raceways and Boxes." Flexible metal conduit shall not be used, **as directed**.
4. Outlet boxes shall be no smaller than 2 inches (50 mm) wide, 3 inches (75 mm) high, and 2-1/2 inches (64 mm) deep.

B. Backboards
1. Backboards: Plywood, fire-retardant treated, **as directed**, 3/4 by 48 by 96 inches (19 by 1220 by 2440 mm). Comply with requirements for plywood backing panels in Division 06 Section "Rough Carpentry".

C. UTP Cable
1. Description: 100-ohm, 4-pair UTP, covered with a blue thermoplastic jacket.
   a. Comply with ICEA S-90-661 for mechanical properties.
   b. Comply with TIA/EIA-568-B.1 for performance specifications.
   c. Comply with TIA/EIA-568-B.2, Category 5e **OR** Category 6, **OR** Category 6e **as directed**.
   d. Listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 444 and NFPA 70 for the following types:
      1) Communications, General Purpose: Type CM or CMG; **OR** MPP, CMP, MPR, CMR, MP, or MPG, **as directed**.
      2) Communications, Plenum Rated: Type CMP **OR** MPP, **as directed**, complying with NFPA 262.
      3) Communications, Riser Rated: Type CMR; **OR** MPP, CMP, or MPR, **as directed**, complying with UL 1666.
      4) Communications, Limited Purpose: Type CMX; **OR** MPP, CMP, MPR, CMR, MP, MPG, CM, or CMG, **as directed**.
      5) Multipurpose: Type MP or MPG; **OR** MPP or MPR, **as directed**.
      6) Multipurpose, Plenum Rated: Type MPP, complying with NFPA 262.
      7) Multipurpose, Riser Rated: Type MPR **OR** MPP, **as directed**, complying with UL 1666.

D. UTP Cable Hardware
1. UTP Cable Connecting Hardware: IDC type, using modules designed for punch-down caps or tools. Cables shall be terminated with connecting hardware of the same category or higher.
2. Connecting Blocks: 110-style for Category 5e **OR** 110-style for Category 6 **OR** 66-style for Category 5e, **OR** 110-style for Category 6e **as directed**. Provide blocks for the number of cables terminated on the block, plus 25, **as directed**, percent spare. Integral with connector bodies, including plugs and jacks where indicated.

E. Optical Fiber Cable
1. Description: Multimode, 50/125 **OR** 62.5/125, **as directed**,-micrometer, 24-fiber, **as directed**, nonconductive, **as directed**, tight buffer, optical fiber cable.

a. Comply with ICEA S-83-596 for indoor cable OR ICEA S-87-640 for outside plant, as directed, for mechanical properties.
b. Comply with TIA/EIA-568-B.3 for performance specifications.
c. Comply with TIA-492AAAB **OR** TIA-492AAAA-A, **as directed**, for detailed specifications.
d. Listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 444, UL 1651, and NFPA 70 for the following types:
   1) General Purpose, Nonconductive: Type OFN or OFNG, **OR** OFNR, OFNP, **as directed**.
   2) Plenum Rated, Nonconductive: Type OFNP, complying with NFPA 262.
   3) Riser Rated, Nonconductive: Type OFNR or OFNP, complying with UL 1666.
   4) General Purpose, Conductive: Type OFC or OFCG; **OR** OFNG, OFN, OFCR, OFNR, OFCP, or OFNP, **as directed**.
   5) Plenum Rated, Conductive: Type OFCP or OFNP, complying with NFPA 262.
   6) Riser Rated, Conductive: Type OFCR; or OFNR, OFCP, or OFNP, **asa directed**, complying with UL 1666.
e. Conductive cable shall be steel **OR** aluminum, **as directed**, armored type.
f. Maximum Attenuation: 3.50 dB/km at 850 nm; 1.5 dB/km at 1300 nm.
g. Minimum Modal Bandwidth: 160 MHz-km at 850 nm; 500 MHz-km at 1300 nm.

2. Jacket:
   a. Jacket Color: Aqua for 50/125-micrometer cable **OR** Orange for 62.5/125-micrometer cable, **as directed**.
   b. Cable cordage jacket, fiber, unit, and group color shall be according to TIA-598-C.
   c. Imprinted with fiber count, fiber type, and aggregate length at regular intervals not to exceed 40 inches (1000 mm).

F. Optical Fiber Cable Hardware
1. Cable Connecting Hardware: Meet the Optical Fiber Connector Intermateability Standards (FOCIS) specifications of TIA-604-2-B, TIA-604-3-B, and TIA/EIA-604-12. Comply with TIA/EIA-568-B.3.
   a. Quick-connect, simplex and duplex, Type SC **OR** Type ST **OR** Type LC **OR** Type MT-RJ, **as directed**, connectors. Insertion loss not more than 0.75 dB.
   b. Type SFF connectors may be used in termination racks, panels, and equipment packages.

G. Coaxial Cable
1. General Coaxial Cable Requirements: Broadband type, recommended by cable manufacturer specifically for broadband data transmission applications. Coaxial cable and accessories shall have 75-ohm nominal impedance with a return loss of 20 dB maximum from 7 to 806 MHz.
2. RG-11/U: NFPA 70, Type CATV.
   a. No. 14 AWG, solid, copper-covered steel conductor.
   b. Gas-injected, foam-PE insulation.
   c. Double shielded with 100 percent aluminum polyester tape and 60 percent aluminum braid.
   d. Jacketed with sunlight-resistant, black PVC or PE.
   e. Suitable for outdoor installations in ambient temperatures ranging from minus 40 to plus 85 deg C.
3. RG59/U: NFPA 70, Type CATVR.
   a. No. 20 AWG, solid, silver-plated, copper-covered steel conductor.
   b. Gas-injected, foam-PE insulation.
   c. Triple shielded with 100 percent aluminum polyester tape and 95 percent aluminum braid; covered by aluminum foil with grounding strip.
   d. Color-coded PVC jacket.
4. RG-6/U: NFPA 70, Type CATV or CM.
   a. No. 16 AWG, solid, copper-covered steel conductor; gas-injected, foam-PE insulation.
   b. Double shielded with 100 percent aluminum-foil shield and 60 percent aluminum braid.
   c. Jacketed with black PVC or PE.

d. Suitable for indoor installations.

5. RG59/U: NFPA 70, Type CATV.
   a. No. 20 AWG, solid, copper-covered steel conductor; gas-injected, foam-PE insulation.
   b. Double shielded with 100 percent aluminum polyester tape and 40 percent aluminum braid.
   c. PVC jacket.
6. RG59/U (Plenum Rated): NFPA 70, Type CMP.
   a. No. 20 AWG, solid, copper-covered steel conductor; foam fluorinated ethylene propylene insulation.
   b. Double shielded with 100 percent aluminum-foil shield and 65 percent aluminum braid.
   c. Copolymer jacket.
7. NFPA and UL Compliance: Coaxial cables shall be listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 1655, and with NFPA 70 "Radio and Television Equipment" and "Community Antenna Television and Radio Distribution" Articles. Types are as follows:
   a. CATV Cable: Type CATV, **OR** CATVP or CATVR, **as directed**.
   b. CATV Plenum Rated: Type CATVP, complying with NFPA 262.
   c. CATV Riser Rated: Type CATVR; **OR** CATVP, CATVR, or CATV, **as directed**, complying with UL 1666.
   d. CATV Limited Rating: Type CATVX.

H. Coaxial Cable Hardware
1. Coaxial-Cable Connectors: Type BNC, 75 ohms.

I. RS-232 Cable
1. Standard Cable: NFPA 70, Type CM.
   a. Paired, 2 pairs, No. 22 AWG, stranded (7x30) tinned copper conductors.
   b. Polypropylene insulation.
   c. Individual aluminum foil-polyester tape shielded pairs with 100 percent shield coverage.
   d. PVC jacket.
   e. Pairs are cabled on common axis with No. 24 AWG, stranded (7x32) tinned copper drain wire.
   f. Flame Resistance: Comply with UL 1581.
2. Plenum-Rated Cable: NFPA 70, Type CMP.
   a. Paired, 2 pairs, No. 22 AWG, stranded (7x30) tinned copper conductors.
   b. Plastic insulation.
   c. Individual aluminum foil-polyester tape shielded pairs with 100 percent shield coverage.
   d. Plastic jacket.
   e. Pairs are cabled on common axis with No. 24 AWG, stranded (7x32) tinned copper drain wire.
   f. Flame Resistance: Comply with NFPA 262.

J. RS-485 Cable
1. Standard Cable: NFPA 70, Type CM **OR** CMG, **as directed**.
   a. Paired, 2 pairs, twisted, No. 22 AWG, stranded (7x30) tinned copper conductors.
   b. PVC insulation.
   c. Unshielded.
   d. PVC jacket.
   e. Flame Resistance: Comply with UL 1581.
2. Plenum-Rated Cable: NFPA 70, Type CMP.
   a. Paired, 2 pairs, No. 22 AWG, stranded (7x30) tinned copper conductors.
   b. Fluorinated ethylene propylene insulation.
   c. Unshielded.
   d. Fluorinated ethylene propylene jacket.
   e. Flame Resistance: NFPA 262, Flame Test.

K. Low-Voltage Control Cable

1. Paired Cable: NFPA 70, Type CMG.
   a. 1 pair, twisted, No. 16 AWG, stranded (19x29) and No. 18 AWG, stranded (19x30) tinned copper conductors.
   b. PVC insulation.
   c. Unshielded.
   d. PVC jacket.
   e. Flame Resistance: Comply with UL 1581.
2. Plenum-Rated, Paired Cable: NFPA 70, Type CMP.
   a. 1 pair, twisted, No. 16 AWG, stranded (19x29) and No. 18 AWG, stranded (19x30) tinned copper conductors.
   b. PVC insulation.
   c. Unshielded.
   d. PVC jacket.
   e. Flame Resistance: Comply with NFPA 262.

L. Control-Circuit Conductors
1. Class 1 Control Circuits: Stranded copper, Type THHN-THWN, complying with UL 83, in raceway **OR** Type XHHN, complying with UL 44, in raceway, **as directed**.
2. Class 2 Control Circuits: Stranded copper, Type THHN-THWN, complying with UL 83, in raceway **OR** power-limited cable, complying with UL 83, concealed in building finishes **OR** power-limited tray cable, complying with UL 83, in cable tray **OR** Type XHHN, complying with UL 44, in raceway, **as directed**.
3. Class 3 Remote-Control and Signal Circuits: Stranded copper, Type TW or TF, complying with UL 83.

M. Fire Alarm Wire And Cable
1. General Wire and Cable Requirements: NRTL listed and labeled as complying with NFPA 70, Article 760.
2. Signaling Line Circuits: Twisted, shielded pair, not less than **OR** No. 18 AWG **OR** size as recommended by system manufacturer, **as directed**.
   a. Circuit Integrity Cable: Twisted shielded pair, NFPA 70, Article 760, Classification CI, for power-limited fire alarm signal service Type FPL. NRTL listed and labeled as complying with UL 1424 and UL 2196 for a 2-hour rating.
3. Non-Power-Limited Circuits: Solid-copper conductors with 600-V rated, 75 deg C, color-coded insulation.
   a. Low-Voltage Circuits: No. 16 AWG, minimum.
   b. Line-Voltage Circuits: No. 12 AWG, minimum.
   c. Multiconductor Armored Cable: NFPA 70, Type MC, copper conductors, Type TFN/THHN conductor insulation, copper drain wire, copper armor with outer jacket, **as directed**, with red identifier stripe, NTRL listed for fire alarm and cable tray installation, plenum rated, and complying with requirements in UL 2196 for a 2-hour rating.

N. Identification Products
1. Comply with UL 969 for a system of labeling materials, including label stocks, laminating adhesives, and inks used by label printers.
2. Comply with requirements in Division 26 Section "Identification For Electrical Systems".

O. Source Quality Control
1. Testing Agency: Engage a qualified testing agency to evaluate cables.
2. Factory test UTP and optical fiber cables on reels according to TIA/EIA-568-B.1.
3. Factory test UTP cables according to TIA/EIA-568-B.2.
4. Factory test multimode optical fiber cables according to TIA-526-14-A and TIA/EIA-568-B.3.

5. Factory sweep test coaxial cables at frequencies from 5 MHz to 1 GHz. Sweep test shall test the frequency response, or attenuation over frequency, of a cable by generating a voltage whose frequency is varied through the specified frequency range and graphing the results.
6. Cable will be considered defective if it does not pass tests and inspections.
7. Prepare test and inspection reports.

1.3 EXECUTION

A. Installation Of Pathways
1. Cable Trays: Comply with NEMA VE 2 and TIA-569-B.
2. Comply with TIA-569-B for pull-box sizing and length of conduit and number of bends between pull points.
3. Comply with requirements in Division 26 Section "Raceway And Boxes For Electrical Systems" for installation of conduits and wireways.
4. Install manufactured conduit sweeps and long-radius elbows whenever possible.
5. Pathway Installation in Equipment Rooms:
   a. Position conduit ends adjacent to a corner on backboard where a single piece of plywood is installed or in the corner of room where multiple sheets of plywood are installed around perimeter walls of room.
   b. Install cable trays to route cables if conduits cannot be located in these positions.
   c. Secure conduits to backboard when entering room from overhead.
   d. Extend conduits 3 inches (75 mm) above finished floor.
   e. Install metal conduits with grounding bushings and connect with grounding conductor to grounding system.
6. Backboards: Install backboards with 96-inch (2440-mm) dimension vertical. Butt adjacent sheets tightly, and form smooth gap-free corners and joints.

B. Installation Of Hangers And Supports
1. Comply with requirements in Division 26 Section "Hangers And Supports For Electrical Systems" for installation of supports for pathways, conductors and cables.

C. Wiring Method
1. Install wiring in metal raceways and wireways. Conceal raceway except in unfinished spaces and as indicated. Minimum conduit size shall be 3/4 inch (21 mm). Control and data transmission wiring shall not share conduit with other building wiring systems.
2. Install wiring in raceways except in accessible indoor ceiling spaces and in interior hollow gypsum board partitions where cable may be used. Conceal raceways and wiring except in unfinished spaces and as indicated. Minimum conduit size shall be 3/4 inch (21 mm). Control and data transmission wiring shall not share conduit with other building wiring systems.
3. Install cable, concealed in accessible ceilings, walls, and floors when possible.
4. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points. Use lacing bars and distribution spools. Separate power-limited and non-power-limited conductors as recommended in writing by manufacturer. Install conductors parallel with or at right angles to sides and back of enclosure. Connect conductors that are terminated, spliced, or interrupted in any enclosure associated with intrusion system to terminal blocks. Mark each terminal according to system's wiring diagrams. Make all connections with approved crimp-on terminal spade lugs, pressure-type terminal blocks, or plug connectors.

D. Installation Of Conductors And Cables
1. Comply with NECA 1.
2. Conductors: Size according to system manufacturer's written instructions unless otherwise indicated.
3. General Requirements for Cabling:
   a. Comply with TIA/EIA-568-B.1.
   b. Comply with BICSI ITSIM, Ch. 6, "Cable Termination Practices."

c. Terminate all conductors; no cable shall contain unterminated elements. Make terminations only at indicated outlets, terminals, and cross-connect and patch panels.
d. Cables may not be spliced. Secure and support cables at intervals not exceeding 30 inches (760 mm) and not more than 6 inches (150 mm) from cabinets, boxes, fittings, outlets, racks, frames, and terminals.
e. Bundle, lace, and train conductors to terminal points without exceeding manufacturer's limitations on bending radii, but not less than radii specified in BICSI ITSIM, "Cabling Termination Practices" Chapter. Install lacing bars and distribution spools.
f. Do not install bruised, kinked, scored, deformed, or abraded cable. Do not splice cable between termination, tap, or junction points. Remove and discard cable if damaged during installation and replace it with new cable.
g. Cold-Weather Installation: Bring cable to room temperature before dereeling. Heat lamps shall not be used for heating.
h. Pulling Cable: Comply with BICSI ITSIM, Ch. 4, "Pulling Cable." Monitor cable pull tensions.

4. UTP Cable Installation: Install using techniques, practices, and methods that are consistent with Category 5e **OR** Category 6, **OR** Category 6e **as directed**, rating of components and that ensure Category 5e **OR** Category 6, **OR** Category 6e **as directed**, performance of completed and linked signal paths, end to end.
   a. Comply with TIA/EIA-568-B.2.
   b. Install 110-style IDC termination hardware unless otherwise indicated.
   c. Do not untwist UTP cables more than 1/2 inch (12 mm) from the point of termination to maintain cable geometry.
5. Optical Fiber Cable Installation:
   a. Comply with TIA/EIA-568-B.3.
   b. Cable shall be terminated on connecting hardware that is rack or cabinet mounted.
6. Outdoor Coaxial Cable Installation:
   a. Install outdoor connections in enclosures complying with NEMA 250, Type 4X. Install corrosion-resistant connectors with properly designed O-rings to keep out moisture.
   b. Attach antenna lead-in cable to support structure at intervals not exceeding 36 inches (915 mm).
7. Open-Cable Installation:
   a. Install cabling with horizontal and vertical cable guides in telecommunications spaces with terminating hardware and interconnection equipment.
   b. Suspend copper cable not in a wireway or pathway a minimum of 8 inches (200 mm) above ceilings by cable supports not more than 60 inches (1525 mm) apart.
   c. Cable shall not be run through structural members or in contact with pipes, ducts, or other potentially damaging items.
8. Installation of Cable Routed Exposed under Raised Floors:
   a. Install plenum-rated cable only.
   b. Install cabling after the flooring system has been installed in raised floor areas.
   c. Coil cable 72 inches (1830 mm) long shall be neatly coiled not less than 12 inches (300 mm) in diameter below each feed point.
9. Separation from EMI Sources:
   a. Comply with BICSI TDMM and TIA-569-B recommendations for separating unshielded copper voice and data communication cable from potential EMI sources, including electrical power lines and equipment.
   b. Separation between open communications cables or cables in nonmetallic raceways and unshielded power conductors and electrical equipment shall be as follows:
      1) Electrical Equipment Rating Less Than 2 kVA: A minimum of 5 inches (127 mm).
      2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of 12 inches (300 mm).
      3) Electrical Equipment Rating More Than 5 kVA: A minimum of 24 inches (600 mm).

c. Separation between communications cables in grounded metallic raceways and unshielded power lines or electrical equipment shall be as follows:
   1) Electrical Equipment Rating Less Than 2 kVA: A minimum of 2-1/2 inches (64 mm).
   2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of 6 inches (150 mm).
   3) Electrical Equipment Rating More Than 5 kVA: A minimum of 12 inches (300 mm).
d. Separation between communications cables in grounded metallic raceways and power lines and electrical equipment located in grounded metallic conduits or enclosures shall be as follows:
   1) Electrical Equipment Rating Less Than 2 kVA: No requirement.
   2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of 3 inches (75 mm).
   3) Electrical Equipment Rating More Than 5 kVA: A minimum of 6 inches (150 mm).
e. Separation between Cables and Electrical Motors and Transformers, 5 kVA or HP and Larger: A minimum of 48 inches (1200 mm).
f. Separation between Cables and Fluorescent Fixtures: A minimum of 5 inches (127 mm).

E. Fire Alarm Wiring Installation
1. Comply with NECA 1 and NFPA 72.
2. Wiring Method: Install wiring in metal raceway according to Division 26 Section "Raceway And Boxes For Electrical Systems".
   a. Install plenum cable in environmental air spaces, including plenum ceilings.
   b. Fire alarm circuits and equipment control wiring associated with the fire alarm system shall be installed in a dedicated raceway system. This system shall not be used for any other wire or cable.
3. Wiring Method:
   a. Cables and raceways used for fire alarm circuits, and equipment control wiring associated with the fire alarm system, may not contain any other wire or cable.
   b. Fire-Rated Cables: Use of 2-hour, fire-rated fire alarm cables, NFPA 70, Types MI and CI, is **OR** is not, **as directed**, permitted.
   c. Signaling Line Circuits: Power-limited fire alarm cables may **OR** shall not, **as directed**, be installed in the same cable or raceway as signaling line circuits.
4. Wiring within Enclosures: Separate power-limited and non-power-limited conductors as recommended by manufacturer. Install conductors parallel with or at right angles to sides and back of the enclosure. Bundle, lace, and train conductors to terminal points with no excess. Connect conductors that are terminated, spliced, or interrupted in any enclosure associated with the fire alarm system to terminal blocks. Mark each terminal according to the system's wiring diagrams. Make all connections with approved crimp-on terminal spade lugs, pressure-type terminal blocks, or plug connectors.
5. Cable Taps: Use numbered terminal strips in junction, pull, and outlet boxes, cabinets, or equipment enclosures where circuit connections are made.
6. Color-Coding: Color-code fire alarm conductors differently from the normal building power wiring. Use one color-code for alarm circuit wiring and another for supervisory circuits. Color-code audible alarm-indicating circuits differently from alarm-initiating circuits. Use different colors for visible alarm-indicating devices. Paint fire alarm system junction boxes and covers red.
7. Risers: Install at least two vertical cable risers to serve the fire alarm system. Separate risers in close proximity to each other with a minimum one-hour-rated wall, so the loss of one riser does not prevent the receipt or transmission of signals from other floors or zones.
8. Wiring to Remote Alarm Transmitting Device: 1-inch (25-mm) conduit between the fire alarm control panel and the transmitter. Install number of conductors and electrical supervision for connecting wiring as needed to suit monitoring function.

F. Power And Control-Circuit Conductors
1. 120-V Power Wiring: Install according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables" unless otherwise indicated.
2. Minimum Conductor Sizes:
   a. Class 1 remote-control and signal circuits, No. 14 AWG.

b. Class 2 low-energy, remote-control and signal circuits, No. 16 AWG.
c. Class 3 low-energy, remote-control, alarm and signal circuits, No. 12 AWG.

G. Connections
1. Comply with requirements in Division 28 Section "Perimeter Security Systems" for connecting, terminating, and identifying wires and cables.
2. Comply with requirements in Division 28 Section "Intrusion Detection" for connecting, terminating, and identifying wires and cables.
3. Comply with requirements in Division 28 Section "Access Control" for connecting, terminating, and identifying wires and cables.
4. Comply with requirements in Division 28 Section "Video Surveillance" for connecting, terminating, and identifying wires and cables.
5. Comply with requirements in Division 28 Section "Plc Electronic Detention Monitoring And Control Systems" for connecting, terminating, and identifying wires and cables.
6. Comply with requirements in Division 28 Section(s) "Digital, Addressable Fire-alarm System" OR "Zoned (dc Loop) Fire-alarm System", **as directed**, for connecting, terminating, and identifying wires and cables.
7. Comply with requirements in Division 28 Section "Refrigerant Detection And Alarm" for connecting, terminating, and identifying wires and cables.

H. Firestopping
1. Comply with requirements in Division 07 Section "Penetration Firestopping".
2. Comply with TIA-569-B, "Firestopping" Annex A.
3. Comply with BICSI TDMM, "Firestopping Systems" Article.

I. Grounding
1. For communications wiring, comply with ANSI-J-STD-607-A and with BICSI TDMM, "Grounding, Bonding, and Electrical Protection" Chapter.
2. For low-voltage wiring and cabling, comply with requirements in Division 26 Section "Grounding And Bonding For Electrical Systems".

J. Identification
1. Identify system components, wiring, and cabling complying with TIA/EIA-606-A. Comply with requirements for identification specified in Division 26 Section "Identification For Electrical Systems".

K. Field Quality Control
1. Perform tests and inspections.
2. Tests and Inspections:
   a. Visually inspect UTP and optical fiber cable jacket materials for NRTL certification markings. Inspect cabling terminations to confirm color-coding for pin assignments, and inspect cabling connections to confirm compliance with TIA/EIA-568-B.1.
   b. Visually inspect cable placement, cable termination, grounding and bonding, equipment and patch cords, and labeling of all components.
   c. Test UTP cabling for DC loop resistance, shorts, opens, intermittent faults, and polarity between conductors. Test operation of shorting bars in connection blocks. Test cables after termination but not cross connection.
      1) Test instruments shall meet or exceed applicable requirements in TIA/EIA-568-B.2. Perform tests with a tester that complies with performance requirements in "Test Instruments (Normative)" Annex, complying with measurement accuracy specified in "Measurement Accuracy (Informative)" Annex. Use only test cords and adapters that are qualified by test equipment manufacturer for channel or link test configuration.
   d. Optical Fiber Cable Tests:

1) Test instruments shall meet or exceed applicable requirements in TIA/EIA-568-B.1. Use only test cords and adapters that are qualified by test equipment manufacturer for channel or link test configuration.
2) Link End-to-End Attenuation Tests:
   a) Multimode Link Measurements: Test at 850 or 1300 nm in 1 direction according to TIA-526-14-A, Method B, One Reference Jumper.
   b) Attenuation test results for links shall be less than 2.0 dB. Attenuation test results shall be less than that calculated according to equation in TIA/EIA-568-B.1.

e. Coaxial Cable Tests: Comply with requirements in Division 27 Section "Master Antenna Television System".

3. Document data for each measurement. Print data for submittals in a summary report that is formatted using Table 10.1 in BICSI TDMM as a guide, or transfer the data from the instrument to the computer, save as text files, print, and submit.
4. End-to-end cabling will be considered defective if it does not pass tests and inspections.
5. Prepare test and inspection reports.

END OF SECTION 26 05 19 16h

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Task	Specification	Specification Description
26 05 19 16	01 22 16 00	No Specification Required
26 05 19 16	26 05 13 00	Conductors And Cables
26 05 19 16	26 05 13 00a	Undercarpet Cables
26 05 19 16	26 05 13 00b	Medium-Voltage Cables
26 05 23 00	26 05 19 16d	Control-Voltage Electrical Power Cables

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SECTION 26 05 26 00 - LIGHTNING PROTECTION

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for lightning protection. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section includes lightning protection for structures, structure elements and building site components.

C. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings: For air terminals and mounting accessories.
   a. Layout of the lightning protection system, along with details of the components to be used in the installation.
   b. Include indications for use of raceway, data on how concealment requirements will be met, and calculations required by NFPA 780 for bonding of grounded and isolated metal bodies.
3. Qualification Data: For qualified Installer and manufacturer. Include data on listing or certification by UL.
4. Certification, signed by Contractor, that roof adhesive is approved by manufacturer of roofing material.
5. Field quality-control reports.
6. Comply with recommendations in NFPA 780, Annex D, "Inspection and Maintenance of Lightning Protection Systems," for maintenance of the lightning protection system.
7. Other Informational Submittals: Plans showing dimensioned as-built locations of grounding features, including the following:
   a. Ground rods.
   b. Ground loop conductor.

D. Quality Assurance
1. Installer Qualifications: Certified by UL or LPI as a Master Installer/Designer, trained and approved for installation of units required for this Project.
2. System Certificate:
   a. UL Master Label.
      OR
      LPI System Certificate.
      OR
      UL Master Label Recertification.
3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 780, "Definitions" Article.

E. Coordination
1. Coordinate installation of lightning protection with installation of other building systems and components, including electrical wiring, supporting structures and building materials, metal bodies requiring bonding to lightning protection components, and building finishes.
2. Coordinate installation of air terminals attached to roof systems with roofing manufacturer and Installer.
3. Flashings of through-roof assemblies shall comply with roofing manufacturers' specifications.

1.2 PRODUCTS

A. Lightning Protection System Components
1. Comply with UL 96 and NFPA 780, **as directed**.
2. Roof-Mounted Air Terminals: NFPA 780, Class I **OR** Class II, **as directed**, aluminum **OR** copper, **as directed**, unless otherwise indicated.
   a. Air Terminals More than 24 Inches (600 mm) Long: With brace attached to the terminal at not less than half the height of the terminal.
   b. Single-Membrane, Roof-Mounted Air Terminals: Designed specifically for single-membrane roof system materials. Comply with requirements in Division 07.
3. Main and Bonding Conductors: Copper **OR** Aluminum, **as directed**.
4. Ground Loop Conductor: The same size and type as the main conductor except tinned.
5. Ground Rods: Copper-clad **OR** Zinc-coated **OR** Stainless, **as directed**, steel, sectional type, **as directed**; 3/4 inch (19 mm) in diameter by 10 feet (3 m) **OR** 5/8 inch (16 mm) in diameter by 96 inches (2400 mm), **as directed**, long.
6. Heavy-Duty, Stack-Mounted, Lightning Protection Components: Stainless steel **OR** Solid copper **OR** Monel metal **OR** Lead sheathed, **as directed**.

1.3 EXECUTION

A. Installation
1. Install lightning protection components and systems according to UL 96A and NFPA 780.
2. Install conductors with direct paths from air terminals to ground connections. Avoid sharp bends.
3. Conceal the following conductors:
   a. System conductors.
   b. Down conductors.
   c. Interior conductors.
   d. Conductors within normal view of exterior locations at grade within 200 feet (60 m) of building.
4. Cable Connections: Use crimped or bolted connections for all conductor splices and connections between conductors and other components. Use exothermic-welded connections in underground portions of the system.
   OR
   Cable Connections: Use exothermic-welded connections for all conductor splices and connections between conductors and other components.
   a. Exception: In single-ply membrane roofing, exothermic-welded connections may be used only below the roof level.
5. Air Terminals on Single-Ply Membrane Roofing: Comply with roofing membrane and adhesive manufacturer's written instructions.
6. Bond extremities of vertical metal bodies exceeding 60 feet (18 m) in length to lightning protection components.
7. Ground Loop: Install ground-level, potential equalization conductor and extend around the perimeter of structure **OR** area or item indicated, **as directed**.
   a. Bury ground ring not less than 24 inches (600 mm) from building foundation.
   b. Bond ground terminals to the ground loop.
   c. Bond grounded building systems to the ground loop conductor within 12 feet (3.6 m) of grade level.
8. Bond lightning protection components with intermediate-level interconnection loop conductors to grounded metal bodies of building at 60-foot (18-m) intervals.

B. Corrosion Protection
1. Do not combine materials that can form an electrolytic couple that will accelerate corrosion in the presence of moisture unless moisture is permanently excluded from junction of such materials.

2. Use conductors with protective coatings where conditions cause deterioration or corrosion of conductors.

C. Field Quality Control
1. Notify the Owner at least 48 hours in advance of inspection before concealing lightning protection components.
2. UL Inspection: Meet requirements to obtain a UL Master Label for system.
OR
LPI System Inspection: Meet requirements to obtain an LPI System Certificate.

END OF SECTION 26 05 26 00

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SECTION 26 05 26 00a - GROUNDING AND BONDING

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for grounding and bonding. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes methods and materials for grounding systems and equipment, plus the following special applications, **as directed**:
   a. Overhead-lines grounding.
   b. Underground distribution grounding.
   c. Common ground bonding with lightning protection system.

C. Submittals
1. Product Data: For each type of product indicated.
2. Informational Submittals: Plans showing dimensioned as-built locations of grounding features specified in "Field Quality Control" Article, including the following:
   a. Test wells.
   b. Ground rods.
   c. Ground rings.
   d. Grounding arrangements and connections for separately derived systems.
   e. Grounding for sensitive electronic equipment.
3. Qualification Data: For qualified testing agency and testing agency's field supervisor.
4. Field quality-control test reports.
5. Operation and Maintenance Data: For grounding to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 01 Section "Operation And Maintenance Data", include the following:
   a. Instructions for periodic testing and inspection of grounding features at test wells **OR** ground rings **OR** grounding connections for separately derived systems**, as directed** based on NETA MTS **OR** NFPA 70B**, as directed.**
      1) Tests shall determine if ground-resistance or impedance values remain within specified maximums, and instructions shall recommend corrective action if values do not.
      2) Include recommended testing intervals.

D. Quality Assurance
1. Testing Agency Qualifications: Member company of NETA or an NRTL.
   a. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.
2. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
3. Comply with UL 467 for grounding and bonding materials and equipment.

1.2 PRODUCTS

A. Conductors
1. Insulated Conductors: Copper **OR** Tinned-copper, **as directed**, wire or cable insulated for 600 V unless otherwise required by applicable Code or authorities having jurisdiction.
2. Bare Copper Conductors:

a. Solid Conductors: ASTM B 3.
b. Stranded Conductors: ASTM B 8.
c. Tinned Conductors: ASTM B 33.
d. Bonding Cable: 28 kcmil, 14 strands of No. 17 AWG conductor, 1/4 inch (6 mm) in diameter.
e. Bonding Conductor: No. 4 or No. 6 AWG, stranded conductor.
f. Bonding Jumper: Copper tape, braided conductors, terminated with copper ferrules; 1-5/8 inches (41 mm) wide and 1/16 inch (1.6 mm) thick.
g. Tinned Bonding Jumper: Tinned-copper tape, braided conductors, terminated with copper ferrules; 1-5/8 inches (41 mm) wide and 1/16 inch (1.6 mm) thick.

3. Bare Grounding Conductor and Conductor Protector for Wood Poles:
   a. No. 4 AWG minimum, soft-drawn copper.
   b. Conductor Protector: Half-round PVC or wood molding. If wood, use pressure-treated fir or cypress or cedar.
4. Grounding Bus: Predrilled rectangular bars of annealed copper, 1/4 by 2 inches (6 by 50 mm), **as directed**, in cross section, with 9/32-inch (7.14-mm) holes spaced 1-1/8 inches (28 mm) apart. Stand-off insulators for mounting shall comply with UL 891 for use in switchboards, 600 V. Lexan or PVC, impulse tested at 5000 V.

B. Connectors
1. Listed and labeled by a nationally recognized testing laboratory acceptable to authorities having jurisdiction for applications in which used, and for specific types, sizes, and combinations of conductors and other items connected.
2. Bolted Connectors for Conductors and Pipes: Copper or copper alloy, bolted pressure-type, with at least two bolts.
   a. Pipe Connectors: Clamp type, sized for pipe.
3. Welded Connectors: Exothermic-welding kits of types recommended by kit manufacturer for materials being joined and installation conditions.
4. Bus-bar Connectors: Mechanical type, cast silicon bronze, solderless compression **OR** exothermic-type wire terminals, **as directed**, and long-barrel, two-bolt connection to ground bus bar.

C. Grounding Electrodes
1. Ground Rods: Copper-clad **OR** Zinc-coated **OR** Stainless, **as directed,** steel, sectional type, **as directed**; 3/4 inch by10 feet (19 mm by 3 m) **OR** 5/8 by 96 inches (16 by 2400 mm), **as directed,** in diameter.
2. Chemical-Enhanced Grounding Electrodes: Copper tube, straight or L-shaped, charged with nonhazardous electrolytic chemical salts.
   a. Termination: Factory-attached No. 4/0 AWG bare conductor at least 48 inches (1200 mm) long.
   b. Backfill Material: Electrode manufacturer's recommended material.

1.3 EXECUTION

A. Applications
1. Conductors: Install solid conductor for No. 8 AWG and smaller, and stranded conductors for No. 6 AWG and larger, unless otherwise indicated.
2. Underground Grounding Conductors: Install bare copper **OR** tinned-copper, **as directed**, conductor, No. 2/0 AWG minimum. Bury at least 24 inches (600 mm) below grade.
   a. Bury at least 24 inches (600 mm) below grade.
   b. Duct-Bank Grounding Conductor: Bury 12 inches (300 mm) above duct bank when indicated as part of duct-bank installation.
3. Isolated Grounding Conductors: Green-colored insulation with continuous yellow stripe. On feeders with isolated ground, identify grounding conductor where visible to normal inspection,

with alternating bands of green and yellow tape, with at least three bands of green and two bands of yellow.

4. Grounding Bus: Install in electrical and telephone equipment rooms, in rooms housing service equipment, and elsewhere as indicated.
   a. Install bus on insulated spacers 1 inch (25 mm), minimum, from wall 6 inches (150 mm) above finished floor, unless otherwise indicated.
   b. Where indicated on both sides of doorways, route bus up to top of door frame, across top of doorway, down to specified height above floor, and connect to horizontal bus.
5. Conductor Terminations and Connections:
   a. Pipe and Equipment Grounding Conductor Terminations: Bolted connectors.
   b. Underground Connections: Welded connectors, except at test wells and as otherwise indicated.
   c. Connections to Ground Rods at Test Wells: Bolted connectors.
   d. Connections to Structural Steel: Welded connectors.

B. Grounding Overhead Lines
1. Comply with IEEE C2 grounding requirements.
2. Install 2 parallel ground rods if resistance to ground by a single, ground-rod electrode exceeds 25 ohms.
3. Drive ground rods until tops are 12 inches (300 mm) below finished grade in undisturbed earth.
4. Ground-Rod Connections: Install bolted connectors for underground connections and connections to rods.
5. Lightning Arrester Grounding Conductors: Separate from other grounding conductors.
6. Secondary Neutral and Transformer Enclosure: Interconnect and connect to grounding conductor.
7. Protect grounding conductors running on surface of wood poles with molding extended from grade level up to and through communication service and transformer spaces.

C. Grounding Underground Distribution System Components
1. Comply with IEEE C2 grounding requirements.
2. Grounding Manholes and Handholes: Install a driven ground rod through manhole or handhole floor, close to wall, and set rod depth so 4 inches (100 mm) will extend above finished floor. If necessary, install ground rod before manhole is placed and provide No. 1/0 AWG bare, tinned-copper conductor from ground rod into manhole through a waterproof sleeve in manhole wall. Protect ground rods passing through concrete floor with a double wrapping of pressure-sensitive insulating tape or heat-shrunk insulating sleeve from 2 inches (50 mm) above to 6 inches (150 mm) below concrete. Seal floor opening with waterproof, nonshrink grout.
3. Grounding Connections to Manhole Components: Bond exposed-metal parts such as inserts, cable racks, pulling irons, ladders, and cable shields within each manhole or handhole, to ground rod or grounding conductor. Make connections with No. 4 AWG minimum, stranded, hard-drawn copper bonding conductor. Train conductors level or plumb around corners and fasten to manhole walls. Connect to cable armor and cable shields as recommended by manufacturer of splicing and termination kits.
4. Pad-Mounted Transformers and Switches: Install two ground rods and ground ring around the pad. Ground pad-mounted equipment and noncurrent-carrying metal items associated with substations by connecting them to underground cable and grounding electrodes. Install tinned-copper conductor not less than No. 2 AWG for ground ring and for taps to equipment grounding terminals. Bury ground ring not less than 6 inches (150 mm) from the foundation.

D. Equipment Grounding
1. Install insulated equipment grounding conductors with all feeders and branch circuits.
2. Install insulated equipment grounding conductors with the following items, in addition to those required by NFPA 70:
   a. Feeders and branch circuits.
   b. Lighting circuits.
   c. Receptacle circuits.

d. Single-phase motor and appliance branch circuits.
e. Three-phase motor and appliance branch circuits.
f. Flexible raceway runs.
g. Armored and metal-clad cable runs.
h. Busway Supply Circuits: Install insulated equipment grounding conductor from grounding bus in the switchgear, switchboard, or distribution panel to equipment grounding bar terminal on busway.
i. Computer and Rack-Mounted Electronic Equipment Circuits: Install insulated equipment grounding conductor in branch-circuit runs from equipment-area power panels and power-distribution units.
j. X-Ray Equipment Circuits: Install insulated equipment grounding conductor in circuits supplying x-ray equipment.

3. Air-Duct Equipment Circuits: Install insulated equipment grounding conductor to duct-mounted electrical devices operating at 120 V and more, including air cleaners, heaters, dampers, humidifiers, and other duct electrical equipment. Bond conductor to each unit and to air duct and connected metallic piping.
4. Water Heater, Heat-Tracing, and Antifrost Heating Cables: Install a separate insulated equipment grounding conductor to each electric water heater and heat-tracing cable. Bond conductor to heater units, piping, connected equipment, and components.
5. Isolated Grounding Receptacle Circuits: Install an insulated equipment grounding conductor connected to the receptacle grounding terminal. Isolate conductor from raceway and from panelboard grounding terminals. Terminate at equipment grounding conductor terminal of the applicable derived system or service, unless otherwise indicated.
6. Isolated Equipment Enclosure Circuits: For designated equipment supplied by a branch circuit or feeder, isolate equipment enclosure from supply circuit raceway with a nonmetallic raceway fitting listed for the purpose. Install fitting where raceway enters enclosure, and install a separate insulated equipment grounding conductor. Isolate conductor from raceway and from panelboard grounding terminals. Terminate at equipment grounding conductor terminal of the applicable derived system or service, unless otherwise indicated.
7. Signal and Communication Equipment: For telephone, alarm, voice and data, and other communication equipment, provide No. 4 AWG minimum insulated grounding conductor in raceway from grounding electrode system to each service location, terminal cabinet, wiring closet, and central equipment location.
   a. Service and Central Equipment Locations and Wiring Closets: Terminate grounding conductor on a 1/4-by-2-by-12-inch (6-by-50-by-300-mm) grounding bus.
   b. Terminal Cabinets: Terminate grounding conductor on cabinet grounding terminal.
8. Metal and Wood Poles Supporting Outdoor Lighting Fixtures: Install grounding electrode and a separate insulated equipment grounding conductor in addition to grounding conductor installed with branch-circuit conductors.

E. Installation
1. Grounding Conductors: Route along shortest and straightest paths possible, unless otherwise indicated or required by Code. Avoid obstructing access or placing conductors where they may be subjected to strain, impact, or damage.
2. Common Ground Bonding with Lightning Protection System: Comply with NFPA 780 and UL 96 when interconnecting with lightning protection system. Bond electrical power system ground directly to lightning protection system grounding conductor at closest point to electrical service grounding electrode. Use bonding conductor sized same as system grounding electrode conductor, and install in conduit.
3. Ground Rods: Drive rods until tops are 2 inches (50 mm) below finished floor or final grade, unless otherwise indicated.
   a. Interconnect ground rods with grounding electrode conductor below grade and as otherwise indicated. Make connections without exposing steel or damaging coating, if any.

b. For grounding electrode system, install at least three rods spaced at least one-rod length from each other and located at least the same distance from other grounding electrodes, and connect to the service grounding electrode conductor.

4. Test Wells: Ground rod driven through drilled hole in bottom of handhole. Handholes are specified in Division 26 Section "Underground Ducts And Raceways For Electrical Systems" and shall be at least 12 inches (300 mm) deep, with cover.
   a. Test Wells: Install at least one test well for each service, unless otherwise indicated. Install at the ground rod electrically closest to service entrance. Set top of test well flush with finished grade or floor.
5. Bonding Straps and Jumpers: Install in locations accessible for inspection and maintenance, except where routed through short lengths of conduit.
   a. Bonding to Structure: Bond straps directly to basic structure, taking care not to penetrate any adjacent parts.
   b. Bonding to Equipment Mounted on Vibration Isolation Hangers and Supports: Install so vibration is not transmitted to rigidly mounted equipment.
   c. Use exothermic-welded connectors for outdoor locations, but if a disconnect-type connection is required, use a bolted clamp.
6. Grounding and Bonding for Piping:
   a. Metal Water Service Pipe: Install insulated copper grounding conductors, in conduit, from building's main service equipment, or grounding bus, to main metal water service entrances to building. Connect grounding conductors to main metal water service pipes, using a bolted clamp connector or by bolting a lug-type connector to a pipe flange, using one of the lug bolts of the flange. Where a dielectric main water fitting is installed, connect grounding conductor on street side of fitting. Bond metal grounding conductor conduit or sleeve to conductor at each end.
   b. Water Meter Piping: Use braided-type bonding jumpers to electrically bypass water meters. Connect to pipe with a bolted connector.
   c. Bond each aboveground portion of gas piping system downstream from equipment shutoff valve.
7. Bonding Interior Metal Ducts: Bond metal air ducts to equipment grounding conductors of associated fans, blowers, electric heaters, and air cleaners. Install tinned bonding jumper to bond across flexible duct connections to achieve continuity.
8. Grounding for Steel Building Structure: Install a driven ground rod at base of each corner column and at intermediate exterior columns at distances not more than 60 feet (18 m) apart.
9. Ground Ring: Install a grounding conductor, electrically connected to each building structure ground rod and to each steel column **OR** indicated item, **as directed**, extending around the perimeter of building **OR** area or item indicated, **as directed**.
   a. Install tinned-copper conductor not less than No. 2/0 AWG for ground ring and for taps to building steel.
   b. Bury ground ring not less than 24 inches (600 mm) from building foundation.
10. Ufer Ground (Concrete-Encased Grounding Electrode): Fabricate according to NFPA 70, using a minimum of 20 feet (6 m) of bare copper conductor not smaller than No. 4 AWG.
    a. If concrete foundation is less than 20 feet (6 m) long, coil excess conductor within base of foundation.
    b. Bond grounding conductor to reinforcing steel in at least four locations and to anchor bolts. Extend grounding conductor below grade and connect to building grounding grid or to grounding electrode external to concrete.

F. Labeling
1. Comply with requirements in Division 26 Section "Identification For Electrical Systems" for instruction signs. The label or its text shall be green.
2. Install labels at the telecommunications bonding conductor and grounding equalizer and at the grounding electrode conductor where exposed.
   a. Label Text: "If this connector or cable is loose or if it must be removed for any reason, notify the facility manager."

G. Field Quality Control
1. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
2. Tests and Inspections:
   a. After installing grounding system but before permanent electrical circuits have been energized, test for compliance with requirements.
   b. Test completed grounding system at each location where a maximum ground-resistance level is specified, at service disconnect enclosure grounding terminal, and at ground test wells.
      1) Measure ground resistance not less than two full days after last trace of precipitation and without soil being moistened by any means other than natural drainage or seepage and without chemical treatment or other artificial means of reducing natural ground resistance.
      2) Perform tests by fall-of-potential method according to IEEE 81.
   c. Prepare dimensioned drawings locating each test well, ground rod and ground rod assembly, and other grounding electrodes. Identify each by letter in alphabetical order, and key to the record of tests and observations. Include the number of rods driven and their depth at each location, and include observations of weather and other phenomena that may affect test results. Describe measures taken to improve test results.
3. Report measured ground resistances that exceed the following values:
   a. Power and Lighting Equipment or System with Capacity 500 kVA and Less: 10 ohms.
   b. Power and Lighting Equipment or System with Capacity 500 to 1000 kVA: 5 ohms.
   c. Power and Lighting Equipment or System with Capacity More Than 1000 kVA: 3 ohms.
   d. Power Distribution Units or Panelboards Serving Electronic Equipment: 1 **OR** 3, **as directed,** ohm(s).
   e. Substations and Pad-Mounted Equipment: 5 ohms.
   f. Manhole Grounds: 10 ohms.
4. Excessive Ground Resistance: If resistance to ground exceeds specified values, notify the Owner promptly and include recommendations to reduce ground resistance.

END OF SECTION 26 05 26 00a

SECTION 26 05 26 00b - OVERHEAD ELECTRICAL DISTRIBUTION

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for overhead electrical distribution. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Conductors, connectors, and splices.
b. Poles and crossarms.
c. Hardware and accessories.
d. Surge arresters.
e. Cutouts, switches, and fuses.
f. Pole-mounted distribution transformers.
g. Primary metering equipment.

C. Definitions
1. BIL: Basic impulse level, stated in kilovolts.
2. RUS: Department of Agriculture, Rural Utilities Service.
3. Sag: The distance measured vertically from a conductor to the straight line joining its two points of support, measured at the midpoint of the span, unless otherwise indicated.
a. Final Sag: The sag of a conductor under specified conditions of loading and temperature applied after it has been subjected, for an appreciable period, to the loading prescribed for the loading district in which it is situated, or equivalent loading, and the loading removed. Final sag includes the effect of inelastic deformation (creep).
b. Initial Unloaded Sag: The sag of a conductor before the application of an external load.
4. Secondary: Conductors and components for circuits operating at the utilization voltage of 600 V or less.
5. Service: Set of insulated conductors extending from a pole to the metering point or service entrance connection at the location of utilization of electricity.

D. Submittals
1. Product Data: For each type of product indicated. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
2. Qualification Data: For qualified manufacturer **OR** testing agency, **as directed**.
3. Material Certificates: For the following items, from manufacturers:
a. Wood poles.
b. Concrete poles.
c. Wood crossarms.
4. Listing Documentation: Indicate that products comply with RUS listing requirements specified in "Quality Assurance" Article.
a. Time-Current Coordination Curves: Illustrate optimum coordination of protective devices involved in the Work of this Section.
b. Source quality-control test reports.
5. Field quality-control reports.
6. Operation and Maintenance Data: For switches **OR** transformers, **as directed**, to include in emergency, operation, and maintenance manuals.
7. Survey records for locations of pole, anchors, and other features for inclusion in Project Record Documents.

E. Quality Assurance
1. Concrete Pole Manufacturer Qualifications: Certified by PCI as a qualified manufacturer of concrete utility poles of type and size indicated for this Project.
2. Inspection Agency Qualifications for Pole and Crossarm Inspection: An independent agency, acceptable to authorities having jurisdiction, qualified to conduct inspections indicated.
3. Testing Agency Qualifications: Member company of NETA or an NRTL.
4. Testing Agency's Field Supervisor: Currently certified by NETA or an NRTL.
5. Treatment Technician Qualifications for Field Treatment of Wood Poles and Crossarms: Certified by authorities having jurisdiction over environmental protection at the location of Project for field application of chemicals required.
6. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
7. Overhead-Line Components, Devices, and Accessories: Currently listed in RUS Informational Publication 202-1 without restriction for the intended application.
8. Comply with IEEE C2 **OR** CPUC General Order 95, **as directed**, except where stricter requirements are indicated or where local requirements that are stricter apply.
9. Strength of Line and Line Components Selected by Contractor: Provide grades of construction and strength required by IEEE C2 for conditions encountered at Project site for heavy **OR** medium **OR** light, **as directed**, line loading unless otherwise indicated.

F. Delivery, Storage, And Handling
1. Wood Pole Storage and Handling: Comply with ATIS O5.1. Do not use pointed handling tools capable of producing indentations greater than 1 inch (25 mm).

G. Project Conditions
1. Interruption of Existing Service: Do not interrupt service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary service according to requirements indicated:
   a. Notify Owner no fewer than two days in advance of proposed interruption of service.
   b. Do not proceed with interruption of service without Owner's written permission.

H. Coordination
1. Coordinate with utility supplying electricity to lines specified in this Section, and make final connections **OR** arrangements for final connections by utility, **as directed**.
2. Coordinate with those responsible for voice **OR** data **OR** video, **as directed**, systems that will have cables supported by poles installed according to this Section.

1.2 PRODUCTS

A. Conductors, Connectors, And Splices
1. Conductor Type AAC: Bare **OR** Bare and covered, **as directed**, all-aluminum, Alloy 1350-H19, complying with ASTM B 230/B 230M and ASTM B 231/B 231M.
   OR
   Conductor Type AAAC: Bare **OR** Bare and covered, **as directed**, all-aluminum-alloy, Alloy 6201-T81, complying with ASTM B 398/B 398M and ASTM B 399/B 399M.
   OR
   Conductor Type ACSR: Bare **OR** Bare and covered, **as directed**, aluminum conductor, steel reinforced, complying with ASTM B 232/B 232M.
   OR
   Conductor Type CU: Bare **OR** Bare and covered, **as directed**, hard-drawn copper, complying with ASTM B 1 and ASTM B 8.
2. Conductor Covering: UV resistant, complying with ICEA-S-70-547. HDPE **OR** XLP, **as directed**, 150 mils (3.81 mm) thick.

3. Self-Supported, Multiconductor, Insulated Medium-Voltage Wiring: Factory-assembled, messenger-supported type, listed under UL 1072 as sunlight-resistant Type MV cable for cable tray use.
   a. Conductors: Aluminum, Alloy 1350, complying with ASTM B 230/B 230M and ASTM B 231/B 231M **OR** Hard-drawn copper, complying with ASTM B 1 and ASTM B 8, **as directed**; stranded for No. 2 AWG and larger.
   b. Conductor Insulation: XLP, complying with NEMA WC 70/ICEA S-95-658 **OR** EPR, complying with NEMA WC 70/ICEA S-95-658, **as directed**.
   c. Insulation Level: 100 **OR** 133, **as directed**, percent of rated circuit line-to-line voltage.
   d. Conductor Shield: Extruded, nonconducting, thermoset material, complying with NEMA WC 70/ICEA S-95-658; 18-mil (0.046-mm) minimum thickness.
   e. Insulation Shield: Include the following two components:
      1) Nonmetallic conducting, material complying with NEMA WC 70/ICEA S-95-658 and UL 1072, extruded over, and free stripping from the insulation.
      2) Metallic Tape Shield: Bare copper, 5-mil (0.127-mm) minimum thickness, helically applied with a 15 percent minimum overlap.
   f. Conductor Jacket: Extruded, chlorosulfonated-polyethylene-based material, complying with NEMA WC 70/ICEA S-95-658.
   g. Messenger: Copper **OR** Composite copper and copper, **as directed**,-clad steel.
   h. Conductor Support Strap: Copper strap, wound around conductors and messenger the full length of the cable.
4. Secondary-Voltage Line Conductors: Aluminum conductor, steel **reinforced**, complying with ASTM B 232/B 232M **OR** Covered aluminum conductor, steel reinforced, complying with ICEA S-70-547, with HDPE or XLP covering, **as directed**, 60 mils (1.52 mm) thick.
   OR
   Secondary-Voltage Line Conductors: Bare hard-drawn copper, complying with ASTM B 1 and ASTM B 8 **OR** Covered hard-drawn copper, complying with ICEA S-70-547, with HDPE or XLP covering, **as directed**, 60 mils (1.52 mm) thick. Neutral-supported, secondary service-drop cable, **as directed**.
   OR
   Racked Secondary Conductors, 600 V and Less: Copper, insulated with XLP, complying with NEMA WC 70/ICEA S-95-658, **as directed**.
5. Neutral-Supported, Secondary Service-Drop Cable, 600 V and Less: Insulated conductors with bare neutral, complying with ICEA S-76-474, and using the following combination of materials:
   a. Conductors and Neutral: Copper with copper-clad-steel neutral **OR** Aluminum with bare Alloy 1350 aluminum neutral **OR** Aluminum with ACSR neutral, **as directed**.
   b. Insulation: XLP, complying with NEMA WC 70/ICEA S-95-658 **OR** High-modular-weight, low-density polyethylene **OR** Weather-resistant polyolefin, complying with ICEA S-70-547, **as directed**.
6. Connectors, Splices, and Conductor Securing and Protecting Components: Items include wire clamps, ties, conductor armor, fittings, connectors, and terminals. Listed for the specific applications and conductor types and combinations of materials used. Descriptions as follows for various applications:
   a. Copper to Copper: Copper alloy, complying with UL 486A-486B.
   b. Aluminum Composition to Aluminum Composition: Aluminum alloy, complying with UL 486A-486B.
   c. Copper to Aluminum Composition: Type suitable for this purpose, complying with UL 486A-486B.
   d. Connectors and Splices for Secondary Conductors: Listed and labeled for the conditions and materials involved in each application.
   e. Taps for Medium-Voltage Line Conductors: Hot-line clamps, screw type, with concealed threads and bare, hard-drawn copper stirrups. Listed for the combination of materials being connected.
   f. Splices under Tension: Compression type with strength exceeding the conductors spliced.

g. Splices and Terminations for Covered Conductors: As recommended by conductor manufacturer for conductor and covering combination and for specific materials and physical arrangement of each splice.
h. Splices and Terminations for Insulated Medium-Voltage Conductors: Comply with requirements in Division 26 Section "Medium-voltage Cables".

B. Wood Poles
1. Comply with ATIS O5.1 and RUS Bulletin 1728F-700, for wood poles pressure treated with creosote **OR** pentachlorophenol, **as directed**, **OR** ammoniacal copper arsenate, **OR** ammoniacal copper zinc arsenate **OR** chromated copper arsenate, **as directed**.
2. Wood Species: Douglas fir **OR** Lodgepole pine **OR** Western larch **OR** Southern yellow pine, **as directed**.
3. Pole Marking:
a. Manufacturer's Mark: Comply with ATIS O5.1; locate 10 feet (3 m) from the pole butt for poles 50 feet (15 m) long or less.
b. Pole Number: Machine-embossed aluminum, alphanumeric characters not less than 2-1/2 inches (65 mm) high, with aluminum nails.
4. Factory Operations: Machine trim poles by turning smooth, full length. Roof, gain, and bore poles before pressure treatment.

C. Concrete Poles
1. Description: Spuncast prestressed concrete, complying with requirements of ASTM C 1089.
a. Comply with requirements of RUS Bulletin 1724E-216.
2. Design: Base design on calculation of strength required by IEEE C2 or indicated on Drawings, whichever is greater. Design shall be suitable for installation at a location where annual temperature range is between minus 4 deg F and plus 100 deg F (minus 20 deg C and plus 38 deg C). Include pole design for embedded attachments matching fittings, brackets, and other items installed in the field.
3. Shaft: Hollow, for poles at overhead-to-underground connections. Provide 3-1/2-inch- (89-mm-) minimum cable raceway capacity, with conduit elbow **OR** cable entry port, **as directed**, at base.
4. Water Absorption: Not more than 3 percent.
5. Surface: Smooth, hard, nonporous, and resistant to soil acids **OR** road salts **OR** frost and freezing damage, **as directed**.
6. Pole Marking:
a. Manufacturer's Mark: Comply with ATIS O5.1; locate 10 feet (3 m) from the pole butt for poles 50 feet (15 m) long or less.
b. Pole Number: Machine-embossed aluminum, alphanumeric characters not less than 2-1/2 inches (65 mm) high.

D. Crossarms
1. Description: Solid-wood distribution type, complying with RUS Bulletin 1728H-701 for specified construction grade **OR** Galvanized, steel angles, **as directed**, and complying with IEEE C2 for required climbing space and wire clearances.
2. Braces: Galvanized, flat, ferrous-metal units; 1/4 inch (6 mm) thick by 1-1/4 inches (30 mm) wide, minimum, with length to suit crossarm dimensions.

E. Guys And Anchors
1. Guy Strand Assemblies: Cable and attachment assemblies shall have uniform minimum breaking strength of the cable.
2. Cable: Seven strands. Zinc-coated steel, complying with ASTM A 475 **OR** Aluminum-clad steel, complying with ASTM B 416 **OR** Copper-clad steel, complying with ASTM B 228, **as directed**. Breaking strength shall be not less than 10,000 lb (45 kN).
3. Cable Termination:
1) Thimble eye.
OR

Hooks and guy strain plates, complying with IEEE C135.1.
2) Preformed galvanized-steel guy grips, matching material, galvanizing, and strength of the guy strand assembly.

4. Anchor and Anchor-Rod Assemblies: Hot-dip galvanized steel.
   a. Power-installed screw-type anchors.
      1) 15-inch (380-mm) screw; with rod 96 inches (2400 mm) long by 1-1/2 inches (38 mm) in diameter. Rated at 10,000 lb (45 kN) when installed.
      2) Guy anchors shall have strength and holding area as required for anchor load and soil conditions at location of that anchor.
5. Strain Insulators: Epoxy-bonded fiberglass of length to meet clearance requirements specified in "Guy Installation" Article.
6. Guy Markers: Round, of vinyl or PVC material, white **OR** yellow, **as directed**, color, 96 inches (2440 mm) long. Shatter resistant at temperatures below 0 deg F (minus 18 deg C).

F. Hardware And Accessories
1. Description: Ferrous-metal items include, but are not limited to, bolts, nuts, washers, crossarm gains and braces, insulator pins, anchor rods, anchors, eyebolts, staples, and transformer brackets.
   a. Comply with IEEE C135.1, IEEE C135.2, ANSI C135.4, ANSI C135.22, and RUS Informational Publication 202-1 listings with the exception that base material shall be malleable iron or ductile iron, and finish shall be hot-dip galvanized, **as directed**.
2. Insulator Brackets: Hot-dip galvanized steel, style as indicated, designed to hold vertical-post-type or pin-type insulators, with one **OR** two, **as directed**,-bolt attachment to pole.
3. Secondary Insulator Racks: Hot-dip galvanized steel, style as indicated, with smooth, rounded 12-gage struts designed to support two **OR** three **OR** four, **as directed**, spool insulators for attachment of secondary drop conductors. Spool spacing of 4 inches (100 mm) **OR** 8 inches (200 mm) **OR** 12 inches (300 mm), **as directed**.
4. Pole Riser Shields: Galvanized steel with boot **OR** backplate **OR** vent, **as directed**.
5. Padlocks: ASTM F 883.
   a. Class: PO1 **OR** PO2, **as directed**.
   b. Grade: 1 **OR** 2 **OR** 3 **OR** 4 **OR** 5 **OR** 6, **as directed**.
   c. Option: A **OR** B **OR** C **OR** D **OR** E **OR** F **OR** G, **as directed**.
6. Insulators: Units rated 6 kV and above shall be free from radio interference.
   a. Porcelain insulators shall be wet-process type, complying with the following:
      1) Pin: ANSI C29.5.
      2) Line Post: ANSI C29.7. Include mounting stud of length suitable for each mounting arrangement used.
      3) Suspension: ANSI C29.2.
      4) Guy Strain: ANSI C29.4.
      5) Secondary Spool: ANSI C29.3, Class 53-2.
   b. Polymer-composite, fiberglass-reinforced insulators shall comply with the following:
      1) Line Post: CEA LWIWG-02.
      2) Dead End/Suspension: CEA LWIWG-01.
      3) Guy Strain: Fiberglass reinforced, epoxy finished. Designed specifically for use in guy assemblies.
7. Grounding Materials: Comply with Division 26 Section "Grounding And Bonding For Electrical Systems", using materials listed by RUS for the intended purpose without restriction.
   a. Conductors: No. 4 AWG, minimum; bare, solid, annealed copper, complying with ASTM B 8 unless otherwise indicated.
   b. Ground Conductor Protectors: PVC or half-round wood molding, fir, pressure treated according to AWPA C25 **OR** cypress **OR** cedar, **as directed**.

G. Surge Arresters
1. Distribution-Class Surge Arresters: Porcelain **OR** Polymer, **as directed**,-enclosed, gapless, metal-oxide type with automatic-indicating type, ground-lead disconnection feature, **as directed**, complying with IEEE C62.11 and NEMA LA 1.

2. Intermediate-Class Surge Arresters: Porcelain **OR** Polymer, **as directed**,-enclosed, gapless, metal-oxide type, complying with IEEE C62.11 and NEMA LA 1.
   a. Voltage Rating: 3 **OR** 6 **OR** 9 **OR** 10 **OR** 12 **OR** 15 **OR** 27 **OR** 30 **OR** 36, **as directed**, kV, at the altitude of Project, unless otherwise indicated.

H. Cutouts, Switches, And Fuses
1. Description: Medium-voltage disconnect, protective, and bypass, **as directed**, units shall be rated for the line-to-line voltage of the systems in which installed, unless higher ratings are indicated. BIL ratings are 45 **OR** 60 **OR** 75 **OR** 95 **OR** 150 **OR** 200, **as directed**, kV.
   a. Momentary Current Rating of Switching Devices: 20 **OR** 40, **as directed**, kA, asymmetrical at nominal system operating voltage.
   b. Fuse Characteristics: Time-current characteristics for each set of fuses selected according to written recommendations of manufacturer of component protected by the fuses and coordinated with upstream and downstream protective devices. Prepare time-current coordination curves according to IEEE 242 that illustrate optimum coordination of devices in this Project.
   c. Interrupting Rating of Fuses: <**Insert value**> symmetrical A at nominal system operating voltage.
2. Fuse Cutouts: Open **OR** enclosed, **as directed**, type, rated 100 **OR** 200, **as directed**, A, continuous, complying with ANSI C37.42.
   a. Fuses: Enclosed link, Type K **OR** Type T, **as directed**, complying with ANSI C37.42.
   b. Fuse Current Rating: 150 percent of the transformer full-load current unless otherwise indicated.
   c. Switching Application: Include switch link instead of fuse.
   d. Switch Current Interrupting Rating: Transformer magnetizing current.
3. Fused Switches: Single-pole, manual units.
   a. Switch Rating: 400 **OR** 600, **as directed**,-A rms continuous and load-current interrupting.
   b. Fuses: Dropout-type power fuses.
4. Nonfused Switches: Single-pole, manual units, rated 100 **OR** 200 **OR** 400 **OR** 600, **as directed**,-A rms continuous.
5. Group-Operated, Load-Interrupter Switches: Fused **OR** Nonfused, **as directed**, three-pole, single-throw units, manually operated by handle through insulated mechanical linkage.
   a. High-pressure contact type, complying with ANSI C37.32.
   b. Factory assembled to suit specific configuration and mounting conditions for this Project.
   c. Operating Handle: Padlock equipped.
   d. Current Interrupting Rating: Equal to continuous current rating of switch.
   e. Fuses: Nondropout power type.
6. Group-Operated, Air-Break (Nonloadbreak) Switches: Three-pole, single-throw units, manually operated by handle through insulated mechanical linkage.
   a. Comply with ANSI C37.32.
   b. Factory assembled to suit specific configuration and mounting conditions for this Project.
   c. Operating Handle: Padlock equipped.
   d. Suitable for field conversion to load-interrupter switch by adding interrupter modules.

I. Distribution Transformers
1. Description: Single-phase, two-winding, single **OR** two, **as directed**,-bushing, liquid-filled, self-cooled, pole-mounting distribution type, suitable for external fuse and surge suppressor protection; complying with IEEE C 57.12.00, and tested according to IEEE C 57.12.90 and with the following additional requirements, **as directed**:
   a. Cooling Class: OA.
   b. Temperature Rise: 65 deg C.
   c. Insulating Liquid: Mineral oil, ASTM D 3487, Type II.
      OR
      Insulating Liquid: High molecular weight, mineral oil based, and UL listed as less-flammable type.

OR
Insulating Liquid: Biodegradable insulating and cooling liquid, UL listed as less flammable type.

d. Identification: Label the transformer as "non-PCB" and place manufacturer's name and type of fluid on the nameplate.

2. BIL: 95 **OR** 75 **OR** 60, **as directed**, kV.
3. Taps: Two, 2.5 percent above and below **OR** Four, 2.5 percent below, **as directed**, high-voltage and full-load rated. Tap changer shall have an external operating handle, **as directed**.
4. Mounting Brackets: Single **OR** Double, **as directed**, integral; suitable for pole mounting, individually or in cluster, or on crossarm.
5. Minimum Efficiency: Class 1, as defined by NEMA TP 1, based on test results that comply with requirements of NEMA TP 2.
6. Bushings: Creepage distance shall exceed nominal value standard for unit rating by at least 75 percent.
7. Hardware: Stainless steel.
8. Tank and Cover: Stainless steel, complying with ASTM A 167, Type 304 or 304L, with paint coating exterior finish system complying with IEEE C57.12.28, including manufacturer's standard color finish coat.
9. Show transformer kiloampere capacity using 2-1/2-inch (65-mm) numerals placed near the low-voltage bushings.

J. Primary Metering Equipment

1. Metering Transformers: Outdoor current and potential transformers, designed for crossarm mounting, complying with IEEE C57.13, and having the following features:
   a. BIL: 45 **OR** 60 **OR** 75 **OR** 95 **OR** 150 **OR** 200, **as directed**, kV.
   b. Secondary connection box arranged for conduit connection.
   c. Potential-Transformer Voltage Rating: 2.4 **OR** 4.16 **OR** 7.2 **OR** 12.0 **OR** 12.47, **as directed**, kV to 120-V ac, 60 Hz.
   d. Potential-Transformer Accuracy Class: Minimum 0.3 at 75-VA burden.
   e. Voltage Rating: 2.4 **OR** 4.16 **OR** 7.2 **OR** 12.0 **OR** 12.47, **as directed**, kV.
   f. Current Rating: <**Insert value**> to 5 A.
   g. Accuracy Class: Minimum 0.2 at 50-VA burden.
2. Watt-Hour Meter: Outdoor solid-state unit, with demand register, **OR** arranged for pulse initiation, **as directed**, complying with ANSI C12.10, and including the following ratings and features:
   a. Form: 8S **OR** 9S, **as directed**.
   b. Element: 2 **OR** 2-1/2 **OR** 3, **as directed**.
   c. Voltage: 120 V.
   d. Current: 2-1/2 A.
   e. Frequency: 60 Hz.
   f. Kilowatt-Hour Register: Five-digit type.
   g. Demand-Register Multiplier: A quantity in even hundreds, indicated on meter face.
   h. Demand-Register Interval: 15 **OR** 30, **as directed**, minutes.
   i. Mounting: On matching socket, complying with ANSI C12.7, and complete with automatic current short-circuiting device.
   j. Meter Test Block: Matched to meter, and furnished and equipped with open knife switches designed to isolate each metering component for test.
   k. Meter Cabinet: Galvanized steel; weatherproof enclosure with pole-mounting bracket and the following features:
      1) Hinged Door: Arranged for padlocking in closed position.
      2) Size: Adequate to house meter and other equipment indicated, but not less than 20 by 30 by 11 inches (510 by 760 by 280 mm) deep.

K. Source Quality Control

1. Factory Tests: Conduct routine tests of transformers **OR** medium-voltage switches **OR** metering equipment, **as directed**, according to referenced standards.

2. Testing Agency: Engage a qualified testing agency to inspect poles and crossarms before and after preservative treatment for compliance of wood poles and crossarms with requirements indicated. RUS quality mark "WQC" on each item is acceptable in place of inspection as evidence of compliance.
3. Poles and crossarms will be considered defective if they do not pass tests and inspections.
4. Prepare test and inspection reports.

1.3 EXECUTION

A. Right-Of-Way Clearance And Tree Trimming
1. Clear right of way according to Division 01 Section(s) "Temporary Tree And Plant Protection" AND Division 31 Section(s) "Site Clearing".
2. Clear right of way to maintain minimum clearances required by IEEE C2, unless Drawings indicate greater clearances or greater clearances are required by state or local codes or regulations. If no minimum requirements are mandated, maintain a minimum of 15 feet (4.5 m) on both sides horizontally and below medium-voltage conductors and 60 inches (1500 mm) on both sides horizontally and below secondary-voltage conductors. Remove overhanging branches.

B. General Installation Requirements
1. Install underground power and metering circuits and those circuits indicated to be in raceways according to Division 26 Section "Underground Ducts And Raceways For Electrical Systems" and Division 26 Section "Medium-voltage Cables", and make splices and terminations for those circuits according to the applicable Sections.
2. Engage the services of a licensed surveyor to verify dimensions by field measurement, to identify locations of poles, anchors, and other features, and to verify all clearances. The survey document shall also identify locations of connections to new and existing supply lines and to primary and secondary services. Notify the Owner of discrepancies and field conditions that are not indicated and that will affect installation.
3. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
4. Apply warning signs and equipment labels according to Division 26 Section "Identification For Electrical Systems".

C. Conductor Installation, General
1. Handle and string conductors to prevent cuts, gouges, scratches, kinks, flattening, or deformation. Remove damaged sections and splice conductors.
   a. String new conductors to "initial" sag values recommended by manufacturer for type and size of conductor except as otherwise indicated.
   b. Conductors Reinstalled or Resagged: String to "final" sag values recommended by manufacturer for type and size of conductor except as otherwise indicated.
2. Connections, Splices, and Terminations: Use kits listed for the specific type of connection and combination of materials in the connection or recommended for the specific use by manufacturer of material on which applied.
   a. Splice Location: Do not install within 10 feet (3 m) of a support.
   b. Line Conductors and Service Drops: Install so strength exceeds ultimate rated strength of conductor.
   c. Splices and Terminations of Covered Conductors: Comply with manufacturer's written instructions.
   d. Splices and Terminations of Insulated Conductors of Self-Supported, Medium-Voltage Cable: Comply with manufacturer's written instructions.

D. Medium-Voltage Line Conductor Installation
1. Application: Install bare conductors unless otherwise indicated.

2. Armor Rod: Install to protect conductors if line conductors are supported by insulators.
3. Flat Aluminum Armor Wire: Install to protect conductors if they are supported by, or attached to, galvanized or coated iron or steel clamps or fittings.
4. Support line conductors and taps as follows:
   a. Use wire ties for conductor attachment to pin and vertical post insulators unless otherwise indicated.
   b. Install wire ties tight against conductor and insulator, and turn ends back and flat against conductor, to eliminate exposed wire ends.
   c. Use wire clamps on horizontal post, dead end, and suspension insulators unless otherwise indicated.

E. Pole And Crossarm Installation
1. Pole Orientation: Align curve of curved wood poles with straight-line runs of three or more poles. Align gained surfaces perpendicular to runs.
2. Elevation of Line above Grade: Install poles with top at same elevation, unless grade changes dictate elevation change in poles, and according to the following:
   a. On level ground, set poles so tops of consecutive poles vary not more than 60 inches (1500 mm) in elevation.
   b. Shorten wood poles by cutting off the top and make cuts to shed water. Apply preservative to cuts.
3. Set poles according to the following:
   a. Make pole holes vertical, uniform in diameter, and large enough to permit effective use of tamping bars all around. Bore or excavate holes with an average diameter at grade less than twice the diameter of the pole at the same grade.
   b. Use minimum depths indicated, except at locations where hole is partly or entirely in rock and if hole is not vertical or has a diameter at grade more than two times the pole diameter at the same level; in these conditions, increase the depth of the hole by the following increments before setting the pole:
      1) Poles up to 35 Feet (10.6 m) Long: 24 inches (600 mm).
      2) Poles 36 to 60 Feet (11 to 18.3 m) Long: 30 inches (760 mm).
      3) Poles 61 to 75 Feet (18.6 to 22.9 m) Long: 36 inches (900 mm).
   c. For poles on slopes, indicated hole depth is from finished grade at lowest side of hole.
   d. Set poles in alignment and plumb except at dead ends, angles, and points of extra strain; rake poles against conductor strain 1 inch (25 mm) minimum, 2 inches (51 mm) maximum, (after conductors are installed at required tension) for each 10 feet (3 m) of pole length. Rake poles so they will not lean or bend in direction of strain when loaded.
   e. Backfill holes in 6-inch (150-mm) maximum lifts, and thoroughly tamp each layer before starting the next.
   f. Place surplus earth around pole in a conical shape, and tamp thoroughly to provide drainage away from pole.
   g. Set poles so alternate crossarm gains face in alternate directions, except at terminals and dead ends; place gains on last two poles on side facing terminal or dead end.
   h. Poles Set in Concrete Paved Areas: Install poles with minimum of 6-inch- (150-mm-) wide, unpaved gap between the pole and the edge of adjacent concrete slab. Fill unpaved ring with pea gravel to a level 1 inch (25 mm) below top of concrete slab.
4. Field treat factory-treated poles and crossarms as follows:
   a. Poles Treated More Than One Year before Installation: Treat portion from 24 inches (600 mm) above ground line to butt.
   b. Field-Bored Holes and Field-Cut Gains and Pole Tops: Treat cut portions.
   c. Unused Holes: Treat and plug with treated-wood-dowel drive pins.
   d. Engage the services of a technician certified according to "Quality Assurance" Article to apply treatment. Comply with requirements in AWPA standards that govern original factory treatment for field-applied treatment and application of chemicals.
5. Crossarm Installation: Set line crossarms at right angle to line for straight runs and for angles 45 degrees and more. Bisect angles less than 45 degrees.
   a. Buck Arms: Install at corners and junction poles unless otherwise indicated.

b. Double Crossarms: Install at dead ends, corners, angles, and line crossings.
c. Equipment Arms: Locate below lines and set parallel or at right angles to them, whichever provides best climbing space.
d. Gains: Install factory-cut or metal-pole gains only. Do not cut gains in field without specific written approval.

6. Locate pole numbers to provide maximum visibility from the road or patrol route.

F. Guy Installation

1. Install guys to resist unbalanced loads, including those developed at angles, corners, and dead ends. Install two or more guys if a single guy will not provide adequate strength. Install separate guys if unbalanced loads are separated by 36 inches (900 mm) or more. Comply with IEEE C2.
   a. Unless a thimble eye is used, at the pole end, install a minimum of two guy hooks and two guy strain plates.
   b. At the anchor end, attach guy strand assembly with preformed grips.
2. Protect guy strands from damage. Replace damaged guy strands. Install guy insulators where required to comply with IEEE C2 clearance requirements.
3. Install guys with a lead-to-height ratio of 1 to 1 unless otherwise indicated. The minimum lead-to-height ratio shall be 1/2 to 1. When less than 1 to 1, increase guy strength by the ratio of the sine of the lead angle indicated to the sine of the lead angle provided.
4. Install screw-type guy anchors aligned in soil with guy. Set with anchor rod pointing at guy attachment on pole and rod projecting 6 to 9 inches (150 to 230 mm) from ground.
5. Install strain insulators to provide a minimum of 12 inches (300 mm) of clearance between the nearest energized surface and the strain insulator fitting farthest from the pole. When loaded to the tension indicated, fiberglass strain insulators shall be loaded to not more than two-thirds of manufacturer's published rating.
6. Guy Markers: Install at anchor end of guys to visually mark the guy wire at all accessible locations. Clamp to guy strand or anchor at top and bottom of marker.

G. Hardware And Accessories Installation

1. Install washers against wood and under nuts, including eyenuts and locknuts.
2. Install nuts and locknuts wrench-tight on threaded connections.

H. Insulator Installation

1. Medium-Voltage Line Application: Install pin **OR** post, **as directed**, type, except install suspension type at corners, angles, dead ends, and other locations where horizontal forces exceed rated values for pin or line-post-type units.
   a. Install suspension insulators and hardware that have mechanical strength exceeding rated breaking strength of attached conductors.
   b. Install horizontal line-post insulators for armless construction.
2. Post-Insulator Conductor Support: Where installed horizontally and for line angles more than 15 degrees, install clamp-top conductor clamps.
3. Install spool-type insulators for secondary lines mounted on clevis attachments or secondary racks.
4. Guy Strain Type: Install porcelain **OR** fiberglass-reinforced, **as directed**, units.

I. Surge Arresters

1. Install surge arresters to protect distribution **OR** metering equipment **OR** reclosers, **as directed**, group-operated, load-interrupter switches, **as directed**, aerial-to-underground transitions, **as directed**, and other items indicated.
   a. Units Installed 6000 Feet (1800 m) or More above Sea Level: Use arresters specifically rated for this service.

J. Cutout, Switch, And Fuse Installation

1. Hook-Stick-Operated Switches: Install to maximize safe operating access.

2. Group-Operated, Load-Interrupter Switches and Air-Break Switches: Install operating handle 42 inches (1067 mm) above finished grade.
   a. Locking Provisions: Install padlock at hasp.

K. Metering Component Installation
1. Current and Voltage Transformers: Install secondary conductors between transformers and cabinet in sleeves made of galvanized rigid steel **OR** intermediate metal **OR** PVC, **as directed**, conduit. Install to prevent collection of moisture in raceway and cabinet system.
2. Meter Cabinet: Mount on pole, 72 inches (1825 mm) above finished grade to center of cabinet.
   a. Make conduit connections with raintight hubs.
   b. Install metering transformer secondary leads without splices. Train leads at sides and bottom of enclosure, and secure with wire ties.
   c. Install meter and meter test block within cabinet.
   d. Install identical phase sequence, and color-code for both potential and current leads.
   e. Identify leads using designations consistent with marking on transformer terminals.

L. Field Quality Control
1. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
2. Perform tests and inspections.
3. Tests and Inspections:
   a. Furnish instruments and equipment required for tests that comply with NETA Acceptance Testing Specification.
   b. Guy Anchors: Test one of each type and capacity installed, plus additional units specifically indicated for testing, **as directed**. Apply rated pull-out force in the same pull direction applied by the guy at the test location.
      1) Acceptable Test Results: Denoted by movement of less than 3/8 inch (10 mm) by the holding component of the anchor in the earth or other medium in which it is installed.
      2) Replace or reinstall, at the Owner 's option, all anchors of same type and capacity as anchor type that fails this test.
   c. Ground Resistance: Comply with Division 26 Section "Grounding And Bonding For Electrical Systems". Measure resistance of each separate grounding electrode, including pole grounds. Also measure resistance of separate grounding electrode systems before bonding together.
      1) Perform tests and obtain acceptable results before energizing any portion of overhead electrical distribution system.
      2) Results and Follow-up: If ground resistance for a single ground electrode or pole ground, tested individually, exceeds 25 ohms, add a ground electrode not less than 10 feet (3 m) away and interconnect with No. 2 AWG, minimum, bare conductor buried at least 12 inches (300 mm) below furnished grade.
   d. Aerial Conductor Sag and Tension: Observe procedures used by Contractor to verify that initial stringing sags and tensions comply with IEEE C2 and conductor manufacturer's product data and written recommendations.
   e. Self-Supported, Medium-Voltage Cable: After installation, while cable is isolated, and after terminations are installed and before connecting or energizing, apply dc voltage between each phase conductor and grounding connections of sheath or metallic shield. Comply with NEMA WC 70/ICEA S-95-658 for method, voltage, duration, pass-fail performance, and other test criteria. Perform other field inspections and tests recommended by manufacturer.
   f. Neutral-Supported, Secondary Service-Drop Cable: Test for insulation resistance while cable is isolated, before connecting or energizing. Minimum acceptable resistance is 100 megohms.
   g. Existing Surge Arresters: Disconnect and measure resistance between line and ground terminals with a megger test rated 600 V or more. Acceptable resistance values are 300 megohms and more.

h. New Surge Arresters, Cutouts, and Switches: Inspect after installation and connection to wiring. Verify that ratings and characteristics match approved submittals and comply with system requirements. Verify that installation complies with requirements and that clearances of units and connecting wiring comply with IEEE C2 requirements.
   1) Verify proper grounding of metallic equipment parts.
   2) Fuses and Disconnect Links: Verify that ratings and characteristics match submittals and comply with system requirements.
   3) Switches:
      a) Manually operate each cutout and switch at least three times, to verify proper operation.
      b) Verify correct contact alignment, blade penetration, travel stops, and arc interrupter operation.
   4) Group-Operated, Load-Interrupter Switches and Air-Break Switches:
      a) Perform mechanical operator tests according to manufacturer's written instructions.
      b) Test resistance to ground of parts to be energized. Acceptable value is 200,000 megohms.
      c) Perform contact-resistance test across all switch blade contacts. Refer to manufacturer's data for acceptable contact resistance.
   5) Verify that clearances of energized parts and connecting wires comply with IEEE C2 requirements.

i. Distribution Transformers: Inspect after installation and connection to wiring and verify that ratings and characteristics match approved submittals and comply with system requirements. Verify the integrity and good condition of unit.
   1) Inspect for physical damage, cracked insulators, leaks, tightness of connections, and overall mechanical and electrical integrity.
   2) Perform preenergizing inspections and tests recommended by manufacturer.
   3) Verify proper equipment grounding.
   4) Verify that clearances of terminals and connecting wires comply with IEEE C2.

j. Metering Transformers: Inspect after installation and connection to wires, and verify that ratings and characteristics match approved submittals and comply with system requirements. Verify the integrity and good condition of unit.
   1) Verify proper connections, tightness of bolted connections, and integrity of mounting provisions.
   2) Verify that required grounding and shorting connections provide good contact.
   3) Verify that clearances of terminals and connecting wires comply with IEEE C2.
   4) Perform electrical tests according to manufacturer's written instructions, including insulation-resistance tests, polarity tests, and turns-ratio and ratio-verification tests.

k. Meters: Inspect after installation and connection to wiring and verify that ratings and characteristics match approved submittals and comply with system requirements. Verify the integrity and good condition of unit.
   1) Verify tightness of electrical connections.
   2) Verify accuracy at 25, 50, 75, and 100 percent of full-rated load and verify all instrument multipliers according to manufacturer's written instructions.

4. Prepare test and inspection reports.

M. Adjusting
   1. Distribution Transformers: Set voltage taps as directed by the Owner.

N. Cleaning
   1. After completing equipment installation, inspect equipment. Remove spots, dirt, and debris. Repair damaged finish to match original finish. For distribution transformer, use tank touchup paint provided by manufacturer.
      a. Clean enclosures internally, on completion of installation, according to manufacturer's written instructions.

O. Demonstration
   1. Train Owner's maintenance personnel to adjust, operate, and maintain overhead electrical distribution.

END OF SECTION 26 05 26 00b

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Task	Specification	Specification Description
26 05 26 00	01 22 16 00	No Specification Required

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SECTION 26 05 29 00 - HANGERS AND SUPPORTS FOR ELECTRICAL SYSTEMS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for hangers and supports for electrical systems. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following:
a. Hangers and supports for electrical equipment and systems.
b. Construction requirements for concrete bases.

C. Definitions
1. EMT: Electrical metallic tubing.
2. IMC: Intermediate metal conduit.
3. RMC: Rigid metal conduit.

D. Performance Requirements
1. Delegated Design: Design supports for multiple raceways, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
2. Design supports for multiple raceways capable of supporting combined weight of supported systems and its contents.
3. Design equipment supports capable of supporting combined operating weight of supported equipment and connected systems and components.
4. Rated Strength: Adequate in tension, shear, and pullout force to resist maximum loads calculated or imposed for this Project, with a minimum structural safety factor of five times the applied force.

E. Submittals
1. Product Data: For the following:
a. Steel slotted support systems.
b. Nonmetallic slotted support systems.
2. Shop Drawings: Signed and sealed by a qualified professional engineer. Show fabrication and installation details and include calculations for the following:
a. Trapeze hangers. Include Product Data for components.
b. Steel slotted channel systems. Include Product Data for components.
c. Nonmetallic slotted channel systems. Include Product Data for components.
d. Equipment supports.
3. Welding certificates.

F. Quality Assurance
1. Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
2. Comply with NFPA 70.

1.2 PRODUCTS

A. Support, Anchorage, And Attachment Components

1. Steel Slotted Support Systems: Comply with MFMA-4, factory-fabricated components for field assembly.
   a. Metallic Coatings: Hot-dip galvanized after fabrication and applied according to MFMA-4.
   b. Nonmetallic Coatings: Manufacturer's standard PVC, polyurethane, or polyester coating applied according to MFMA-4.
   c. Painted Coatings: Manufacturer's standard painted coating applied according to MFMA-4.
   d. Channel Dimensions: Selected for applicable load criteria.
2. Nonmetallic Slotted Support Systems: Structural-grade, factory-formed, glass-fiber-resin channels and angles with 9/16-inch- (14-mm-) diameter holes at a maximum of 8 inches (200 mm) o.c., in at least 1 surface.
   a. Fittings and Accessories: Products of channel and angle manufacturer and designed for use with those items.
   b. Fitting and Accessory Materials: Same as channels and angles, except metal items may be stainless steel.
   c. Rated Strength: Selected to suit applicable load criteria.
3. Raceway and Cable Supports: As described in NECA 1 and NECA 101.
4. Conduit and Cable Support Devices: Steel **OR** Steel and malleable-iron, **as directed**, hangers, clamps, and associated fittings, designed for types and sizes of raceway or cable to be supported.
5. Support for Conductors in Vertical Conduit: Factory-fabricated assembly consisting of threaded body and insulating wedging plug or plugs for non-armored electrical conductors or cables in riser conduits. Plugs shall have number, size, and shape of conductor gripping pieces as required to suit individual conductors or cables supported. Body shall be malleable iron.
6. Structural Steel for Fabricated Supports and Restraints: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.
7. Mounting, Anchoring, and Attachment Components: Items for fastening electrical items or their supports to building surfaces include the following:
   a. Powder-Actuated Fasteners: Threaded-steel stud, for use in hardened portland cement concrete, steel, or wood, with tension, shear, and pullout capacities appropriate for supported loads and building materials where used.
   b. Mechanical-Expansion Anchors: Insert-wedge-type, zinc-coated steel **OR** stainless steel, **as directed**, for use in hardened portland cement concrete with tension, shear, and pullout capacities appropriate for supported loads and building materials in which used.
   c. Concrete Inserts: Steel or malleable-iron, slotted support system units similar to MSS Type 18; complying with MFMA-4 or MSS SP-58.
   d. Clamps for Attachment to Steel Structural Elements: MSS SP-58, type suitable for attached structural element.
   e. Through Bolts: Structural type, hex head, and high strength. Comply with ASTM A 325.
   f. Toggle Bolts: All-steel springhead type.
   g. Hanger Rods: Threaded steel.

B. Fabricated Metal Equipment Support Assemblies
   1. Description: Welded or bolted, structural-steel shapes, shop or field fabricated to fit dimensions of supported equipment.
   2. Materials: Comply with requirements in Division 05 Section "Metal Fabrications" for steel shapes and plates.

1.3 EXECUTION

A. Application
   1. Comply with NECA 1 and NECA 101 for application of hangers and supports for electrical equipment and systems except if requirements in this Section are stricter.
   2. Maximum Support Spacing and Minimum Hanger Rod Size for Raceway: Space supports for EMT, IMC, and RMC as required by **OR** scheduled in NECA 1, where its Table 1 lists maximum

spacings less than stated in, **as directed**, NFPA 70. Minimum rod size shall be 1/4 inch (6 mm) in diameter.

3. Multiple Raceways or Cables: Install trapeze-type supports fabricated with steel slotted or other support system, sized so capacity can be increased by at least 25 percent in future without exceeding specified design load limits.
   a. Secure raceways and cables to these supports with two-bolt conduit clamps **OR** single-bolt conduit clamps **OR** single-bolt conduit clamps using spring friction action for retention in support channel, **as directed**.
4. Spring-steel clamps designed for supporting single conduits without bolts may be used for 1-1/2-inch (38-mm) and smaller raceways serving branch circuits and communication systems above suspended ceilings and for fastening raceways to trapeze supports.

B. Support Installation
1. Comply with NECA 1 and NECA 101 for installation requirements except as specified in this Article.
2. Raceway Support Methods: In addition to methods described in NECA 1, EMT **OR** IMC **OR** RMC, **as directed**, may be supported by openings through structure members, as permitted in NFPA 70.
3. Strength of Support Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static loads within specified loading limits. Minimum static design load used for strength determination shall be weight of supported components plus 200 lb (90 kg).
4. Mounting and Anchorage of Surface-Mounted Equipment and Components: Anchor and fasten electrical items and their supports to building structural elements by the following methods unless otherwise indicated by code:
   a. To Wood: Fasten with lag screws or through bolts.
   b. To New Concrete: Bolt to concrete inserts.
   c. To Masonry: Approved toggle-type bolts on hollow masonry units and expansion anchor fasteners on solid masonry units.
   d. To Existing Concrete: Expansion anchor fasteners.
   e. Instead of expansion anchors, powder-actuated driven threaded studs provided with lock washers and nuts may be used in existing standard-weight concrete 4 inches (100 mm) thick or greater. Do not use for anchorage to lightweight-aggregate concrete or for slabs less than 4 inches (100 mm) thick.
   f. To Steel: Welded threaded studs complying with AWS D1.1/D1.1M, with lock washers and nuts **OR** Beam clamps (MSS Type 19, 21, 23, 25, or 27) complying with MSS SP-69 **OR** Spring-tension clamps, **as directed**.
   g. To Light Steel: Sheet metal screws.
   h. Items Mounted on Hollow Walls and Nonstructural Building Surfaces: Mount cabinets, panelboards, disconnect switches, control enclosures, pull and junction boxes, transformers, and other devices on slotted-channel racks attached to substrate by means that meet seismic-restraint strength and anchorage requirements.
5. Drill holes for expansion anchors in concrete at locations and to depths that avoid reinforcing bars.

C. Installation Of Fabricated Metal Supports
1. Comply with installation requirements in Division 05 Section "Metal Fabrications" for site-fabricated metal supports.
2. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor electrical materials and equipment.
3. Field Welding: Comply with AWS D1.1/D1.1M.

D. Concrete Bases
1. Construct concrete bases of dimensions indicated but not less than 4 inches (100 mm) larger in both directions than supported unit, and so anchors will be a minimum of 10 bolt diameters from edge of the base.

2. Use 3000-psi (20.7-MPa), 28-day compressive-strength concrete. Concrete materials, reinforcement, and placement requirements are specified in Division 03 Section "Cast-in-place Concrete".
3. Anchor equipment to concrete base.
   a. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   b. Install anchor bolts to elevations required for proper attachment to supported equipment.
   c. Install anchor bolts according to anchor-bolt manufacturer's written instructions.

E. Painting
1. Touchup: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.
   a. Apply paint by brush or spray to provide minimum dry film thickness of 2.0 mils (0.05 mm).
2. Touchup: Comply with requirements in Division 07 OR Division 09 Section(s) "High-performance Coatings" **as directed,** for cleaning and touchup painting of field welds, bolted connections, and abraded areas of shop paint on miscellaneous metal.
3. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

END OF SECTION 26 05 29 00

SECTION 26 05 29 00a - VIBRATION AND SEISMIC CONTROLS FOR ELECTRICAL SYSTEMS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for vibration and seismic controls for electrical systems. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following:
a. Isolation pads.
b. Spring isolators.
c. Restrained spring isolators.
d. Channel support systems.
e. Restraint cables.
f. Hanger rod stiffeners.
g. Anchorage bushings and washers.

C. Definitions
1. The IBC: International Building Code.
2. ICC-ES: ICC-Evaluation Service.
3. OSHPD: Office of Statewide Health Planning and Development for the State of California.

D. Performance Requirements
1. Seismic-Restraint Loading:
a. Site Class as Defined in the IBC: A **OR** B **OR** C **OR** D **OR** E **OR** F, **as directed**.
b. Assigned Seismic Use Group or Building Category as Defined in the IBC: I **OR** II **OR** III, **as directed**.
1) Component Importance Factor: 1.0 **OR** 1.5, **as directed**.
2) Component Response Modification Factor: 1.5 **OR** 2.5 **OR** 3.5 **OR** 5.0, **as directed**.
3) Component Amplification Factor: 1.0 **OR** 2.5, **as directed**.
c. Design Spectral Response Acceleration at Short Periods (0.2 Second): As required to meet Project requirements.
d. Design Spectral Response Acceleration at 1.0-Second Period: As required to meet Project requirements.

E. Submittals
1. Product Data: For the following:
a. Include rated load, rated deflection, and overload capacity for each vibration isolation device.
b. Illustrate and indicate style, material, strength, fastening provision, and finish for each type and size of seismic-restraint component used.
1) Tabulate types and sizes of seismic restraints, complete with report numbers and rated strength in tension and shear as evaluated by an evaluation service member of ICC-ES **OR** OSHPD **OR** an agency acceptable to authorities having jurisdiction, **as directed**.
2) Annotate to indicate application of each product submitted and compliance with requirements.
c. Restrained-Isolation Devices: Include ratings for horizontal, vertical, and combined loads.
2. Delegated-Design Submittal: For vibration isolation and seismic-restraint details indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

a. Design Calculations: Calculate static and dynamic loading due to equipment weight and operation, seismic forces required to select vibration isolators and seismic restraints.
   1) Coordinate design calculations with wind-load calculations required for equipment mounted outdoors. Comply with requirements in other Division 22 for equipment mounted outdoors.
b. Indicate materials and dimensions and identify hardware, including attachment and anchorage devices.
c. Field-fabricated supports.
d. Seismic-Restraint Details:
   1) Design Analysis: To support selection and arrangement of seismic restraints. Include calculations of combined tensile and shear loads.
   2) Details: Indicate fabrication and arrangement. Detail attachments of restraints to the restrained items and to the structure. Show attachment locations, methods, and spacings. Identify components, list their strengths, and indicate directions and values of forces transmitted to the structure during seismic events. Indicate association with vibration isolation devices.
   3) Preapproval and Evaluation Documentation: By an evaluation service member of ICC-ES **OR** OSHPD **OR** an agency acceptable to authorities having jurisdiction, **as directed**, showing maximum ratings of restraint items and the basis for approval (tests or calculations).

3. Welding certificates.
4. Field quality-control test reports.

F. Quality Assurance
1. Comply with seismic-restraint requirements in the IBC unless requirements in this Section are more stringent.
2. Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
3. Seismic-restraint devices shall have horizontal and vertical load testing and analysis and shall bear anchorage preapproval OPA number from OSHPD, preapproval by ICC-ES, or preapproval by another agency acceptable to authorities having jurisdiction, showing maximum seismic-restraint ratings. Ratings based on independent testing are preferred to ratings based on calculations. If preapproved ratings are not available, submittals based on independent testing are preferred. Calculations (including combining shear and tensile loads) to support seismic-restraint designs must be signed and sealed by a qualified professional engineer.
4. Comply with NFPA 70.

1.2 PRODUCTS

A. Vibration Isolators
1. Pads: Arrange in single or multiple layers of sufficient stiffness for uniform loading over pad area, molded with a nonslip pattern and galvanized-steel baseplates, and factory cut to sizes that match requirements of supported equipment.
   a. Resilient Material: Oil- and water-resistant neoprene **OR** rubber **OR** hermetically sealed compressed fiberglass, **as directed**.
2. Spring Isolators: Freestanding, laterally stable, open-spring isolators.
   a. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.
   b. Minimum Additional Travel: 50 percent of the required deflection at rated load.
   c. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
   d. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

e. Baseplates: Factory drilled for bolting to structure and bonded to 1/4-inch- (6-mm-) thick, rubber isolator pad attached to baseplate underside. Baseplates shall limit floor load to 500 psig (3447 kPa).

f. Top Plate and Adjustment Bolt: Threaded top plate with adjustment bolt and cap screw to fasten and level equipment.

3. Restrained Spring Isolators: Freestanding, steel, open-spring isolators with seismic or limit-stop restraint.

a. Housing: Steel with resilient vertical-limit stops to prevent spring extension due to weight being removed; factory-drilled baseplate bonded to 1/4-inch- (6-mm-) thick, neoprene or rubber isolator pad attached to baseplate underside; and adjustable equipment mounting and leveling bolt that acts as blocking during installation.

b. Restraint: Seismic or limit-stop as required for equipment and authorities having jurisdiction.

c. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.

d. Minimum Additional Travel: 50 percent of the required deflection at rated load.

e. Lateral Stiffness: More than 80 percent of rated vertical stiffness.

f. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

B. Seismic-Restraint Devices

1. General Requirements for Restraint Components: Rated strengths, features, and application requirements shall be as defined in reports by an evaluation service member of ICC-ES **OR** OSHPD **OR** an agency acceptable to authorities having jurisdiction, **as directed**.

a. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least four times the maximum seismic forces to which they will be subjected.

2. Channel Support System: MFMA-3, shop- or field-fabricated support assembly made of slotted steel channels with accessories for attachment to braced component at one end and to building structure at the other end and other matching components and with corrosion-resistant coating; and rated in tension, compression, and torsion forces.

3. Restraint Cables: ASTM A 603 galvanized-steel **OR** ASTM A 492 stainless-steel, **as directed**, cables with end connections made of steel assemblies with thimbles, brackets, swivels, and bolts designed for restraining cable service; and with a minimum of two clamping bolts for cable engagement.

4. Hanger Rod Stiffener: Steel tube or steel slotted-support-system sleeve with internally bolted connections **OR** Reinforcing steel angle clamped, **as directed**, to hanger rod. Do not weld stiffeners to rods.

5. Bushings for Floor-Mounted Equipment Anchor: Neoprene bushings designed for rigid equipment mountings, and matched to type and size of anchors and studs.

6. Bushing Assemblies for Wall-Mounted Equipment Anchorage: Assemblies of neoprene elements and steel sleeves designed for rigid equipment mountings, and matched to type and size of attachment devices.

7. Resilient Isolation Washers and Bushings: One-piece, molded, oil- and water-resistant neoprene, with a flat washer face.

8. Mechanical Anchor: Drilled-in and stud-wedge or female-wedge type in zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchors with strength required for anchor and as tested according to ASTM E 488. Minimum length of eight times diameter.

9. Adhesive Anchor: Drilled-in and capsule anchor system containing polyvinyl or urethane methacrylate-based resin and accelerator, or injected polymer or hybrid mortar adhesive. Provide anchor bolts and hardware with zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488.

C. Factory Finishes

1. Finish:
   a. Manufacturer's standard prime-coat finish ready for field painting.
   b. Manufacturer's standard paint applied to factory-assembled and -tested equipment before shipping.
      1) Powder coating on springs and housings.
      2) All hardware shall be galvanized. Hot-dip galvanize metal components for exterior use.
      3) Baked enamel or powder coat for metal components on isolators for interior use.
      4) Color-code or otherwise mark vibration isolation and seismic-control devices to indicate capacity range.

1.3 EXECUTION

A. Applications
   1. Multiple Raceways or Cables: Secure raceways and cables to trapeze member with clamps approved for application by an evaluation service member of ICC-ES **OR** OSHPD **OR** an agency acceptable to authorities having jurisdiction, **as directed**.
   2. Hanger Rod Stiffeners: Install hanger rod stiffeners where indicated or scheduled on Drawings to receive them and where required to prevent buckling of hanger rods due to seismic forces.
   3. Strength of Support and Seismic-Restraint Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static and seismic loads within specified loading limits.

B. Seismic-Restraint Device Installation
   1. Equipment and Hanger Restraints:
      a. Install restrained isolators on electrical equipment.
      b. Install resilient, bolt-isolation washers on equipment anchor bolts where clearance between anchor and adjacent surface exceeds 0.125 inch (3.2 mm).
      c. Install seismic-restraint devices using methods approved by an evaluation service member of ICC-ES **OR** OSHPD **OR** an agency acceptable to authorities having jurisdiction, **as directed**, providing required submittals for component.
   2. Install bushing assemblies for mounting bolts for wall-mounted equipment, arranged to provide resilient media where equipment or equipment-mounting channels are attached to wall.
   3. Attachment to Structure: If specific attachment is not indicated, anchor bracing to structure at flanges of beams, at upper truss chords of bar joists, or at concrete members.
   4. Drilled-in Anchors:
      a. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling. Notify the structural engineer if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
      b. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
      c. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
      d. Adhesive Anchors: Clean holes to remove loose material and drilling dust prior to installation of adhesive. Place adhesive in holes proceeding from the bottom of the hole and progressing toward the surface in such a manner as to avoid introduction of air pockets in the adhesive.
      e. Set anchors to manufacturer's recommended torque, using a torque wrench.
      f. Install zinc-coated steel anchors for interior and stainless-steel anchors for exterior applications.

C. Accommodation Of Differential Seismic Motion
   1. Install flexible connections in runs of raceways, cables, wireways, cable trays, and busways where they cross seismic joints, where adjacent sections or branches are supported by different structural elements, and where they terminate with connection to equipment that is anchored to a different structural element from the one supporting them as they approach equipment.

D. Field Quality Control
   1. Tests and Inspections:
      a. Provide evidence of recent calibration of test equipment by a testing agency acceptable to authorities having jurisdiction.
      b. Schedule test with the Owner, through Architect, before connecting anchorage device to restrained component (unless postconnection testing has been approved), and with at least seven days' advance notice.
      c. Obtain Architect's approval before transmitting test loads to structure. Provide temporary load-spreading members.
      d. Test at least four of each type and size of installed anchors and fasteners selected by Architect.
      e. Test to 90 percent of rated proof load of device.
      f. Measure isolator restraint clearance.
      g. Measure isolator deflection.
      h. Verify snubber minimum clearances.
      i. If a device fails test, modify all installations of same type and retest until satisfactory results are achieved.
   2. Remove and replace malfunctioning units and retest as specified above.
   3. Prepare test and inspection reports.

E. Adjusting
   1. Adjust isolators after isolated equipment is at operating weight.
   2. Adjust limit stops on restrained spring isolators to mount equipment at normal operating height. After equipment installation is complete, adjust limit stops so they are out of contact during normal operation.
   3. Adjust active height of spring isolators.
   4. Adjust restraints to permit free movement of equipment within normal mode of operation.

END OF SECTION 26 05 29 00a

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Task	Specification	Specification Description
26 05 33 13	26 05 19 16	Common Work Results for Electrical
26 05 33 13	26 05 19 16a	Common Work Results for Communications
26 05 33 13	26 05 19 16b	Common Work Results for Electronic Safety and Security
26 05 33 13	26 05 19 16c	Electrical Renovation
26 05 33 13	26 05 13 00	Conductors And Cables
26 05 33 13	26 05 19 16e	Communications Equipment Room Fittings
26 05 33 13	26 05 19 16f	Communications Backbone Cabling
26 05 33 13	26 05 19 16g	Communications Horizontal Cabling
26 05 33 13	26 05 19 16h	Conductors and Cables for Electronic Safety and Security

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SECTION 26 05 33 16 - RACEWAYS AND BOXES

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of raceways and boxes. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes raceways, fittings, boxes, enclosures, and cabinets for electrical wiring.

C. Definitions
1. EMT: Electrical metallic tubing.
2. ENT: Electrical nonmetallic tubing.
3. EPDM: Ethylene-propylene-diene terpolymer rubber.
4. FMC: Flexible metal conduit.
5. IMC: Intermediate metal conduit.
6. LFMC: Liquidtight flexible metal conduit.
7. LFNC: Liquidtight flexible nonmetallic conduit.
8. NBR: Acrylonitrile-butadiene rubber.
9. RNC: Rigid nonmetallic conduit.

D. Submittals
1. Product Data: For surface raceways, wireways and fittings, floor boxes, hinged-cover enclosures, and cabinets.
2. Shop Drawings: For the following raceway components. Include plans, elevations, sections, details, and attachments to other work.
   a. Custom enclosures and cabinets.
   b. For handholes and boxes for underground wiring, including the following:
      1) Duct entry provisions, including locations and duct sizes.
      2) Frame and cover design.
      3) Grounding details.
      4) Dimensioned locations of cable rack inserts, and pulling-in and lifting irons.
      5) Joint details.
3. Samples: For each type of exposed finish required for wireways, nonmetallic wireways and surface raceways, prepared on Samples of size indicated below.
4. Coordination Drawings: Conduit routing plans, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:
   a. Structural members in the paths of conduit groups with common supports.
   b. HVAC and plumbing items and architectural features in the paths of conduit groups with common supports.
5. Manufacturer Seismic Qualification Certification: Submit certification that enclosures and cabinets and their mounting provisions, including those for internal components, will withstand seismic forces defined in Division 26 Section(s) "Hangers And Supports For Electrical Systems" AND "Vibration And Seismic Controls For Electrical Systems". Include the following:
   a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
      1) The term "withstand" means "the cabinet or enclosure will remain in place without separation of any parts when subjected to the seismic forces specified and the unit will retain its enclosure characteristics, including its interior accessibility, after the seismic event."

b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

6. Qualification Data: For professional engineer and testing agency.
7. Source quality-control test reports.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Comply with NFPA 70.

1.2 PRODUCTS

A. Metal Conduit And Tubing
1. Rigid Steel Conduit: ANSI C80.1.
2. Aluminum Rigid Conduit: ANSI C80.5.
3. IMC: ANSI C80.6.
4. PVC-Coated Steel Conduit: PVC-coated rigid steel conduit **OR** IMC, **as directed**.
a. Comply with NEMA RN 1.
b. Coating Thickness: 0.040 inch (1 mm), minimum.
5. EMT: ANSI C80.3.
6. FMC: Zinc-coated steel **OR** Aluminum **OR** Zinc-coated steel or aluminum, **as directed**.
7. LFMC: Flexible steel conduit with PVC jacket.
8. Fittings for Conduit (Including all Types and Flexible and Liquidtight), EMT, and Cable: NEMA FB 1; listed for type and size raceway with which used, and for application and environment in which installed.
a. Conduit Fittings for Hazardous (Classified) Locations: Comply with UL 886.
b. Fittings for EMT: Steel **OR** Die-cast, **as directed**, set-screw **OR** compression, **as directed**, type.
c. Coating for Fittings for PVC-Coated Conduit: Minimum thickness, 0.040 inch (1 mm), with overlapping sleeves protecting threaded joints.
9. Joint Compound for Rigid Steel Conduit or IMC: Listed for use in cable connector assemblies, and compounded for use to lubricate and protect threaded raceway joints from corrosion and enhance their conductivity.

B. Nonmetallic Conduit And Tubing
1. ENT: NEMA TC 13.
2. RNC: NEMA TC 2, Type EPC-40-PVC, unless otherwise indicated.
3. LFNC: UL 1660.
4. Fittings for ENT and RNC: NEMA TC 3; match to conduit or tubing type and material.
5. Fittings for LFNC: UL 514B.

C. Optical Fiber/Communications Cable Raceway And Fittings
1. Description: Comply with UL 2024; flexible type, approved for plenum **OR** riser **OR** general-use, **as directed**, installation.

D. Metal Wireways
1. Description: Sheet metal sized and shaped as indicated, NEMA 250, Type 1 **OR** 12 **OR** 3R, **as directed**, unless otherwise indicated.
2. Fittings and Accessories: Include couplings, offsets, elbows, expansion joints, adapters, hold-down straps, end caps, and other fittings to match and mate with wireways as required for complete system.

3. Wireway Covers: Hinged type **OR** Screw-cover type **OR** Flanged-and-gasketed type **OR** As indicated, **as directed**.
4. Finish: Manufacturer's standard enamel finish.

E. Nonmetallic Wireways
1. Description: Fiberglass polyester, extruded and fabricated to size and shape indicated, with no holes or knockouts. Cover is gasketed with oil-resistant gasket material and fastened with captive screws treated for corrosion resistance. Connections are flanged, with stainless-steel screws and oil-resistant gaskets.
OR
Description: PVC plastic, extruded and fabricated to size and shape indicated, with snap-on cover and mechanically coupled connections with plastic fasteners.
2. Fittings and Accessories: Include couplings, offsets, elbows, expansion joints, adapters, hold-down straps, end caps, and other fittings to match and mate with wireways as required for complete system.

F. Surface Raceways
1. Surface Metal Raceways: Galvanized steel with snap-on covers. Manufacturer's standard enamel finish in color selected **OR** Prime coating, ready for field painting, **as directed**.
2. Surface Nonmetallic Raceways: Two-piece construction, manufactured of rigid PVC with texture and color selected from manufacturer's standard **OR** custom, **as directed**, colors.

G. Boxes, Enclosures, And Cabinets
1. Sheet Metal Outlet and Device Boxes: NEMA OS 1.
2. Cast-Metal Outlet and Device Boxes: NEMA FB 1, ferrous alloy **OR** aluminum, **as directed**, Type FD, with gasketed cover.
3. Nonmetallic Outlet and Device Boxes: NEMA OS 2.
4. Metal Floor Boxes: Cast metal **OR** Sheet metal, **as directed**, fully adjustable **OR** semi-adjustable, **as directed**, rectangular.
5. Nonmetallic Floor Boxes: Nonadjustable, round.
6. Small Sheet Metal Pull and Junction Boxes: NEMA OS 1.
7. Cast-Metal Access, Pull, and Junction Boxes: NEMA FB 1, cast aluminum **OR** galvanized, cast iron, **as directed**, with gasketed cover.
8. Hinged-Cover Enclosures: NEMA 250, Type 1, with continuous-hinge cover with flush latch, unless otherwise indicated.
   a. Metal Enclosures: Steel, finished inside and out with manufacturer's standard enamel.
   b. Nonmetallic Enclosures: Plastic, finished inside with radio-frequency-resistant paint, **as directed**.
9. Cabinets:
   a. NEMA 250, Type 1, galvanized-steel box with removable interior panel and removable front, finished inside and out with manufacturer's standard enamel.
   b. Hinged door in front cover with flush latch and concealed hinge.
   c. Key latch to match panelboards.
   d. Metal barriers to separate wiring of different systems and voltage.
   e. Accessory feet where required for freestanding equipment.

H. Handholes And Boxes For Exterior Underground Wiring
1. Description: Comply with SCTE 77.
   a. Color of Frame and Cover: Gray **OR** Green **as directed**.
   b. Configuration: Units shall be designed for flush burial and have open **OR** closed **OR** integral closed, **as directed**, bottom, unless otherwise indicated.
   c. Cover: Weatherproof, secured by tamper-resistant locking devices and having structural load rating consistent with enclosure.
   d. Cover Finish: Nonskid finish shall have a minimum coefficient of friction of 0.50.
   e. Cover Legend: Molded lettering, "ELECTRIC" **OR** "TELEPHONE" **OR** as indicated for each service, **as directed**.

f. Conduit Entrance Provisions: Conduit-terminating fittings shall mate with entering ducts for secure, fixed installation in enclosure wall.
g. Handholes 12 inches wide by 24 inches long (300 mm wide by 600 mm long) and larger shall have inserts for cable racks and pulling-in irons installed before concrete is poured.

2. Polymer-Concrete Handholes and Boxes with Polymer-Concrete Cover: Molded of sand and aggregate, bound together with polymer resin, and reinforced with steel or fiberglass or a combination of the two.
3. Fiberglass Handholes and Boxes with Polymer-Concrete Frame and Cover: Sheet-molded, fiberglass-reinforced, polyester-resin enclosure joined to polymer-concrete top ring or frame.
4. Fiberglass Handholes and Boxes: Molded of fiberglass-reinforced polyester resin, with covers of polymer concrete **OR** reinforced concrete **OR** cast iron **OR** hot-dip galvanized-steel diamond plate **OR** fiberglass, **as directed**.

I. Sleeves For Raceways
1. Steel Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, galvanized steel, plain ends.
2. Cast-Iron Pipe Sleeves: Cast or fabricated "wall pipe," equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop, unless otherwise indicated.
3. Sleeves for Rectangular Openings: Galvanized sheet steel with minimum 0.052- or 0.138-inch (1.3- or 3.5-mm) thickness as indicated and of length to suit application.
4. Coordinate sleeve selection and application with selection and application of firestopping specified in Division 07 Section "Penetration Firestopping".

J. Sleeve Seals
1. Description: Modular sealing device, designed for field assembly, to fill annular space between sleeve and cable.
a. Sealing Elements: EPDM **OR** NBR, **as directed**, interlocking links shaped to fit surface of cable or conduit. Include type and number required for material and size of raceway or cable.
b. Pressure Plates: Plastic **OR** Carbon steel **OR** Stainless steel, **as directed**. Include two for each sealing element.
c. Connecting Bolts and Nuts: Carbon steel with corrosion-resistant coating **OR** Stainless steel, **as directed**, of length required to secure pressure plates to sealing elements. Include one for each sealing element.

K. Source Quality Control For Underground Enclosures
1. Handhole and Pull-Box Prototype Test: Test prototypes of handholes and boxes for compliance with SCTE 77. Strength tests shall be for specified tier ratings of products supplied.
a. Tests of materials shall be performed by a independent testing agency.
b. Strength tests of complete boxes and covers shall be by either an independent testing agency or manufacturer. A qualified registered professional engineer shall certify tests by manufacturer.
c. Testing machine pressure gages shall have current calibration certification complying with ISO 9000 and ISO 10012, and traceable to NIST standards.

1.3 EXECUTION

A. Raceway Application
1. Outdoors: Apply raceway products as specified below, unless otherwise indicated:
a. Exposed Conduit: Rigid steel conduit **OR** IMC **OR** RNC, Type EPC-40-PVC **OR** RNC, Type EPC-80-PVC, **as directed**.
b. Concealed Conduit, Aboveground: Rigid steel conduit **OR** IMC **OR** EMT **OR** RNC, Type EPC-40-PVC, **as directed**.
c. Underground Conduit: RNC, Type EPC-40 **OR** 80, **as directed**,-PVC, direct buried.

d. Connection to Vibrating Equipment (Including Transformers and Hydraulic, Pneumatic, Electric Solenoid, or Motor-Driven Equipment): LFMC **OR** LFNC, **as directed**.
e. Boxes and Enclosures, Aboveground: NEMA 250, Type 3R **OR** 4, **as directed**.
f. Application of Handholes and Boxes for Underground Wiring:
1) Handholes and Pull Boxes in Driveway, Parking Lot, and Off-Roadway Locations, Subject to Occasional, Nondeliberate Loading by Heavy Vehicles: Polymer concrete **OR** Fiberglass enclosures with polymer-concrete frame and cover **OR** Fiberglass-reinforced polyester resin, **as directed**, SCTE 77, Tier 15 structural load rating.
2) Handholes and Pull Boxes in Sidewalk and Similar Applications with a Safety Factor for Nondeliberate Loading by Vehicles: Polymer-concrete units **OR** Heavy-duty fiberglass units with polymer-concrete frame and cover, **as directed**, SCTE 77, Tier 8 structural load rating.
3) Handholes and Pull Boxes Subject to Light-Duty Pedestrian Traffic Only: Fiberglass-reinforced polyester resin, structurally tested according to SCTE 77 with 3000-lbf (13 345-N) vertical loading.

2. Comply with the following indoor applications, unless otherwise indicated:
a. Exposed, Not Subject to Physical Damage: EMT **OR** ENT **OR** RNC, **as directed**.
b. Exposed, Not Subject to Severe Physical Damage: EMT **OR** RNC identified for such use, **as directed**.
c. Exposed and Subject to Severe Physical Damage: Rigid steel conduit **OR** IMC, **as directed**. Includes raceways in the following locations:
1) Loading dock.
2) Corridors used for traffic of mechanized carts, forklifts, and pallet-handling units.
3) Mechanical rooms.
d. Concealed in Ceilings and Interior Walls and Partitions: EMT **OR** ENT **OR** RNC, Type EPC-40-PVC, **as directed**.
e. Connection to Vibrating Equipment (Including Transformers and Hydraulic, Pneumatic, Electric Solenoid, or Motor-Driven Equipment): FMC, except use LFMC in damp or wet locations.
f. Damp or Wet Locations: PVC Coated Rigid steel conduit.
g. Raceways for Optical Fiber or Communications Cable in Spaces Used for Environmental Air: Plenum-type, optical fiber/communications cable raceway **OR** EMT, **as directed**.
h. Raceways for Optical Fiber or Communications Cable Risers in Vertical Shafts: Riser-type, optical fiber/communications cable raceway **OR** EMT, **as directed**.
i. Raceways for Concealed General Purpose Distribution of Optical Fiber or Communications Cable: General-use, optical fiber/communications cable raceway **OR** Riser-type, optical fiber/communications cable raceway **OR** Plenum-type, optical fiber/communications cable raceway **OR** EMT, **as directed**.
j. Boxes and Enclosures: NEMA 250, Type 1, except use NEMA 250, Type 4, stainless steel **OR** nonmetallic, **as directed**, in damp or wet locations.

3. Minimum Raceway Size: 1/2-inch (16-mm) **OR** 3/4-inch (21-mm), **as directed**, trade size.
4. Raceway Fittings: Compatible with raceways and suitable for use and location.
a. Rigid and Intermediate Steel Conduit: Use threaded rigid steel conduit fittings, unless otherwise indicated.
b. PVC Externally Coated, Rigid Steel Conduits: Use only fittings listed for use with that material. Patch and seal all joints, nicks, and scrapes in PVC coating after installing conduits and fittings. Use sealant recommended by fitting manufacturer.
5. Install nonferrous conduit or tubing for circuits operating above 60 Hz. Where aluminum raceways are installed for such circuits and pass through concrete, install in nonmetallic sleeve.
6. Do not install aluminum conduits in contact with concrete.

B. Installation
1. Comply with NECA 1 for installation requirements applicable to products specified in Part 2 except where requirements on Drawings or in this Article are stricter.
2. Keep raceways at least 6 inches (150 mm) away from parallel runs of flues and steam or hot-water pipes. Install horizontal raceway runs above water and steam piping.

3. Complete raceway installation before starting conductor installation.
4. Support raceways as specified in Division 26 Section(s) "Hangers And Supports For Electrical Systems" AND "Vibration And Seismic Controls For Electrical Systems".
5. Arrange stub-ups so curved portions of bends are not visible above the finished slab.
6. Install no more than the equivalent of three 90-degree bends in any conduit run except for communications conduits, for which fewer bends are allowed.
7. Conceal conduit and EMT within finished walls, ceilings, and floors, unless otherwise indicated.
8. Raceways Embedded in Slabs:
   a. Run conduit larger than 1-inch (27-mm) trade size, parallel or at right angles to main reinforcement. Where at right angles to reinforcement, place conduit close to slab support.
   b. Arrange raceways to cross building expansion joints at right angles with expansion fittings.
   c. Change from ENT to RNC, Type EPC-40-PVC, rigid steel conduit, or IMC before rising above the floor.
9. Threaded Conduit Joints, Exposed to Wet, Damp, Corrosive, or Outdoor Conditions: Apply listed compound to threads of raceway and fittings before making up joints. Follow compound manufacturer's written instructions.
10. Raceway Terminations at Locations Subject to Moisture or Vibration: Use insulating bushings to protect conductors, including conductors smaller than No. 4 AWG.
11. Install pull wires in empty raceways. Use polypropylene or monofilament plastic line with not less than 200-lb (90-kg) tensile strength. Leave at least 12 inches (300 mm) of slack at each end of pull wire.
12. Raceways for Optical Fiber and Communications Cable: Install raceways, metallic and nonmetallic, rigid and flexible, as follows:
    a. 3/4-Inch (19-mm) Trade Size and Smaller: Install raceways in maximum lengths of 50 feet (15 m).
    b. 1-Inch (25-mm) Trade Size and Larger: Install raceways in maximum lengths of 75 feet (23 m).
    c. Install with a maximum of two 90-degree bends or equivalent for each length of raceway unless Drawings show stricter requirements. Separate lengths with pull or junction boxes or terminations at distribution frames or cabinets where necessary to comply with these requirements.
13. Install raceway sealing fittings at suitable, approved, and accessible locations and fill them with listed sealing compound. For concealed raceways, install each fitting in a flush steel box with a blank cover plate having a finish similar to that of adjacent plates or surfaces. Install raceway sealing fittings at the following points:
    a. Where conduits pass from warm to cold locations, such as boundaries of refrigerated spaces.
    b. Where otherwise required by NFPA 70.
14. Expansion-Joint Fittings for RNC: Install in each run of aboveground conduit that is located where environmental temperature change may exceed 30 deg F (17 deg C), and that has straight-run length that exceeds 25 feet (7.6 m).
    a. Install expansion-joint fittings for each of the following locations, and provide type and quantity of fittings that accommodate temperature change listed for location:
       1) Outdoor Locations Not Exposed to Direct Sunlight: 125 deg F (70 deg C) temperature change.
       2) Outdoor Locations Exposed to Direct Sunlight: 155 deg F (86 deg C) temperature change.
       3) Indoor Spaces: Connected with the Outdoors without Physical Separation: 125 deg F (70 deg C) temperature change.
       4) Attics: 135 deg F (75 deg C) temperature change.
    b. Install fitting(s) that provide expansion and contraction for at least 0.00041 inch per foot of length of straight run per deg F (0.06 mm per meter of length of straight run per deg C) of temperature change.

c. Install each expansion-joint fitting with position, mounting, and piston setting selected according to manufacturer's written instructions for conditions at specific location at the time of installation.

15. Flexible Conduit Connections: Use maximum of 72 inches (1830 mm) of flexible conduit for recessed and semirecessed lighting fixtures, **as directed**, equipment subject to vibration, noise transmission, or movement; and for transformers and motors.
    a. Use LFMC in damp or wet locations subject to severe physical damage.
    b. Use LFMC or LFNC in damp or wet locations not subject to severe physical damage.
16. Recessed Boxes in Masonry Walls: Saw-cut opening for box in center of cell of masonry block, and install box flush with surface of wall.
17. Set metal floor boxes level and flush with finished floor surface.
18. Set nonmetallic floor boxes level. Trim after installation to fit flush with finished floor surface.

C. Installation Of Underground Conduit
1. Direct-Buried Conduit:
    a. Excavate trench bottom to provide firm and uniform support for conduit. Prepare trench bottom as specified in Division 31 Section "Earth Moving" for pipe less than 6 inches (150 mm) in nominal diameter.
    b. Install backfill as specified in Division 31 Section "Earth Moving"
    c. After installing conduit, backfill and compact. Start at tie-in point, and work toward end of conduit run, leaving conduit at end of run free to move with expansion and contraction as temperature changes during this process. Firmly hand tamp backfill around conduit to provide maximum supporting strength. After placing controlled backfill to within 12 inches (300 mm) of finished grade, make final conduit connection at end of run and complete backfilling with normal compaction as specified in Division 31 Section "Earth Moving".
    d. Install manufactured duct elbows for stub-ups at poles and equipment and at building entrances through the floor, unless otherwise indicated. Encase elbows for stub-up ducts throughout the length of the elbow.
    OR
    Install manufactured rigid steel conduit elbows for stub-ups at poles and equipment and at building entrances through the floor.
        1) Couple steel conduits to ducts with adapters designed for this purpose, and encase coupling with 3 inches (75 mm) of concrete.
        OR
        For stub-ups at equipment mounted on outdoor concrete bases, extend steel conduit horizontally a minimum of 60 inches (1500 mm) from edge of equipment pad or foundation. Install insulated grounding bushings on terminations at equipment.
    e. Warning Planks: Bury warning planks approximately 12 inches (300 mm) above direct-buried conduits, placing them 24 inches (600 mm) o.c. Align planks along the width and along the centerline of conduit.

D. Installation Of Underground Handholes And Boxes
1. Install handholes and boxes level and plumb and with orientation and depth coordinated with connecting conduits to minimize bends and deflections required for proper entrances.
2. Unless otherwise indicated, support units on a level bed of crushed stone or gravel, graded from 1/2-inch (12.5-mm) sieve to No. 4 (4.75-mm) sieve and compacted to same density as adjacent undisturbed earth.
3. Elevation: In paved areas, set so cover surface will be flush with finished grade. Set covers of other enclosures 1 inch (25 mm) above finished grade.
4. Install handholes and boxes with bottom below the frost line, <**Insert depth of frost line below grade at Project site**> below grade.
5. Install removable hardware, including pulling eyes, cable stanchions, cable arms, and insulators, as required for installation and support of cables and conductors and as indicated. Select arm lengths to be long enough to provide spare space for future cables, but short enough to preserve adequate working clearances in the enclosure.

6. Field-cut openings for conduits according to enclosure manufacturer's written instructions. Cut wall of enclosure with a tool designed for material to be cut. Size holes for terminating fittings to be used, and seal around penetrations after fittings are installed.

E. Sleeve Installation For Electrical Penetrations
1. Coordinate sleeve selection and application with selection and application of firestopping specified in Division 07 Section "Penetration Firestopping".
2. Concrete Slabs and Walls: Install sleeves for penetrations unless core-drilled holes or formed openings are used. Install sleeves during erection of slabs and walls.
3. Use pipe sleeves unless penetration arrangement requires rectangular sleeved opening.
4. Rectangular Sleeve Minimum Metal Thickness:
   a. For sleeve cross-section rectangle perimeter less than 50 inches (1270 mm) and no side greater than 16 inches (400 mm), thickness shall be 0.052 inch (1.3 mm).
   b. For sleeve cross-section rectangle perimeter equal to, or greater than, 50 inches (1270 mm) and 1 or more sides equal to, or greater than, 16 inches (400 mm), thickness shall be 0.138 inch (3.5 mm).
5. Fire-Rated Assemblies: Install sleeves for penetrations of fire-rated floor and wall assemblies unless openings compatible with firestop system used are fabricated during construction of floor or wall.
6. Cut sleeves to length for mounting flush with both surfaces of walls.
7. Extend sleeves installed in floors 2 inches (50 mm) above finished floor level.
8. Size pipe sleeves to provide 1/4-inch (6.4-mm) annular clear space between sleeve and raceway unless sleeve seal is to be installed or unless seismic criteria require different clearance.
9. Seal space outside of sleeves with grout for penetrations of concrete and masonry and with approved joint compound for gypsum board assemblies, **as directed**.
10. Interior Penetrations of Non-Fire-Rated Walls and Floors: Seal annular space between sleeve and raceway, using joint sealant appropriate for size, depth, and location of joint. Refer to Division 07 Section "Joint Sealants" for materials and installation.
11. Fire-Rated-Assembly Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at raceway penetrations. Install sleeves and seal with firestop materials. Comply with Division 07 Section "Penetration Firestopping".
12. Roof-Penetration Sleeves: Seal penetration of individual raceways with flexible, boot-type flashing units applied in coordination with roofing work.
13. Aboveground, Exterior-Wall Penetrations: Seal penetrations using sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch (25-mm) annular clear space between pipe and sleeve for installing mechanical sleeve seals.
14. Underground, Exterior-Wall Penetrations: Install cast-iron "wall pipes" for sleeves. Size sleeves to allow for 1-inch (25-mm) annular clear space between raceway and sleeve for installing mechanical sleeve seals.

F. Sleeve-Seal Installation
1. Install to seal underground, exterior wall penetrations.
2. Use type and number of sealing elements recommended by manufacturer for raceway material and size. Position raceway in center of sleeve. Assemble mechanical sleeve seals and install in annular space between raceway and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

G. Firestopping
1. Apply firestopping to electrical penetrations of fire-rated floor and wall assemblies to restore original fire-resistance rating of assembly. Firestopping materials and installation requirements are specified in Division 07 Section "Penetration Firestopping".

H. Protection
1. Provide final protection and maintain conditions that ensure coatings, finishes, and cabinets are without damage or deterioration at time of Substantial Completion.

a. Repair damage to galvanized finishes with zinc-rich paint recommended by manufacturer.
b. Repair damage to PVC or paint finishes with matching touchup coating recommended by manufacturer.

END OF SECTION 26 05 33 16

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SECTION 26 05 33 16a - WIRING DEVICES

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of wiring devices. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following:
a. Receptacles, receptacles with integral GFCI, and associated device plates.
b. Twist-locking receptacles.
c. Receptacles with integral surge suppression units.
d. Wall-box motion sensors.
e. Isolated-ground receptacles.
f. Hospital-grade receptacles.
g. Snap switches and wall-box dimmers.
h. Solid-state fan speed controls.
i. Wall-switch and exterior occupancy sensors.
j. Communications outlets.
k. Pendant cord-connector devices.
l. Cord and plug sets.
m. Floor service outlets, poke-through assemblies, service poles, and multioutlet assemblies.

C. Definitions
1. EMI: Electromagnetic interference.
2. GFCI: Ground-fault circuit interrupter.
3. Pigtail: Short lead used to connect a device to a branch-circuit conductor.
4. RFI: Radio-frequency interference.
5. TVSS: Transient voltage surge suppressor.
6. UTP: Unshielded twisted pair.

D. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings: List of legends and description of materials and process used for premarking wall plates.
3. Samples: One for each type of device and wall plate specified, in each color specified.
4. Operation and Maintenance Data: For wiring devices to include in all manufacturers' packing label warnings and instruction manuals that include labeling conditions.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Comply with NFPA 70.

1.2 PRODUCTS

A. Straight Blade Receptacles
1. Convenience Receptacles, 125 V, 20 A: Comply with NEMA WD 1, NEMA WD 6 configuration 5-20R, and UL 498.

2. Hospital-Grade, Duplex Convenience Receptacles, 125 V, 20 A: Comply with NEMA WD 1, NEMA WD 6 configuration 5-20R, and UL 498 Supplement SD.
3. Isolated-Ground, Duplex Convenience Receptacles, 125 V, 20 A: Comply with NEMA WD 1, NEMA WD 6 configuration 5-20R, and UL 498.
   a. Description: Straight blade; equipment grounding contacts shall be connected only to the green grounding screw terminal of the device and with inherent electrical isolation from mounting strap. Isolation shall be integral to receptacle construction and not dependent on removable parts.
4. Tamper-Resistant Convenience Receptacles, 125 V, 20 A: Comply with NEMA WD 1, NEMA WD 6 configuration 5-20R, and UL 498.
   a. Description: Labeled to comply with NFPA 70, "Health Care Facilities" Article, "Pediatric Locations" Section.

B. GFCI Receptacles
1. General Description: Straight blade, feed **OR** non-feed, **as directed**,-through type. Comply with NEMA WD 1, NEMA WD 6, UL 498, and UL 943, Class A, and include indicator light that is lighted when device is tripped.
2. Duplex GFCI Convenience Receptacles, 125 V, 20 A:
3. Hospital-Grade, Duplex GFCI Convenience Receptacles, 125 V, 20 A: Comply with UL 498 Supplement SD.

C. TVSS Receptacles
1. General Description: Comply with NEMA WD 1, NEMA WD 6, UL 498, and UL 1449, with integral TVSS in line to ground, line to neutral, and neutral to ground.
   a. TVSS Components: Multiple metal-oxide varistors; with a nominal clamp-level rating of 400 volts and minimum single transient pulse energy dissipation of 240 J, according to IEEE C62.41.2 and IEEE C62.45.
   b. Active TVSS Indication: Visual and audible, with light visible in face of device to indicate device is "active" or "no longer in service."
2. Duplex TVSS Convenience Receptacles:
   a. Description: Straight blade, 125 V, 20 A; NEMA WD 6 configuration 5-20R.
3. Isolated-Ground, Duplex Convenience Receptacles:
   a. Description: Straight blade, 125 V, 20 A; NEMA WD 6 configuration 5-20R. Equipment grounding contacts shall be connected only to the green grounding screw terminal of the device and with inherent electrical isolation from mounting strap. Isolation shall be integral to receptacle construction and not dependent on removable parts.
4. Hospital-Grade, Duplex Convenience Receptacles: Comply with UL 498 Supplement SD.
   a. Description: Straight blade, 125 V, 20 A; NEMA WD 6 configuration 5-20R.
5. Isolated-Ground, Hospital-Grade, Duplex Convenience Receptacles:
   a. Description: Straight blade, 125 V, 20 A; NEMA WD 6 configuration 5-20R. Comply with UL 498 Supplement SD. Equipment grounding contacts shall be connected only to the green grounding screw terminal of the device and with inherent electrical isolation from mounting strap. Isolation shall be integral to receptacle construction and not dependent on removable parts.

D. Hazardous (Classified) Location Receptacles
1. Available Wiring Devices for Hazardous (Classified) Locations: Comply with NEMA FB 11 and UL 1010.

E. Twist-Locking Receptacles
1. Single Convenience Receptacles, 125 V, 20 A: Comply with NEMA WD 1, NEMA WD 6 configuration L5-20R, and UL 498.
2. Isolated-Ground, Single Convenience Receptacles, 125 V, 20 A:
   a. Description: Comply with NEMA WD 1, NEMA WD 6 configuration L5-20R, and UL 498. Equipment grounding contacts shall be connected only to the green grounding screw

terminal of the device and with inherent electrical isolation from mounting strap. Isolation shall be integral to receptacle construction and not dependent on removable parts.

F. Pendant Cord-Connector Devices
1. Description: Matching, locking-type plug and receptacle body connector; NEMA WD 6 configurations L5-20P and L5-20R, heavy-duty grade.
   a. Body: Nylon with screw-open cable-gripping jaws and provision for attaching external cable grip.
   b. External Cable Grip: Woven wire-mesh type made of high-strength galvanized-steel wire strand, matched to cable diameter, and with attachment provision designed for corresponding connector.

G. Cord And Plug Sets
1. Description: Match voltage and current ratings and number of conductors to requirements of equipment being connected.
   a. Cord: Rubber-insulated, stranded-copper conductors, with Type SOW-A jacket; with green-insulated grounding conductor and equipment-rating ampacity plus a minimum of 30 percent.
   b. Plug: Nylon body and integral cable-clamping jaws. Match cord and receptacle type for connection.

H. Snap Switches
1. Comply with NEMA WD 1 and UL 20.
2. Switches, 120/277 V, 20 A:
3. Pilot Light Switches, 20 A:
   a. Description: Single pole, with neon-lighted handle, illuminated when switch is "ON."
4. Key-Operated Switches, 120/277 V, 20 A:
   a. Description: Single pole, with factory-supplied key in lieu of switch handle.
5. Single-Pole, Double-Throw, Momentary Contact, Center-Off Switches, 120/277 V, 20 A; for use with mechanically held lighting contactors.
6. Key-Operated, Single-Pole, Double-Throw, Momentary Contact, Center-Off Switches, 120/277 V, 20 A; for use with mechanically held lighting contactors, with factory-supplied key in lieu of switch handle.

I. Wall-Box Dimmers
1. Dimmer Switches: Modular, full-wave, solid-state units with integral, quiet on-off switches, with audible frequency and EMI/RFI suppression filters.
2. Control: Continuously adjustable slider **OR** toggle switch **OR** rotary knob, **as directed**; with single-pole or three-way switching. Comply with UL 1472.
3. Incandescent Lamp Dimmers: 120 V; control shall follow square-law dimming curve. On-off switch positions shall bypass dimmer module.
   a. 600 W; dimmers shall require no derating when ganged with other devices. Illuminated when "OFF," **as directed**.
4. Fluorescent Lamp Dimmer Switches: Modular; compatible with dimmer ballasts; trim potentiometer to adjust low-end dimming; dimmer-ballast combination capable of consistent dimming with low end not greater than 20 percent of full brightness.

J. Fan Speed Controls
1. Modular, 120-V, full-wave, solid-state units with integral, quiet on-off switches and audible frequency and EMI/RFI filters. Comply with UL 1917.
   a. Continuously adjustable slider **OR** toggle switch **OR** rotary knob, **as directed**, 5 A **OR** 1.5 A, **as directed**.
   b. Three-speed adjustable slider **OR** rotary knob, **as directed**, 1.5 A.

K. Occupancy Sensors
1. Wall-Switch Sensors:

a. Description: Passive-infrared type, 120/277 V, adjustable time delay up to 30 minutes, 180-degree field of view, with a minimum coverage area of 900 sq. ft. (84 sq. m).

2. Wall-Switch Sensors:
   a. Description: Adaptive-technology type, 120/277 V, adjustable time delay up to 20 minutes, 180-degree field of view, with a minimum coverage area of 900 sq. ft. (84 sq. m).
3. Long-Range Wall-Switch Sensors:
   a. Description: Passive-infrared type, 120/277 V, adjustable time delay up to 30 minutes, 110-degree field of view, with a minimum coverage area of 1200 sq. ft. (111 sq. m).
4. Long-Range Wall-Switch Sensors:
   a. Description: Dual technology, with both passive-infrared- and ultrasonic-type sensing, 120/277 V, adjustable time delay up to 30 minutes, 110-degree field of view, and a minimum coverage area of 1200 sq. ft. (111 sq. m).
5. Wide-Range Wall-Switch Sensors:
   a. Description: Passive-infrared type, 120/277 V, adjustable time delay up to 30 minutes, 150-degree field of view, with a minimum coverage area of 1200 sq. ft. (111 sq. m).
6. Exterior Occupancy Sensors:
   a. Description: Passive-infrared type, 120/277 V, weatherproof, adjustable time delay up to 15 minutes, 180-degree field of view, and 110-foot (34-m) detection range. Minimum switch rating: 1000-W incandescent, 500-VA fluorescent.

L. Communications Outlets
1. Telephone Outlet:
   a. Description: Single RJ-45 jack for terminating 100-ohm, balanced, four-pair UTP; TIA/EIA-568-B.1; complying with Category 5e. Comply with UL 1863.
2. Combination TV and Telephone Outlet:
   a. Description: Single RJ-45 jack for 100-ohm, balanced, four-pair UTP; TIA/EIA-568-B.1; complying with Category 5e; and one Type F coaxial cable connector.

M. Wall Plates
1. Single and combination types to match corresponding wiring devices.
   a. Plate-Securing Screws: Metal with head color to match plate finish.
   b. Material for Finished Spaces: Steel with white baked enamel, suitable for field painting **OR** Smooth, high-impact thermoplastic **OR** 0.035-inch- (1-mm-) thick, satin-finished stainless steel **OR** 0.04-inch- (1-mm-) thick, brushed brass with factory polymer finish **OR** 0.05-inch- (1.2-mm-) thick anodized aluminum **OR** 0.04-inch- (1-mm-) thick steel with chrome-plated finish, **as directed**.
   c. Material for Unfinished Spaces: Galvanized steel **OR** Smooth, high-impact thermoplastic, **as directed**.
   d. Material for Damp Locations: Thermoplastic **OR** Cast aluminum, **as directed**, with spring-loaded lift cover, and listed and labeled for use in "wet locations."
2. Wet-Location, Weatherproof Cover Plates: NEMA 250, complying with type 3R weather-resistant, die-cast aluminum **OR** thermoplastic, **as directed**, with lockable cover.

N. Floor Service Fittings
1. Type: Modular, flush-type **OR** flap-type **OR** above-floor, **as directed**, dual-service units suitable for wiring method used.
2. Compartments: Barrier separates power from voice and data communication cabling.
3. Service Plate: Rectangular **OR** Round, **as directed**, die-cast aluminum **OR** solid brass, **as directed**, with satin finish.
4. Power Receptacle: NEMA WD 6 configuration 5-20R, gray finish, unless otherwise indicated.
5. Voice and Data Communication Outlet: Blank cover with bushed cable opening **OR** Two modular, keyed, color-coded, RJ-45 Category 5e jacks for UTP cable, **as directed**.

O. Poke-Through Assemblies

1. Description: Factory-fabricated and -wired assembly of below-floor junction box with multichanneled, through-floor raceway/firestop unit and detachable matching floor service outlet assembly.
   a. Service Outlet Assembly: Pedestal type with services indicated **OR** Flush type with two simplex receptacles and space for two RJ-45 jacks **OR** Flush type with four simplex receptacles and space for four RJ-45 jacks, **as directed**.
   b. Size: Selected to fit nominal 3-inch (75-mm) **OR** 4-inch (100-mm), **as directed**, cored holes in floor and matched to floor thickness.
   c. Fire Rating: Unit is listed and labeled for fire rating of floor-ceiling assembly.
   d. Closure Plug: Arranged to close unused 3-inch (75-mm) **OR** 4-inch (100-mm), **as directed**, cored openings and reestablish fire rating of floor.
   e. Wiring Raceways and Compartments: For a minimum of four No. 12 AWG conductors and a minimum of two **OR** four, **as directed**, 4-pair, Category 5e voice and data communication cables.

P. Multioutlet Assemblies
1. Components of Assemblies: Products from a single manufacturer designed for use as a complete, matching assembly of raceways and receptacles.
2. Raceway Material: Metal, with manufacturer's standard finish **OR** PVC, **as directed**.
3. Wire: No. 12 AWG.

Q. Service Poles
1. Description: Factory-assembled and -wired units to extend power and voice and data communication from distribution wiring concealed in ceiling to devices or outlets in pole near floor.
   a. Poles: Nominal 2.5-inch- (65-mm-) square cross section, with height adequate to extend from floor to at least 6 inches (150 mm) above ceiling, and with separate channels for power wiring and voice and data communication cabling.
   b. Mounting: Ceiling trim flange with concealed bracing arranged for positive connection to ceiling supports; with pole foot and carpet pad attachment.
   c. Finishes: Manufacturer's standard painted finish and trim combination **OR** Satin-anodized aluminum, **as directed**.
   d. Wiring: Sized for minimum of five No. 12 AWG power and ground conductors and a minimum of four, 4-pair, Category 3 or 5 voice and data communication cables.
   e. Power Receptacles: Two duplex, 20-A, heavy-duty, NEMA WD 6 configuration 5-20R units.
   f. Voice and Data Communication Outlets: Blank insert with bushed cable opening **OR** Two RJ-45 Category 5e jacks **OR** Four RJ-45 Category 5e jacks, **as directed**.

R. Finishes
1. Color: Wiring device catalog numbers in Section Text do not designate device color.
   a. Wiring Devices Connected to Normal Power System: Almond **OR** Black **OR** Brown **OR** Gray **OR** Ivory **OR** White **OR** As selected, **as directed**, unless otherwise indicated or required by NFPA 70 or device listing.
   b. Wiring Devices Connected to Emergency Power System: Red.
   c. TVSS Devices: Blue.
   d. Isolated-Ground Receptacles: Orange **OR** As specified above, with orange triangle on face, **as directed**.

1.3 EXECUTION

A. Installation
1. Comply with NECA 1, including the mounting heights listed in that standard, unless otherwise noted.
2. Coordination with Other Trades:

a. Take steps to insure that devices and their boxes are protected. Do not place wall finish materials over device boxes and do not cut holes for boxes with routers that are guided by riding against outside of the boxes.
b. Keep outlet boxes free of plaster, drywall joint compound, mortar, cement, concrete, dust, paint, and other material that may contaminate the raceway system, conductors, and cables.
c. Install device boxes in brick or block walls so that the cover plate does not cross a joint unless the joint is troweled flush with the face of the wall.
d. Install wiring devices after all wall preparation, including painting, is complete.

3. Conductors:
   a. Do not strip insulation from conductors until just before they are spliced or terminated on devices.
   b. Strip insulation evenly around the conductor using tools designed for the purpose. Avoid scoring or nicking of solid wire or cutting strands from stranded wire.
   c. The length of free conductors at outlets for devices shall meet provisions of NFPA 70, Article 300, without pigtails.
   d. Existing Conductors:
      1) Cut back and pigtail, or replace all damaged conductors.
      2) Straighten conductors that remain and remove corrosion and foreign matter.
      3) Pigtailing existing conductors is permitted provided the outlet box is large enough.
4. Device Installation:
   a. Replace all devices that have been in temporary use during construction or that show signs that they were installed before building finishing operations were complete.
   b. Keep each wiring device in its package or otherwise protected until it is time to connect conductors.
   c. Do not remove surface protection, such as plastic film and smudge covers, until the last possible moment.
   d. Connect devices to branch circuits using pigtails that are not less than 6 inches (152 mm) in length.
   e. When there is a choice, use side wiring with binding-head screw terminals. Wrap solid conductor tightly clockwise, 2/3 to 3/4 of the way around terminal screw.
   f. Use a torque screwdriver when a torque is recommended or required by the manufacturer.
   g. When conductors larger than No. 12 AWG are installed on 15- or 20-A circuits, splice No. 12 AWG pigtails for device connections.
   h. Tighten unused terminal screws on the device.
   i. When mounting into metal boxes, remove the fiber or plastic washers used to hold device mounting screws in yokes, allowing metal-to-metal contact.
5. Receptacle Orientation:
   a. Install ground pin of vertically mounted receptacles up **OR** down, **as directed**, and on horizontally mounted receptacles to the right **OR** left, **as directed**.
   b. Install hospital-grade receptacles in patient-care areas with the ground pin or neutral blade at the top.
6. Device Plates: Do not use oversized or extra-deep plates. Repair wall finishes and remount outlet boxes when standard device plates do not fit flush or do not cover rough wall opening.
7. Dimmers:
   a. Install dimmers within terms of their listing.
   b. Verify that dimmers used for fan speed control are listed for that application.
   c. Install unshared neutral conductors on line and load side of dimmers according to manufacturers' device listing conditions in the written instructions.
8. Arrangement of Devices: Unless otherwise indicated, mount flush, with long dimension vertical and with grounding terminal of receptacles on top. Group adjacent switches under single, multigang wall plates.
9. Adjust locations of floor service outlets and service poles to suit arrangement of partitions and furnishings.

B. Identification
1. Comply with Division 26 Section "Identification For Electrical Systems".
   a. Receptacles: Identify panelboard and circuit number from which served. Use hot, stamped or engraved machine printing with black **OR** white **OR** red, **as directed**,-filled lettering on face of plate, and durable wire markers or tags inside outlet boxes.

C. Field Quality Control
1. Perform tests and inspections and prepare test reports.
   a. In healthcare facilities, prepare reports that comply with recommendations in NFPA 99.
   b. Test Instruments: Use instruments that comply with UL 1436.
   c. Test Instrument for Convenience Receptacles: Digital wiring analyzer with digital readout or illuminated LED indicators of measurement.
2. Tests for Convenience Receptacles:
   a. Line Voltage: Acceptable range is 105 to 132 V.
   b. Percent Voltage Drop under 15-A Load: A value of 6 percent or higher is not acceptable.
   c. Ground Impedance: Values of up to 2 ohms are acceptable.
   d. GFCI Trip: Test for tripping values specified in UL 1436 and UL 943.
   e. Using the test plug, verify that the device and its outlet box are securely mounted.
   f. The tests shall be diagnostic, indicating damaged conductors, high resistance at the circuit breaker, poor connections, inadequate fault current path, defective devices, or similar problems. Correct circuit conditions, remove malfunctioning units and replace with new ones, and retest as specified above.
3. Test straight blade convenience outlets in patient-care areas **OR** hospital-grade convenience outlets, **as directed**, for the retention force of the grounding blade according to NFPA 99. Retention force shall be not less than 4 oz. (115 g).

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Task	Specification	Specification Description
26 05 33 16	26 05 19 16c	Electrical Renovation

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SECTION 26 05 33 23 - UNDERFLOOR RACEWAYS FOR ELECTRICAL SYSTEMS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of underfloor raceways for electrical systems. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following:
a. Flat-top, single-channel, underfloor raceways.
b. Flat-top, multichannel, underfloor raceways.
c. Flush, flat-top underfloor raceways.
d. Cellular metal underfloor raceways.
e. Trench-type underfloor raceways.
f. Electrical connection components for precast concrete, hollow-core, floor decks.
g. Electrical connection components for electrified cellular steel floor decks.
h. Service fittings.

C. Definitions
1. Flush Outlet: Underfloor raceway outlet installed so the top of the fixed portions of the receptacles, jacks, and connector assemblies is located approximately at the surface of the floor or floor covering, and with the bodies of connected plugs exposed above the surface of the floor.
2. Flush Underfloor Raceway: Rectangular cross-section, flat-top raceway installed with the top of the raceway flush with the surface of the concrete in which it is embedded.
3. Header Raceway: Rectangular cross-section, single-channel or multichannel, underfloor raceway arranged as feeder raceway to bring wires and cables to service raceways from panelboards and communication terminal components.
4. Recessed Outlet: Underfloor raceway outlet installed with the top of the fixed portion of the connector assemblies located below the surface of the floor or floor covering and arranged to receive plug connectors with the bodies of the plugs concealed below the floor level.
5. Service Raceway: Underfloor distribution raceway providing direct connection to service fittings using preset or afterset inserts.
6. Trench Header: Trench-type raceway arranged as feeder raceway to bring wires and cables to service raceways from panelboards and communication terminal equipment.
7. Underfloor Raceway: A conduit, duct, or cell assembly, or trench located within the floor material or with its top at the floor surface.

D. Submittals
1. Product Data: For underfloor raceway components, fittings, and accessories.
2. Shop Drawings: For underfloor raceways. Include floor plans, assembly drawings, sections, and details.
a. Identify components and accessories such as expansion-joint assemblies, straight raceway lengths, preset and afterset inserts, and service fittings.
b. Provide dimensions locating raceway header and distribution elements. Include spacing between preset inserts and between preset inserts and ends of duct runs, walls, columns, junction boxes, and header duct connections.
c. Show connections between raceway elements and relationships between components and adjacent structural and architectural elements including slab reinforcement, floor finish work, permanent partitions, architectural module lines, and pretensioning or post-tensioning components.

d. Indicate height of preset inserts, junction boxes, and raceways coordinated with depth of concrete slab and floor fill.
e. Indicate thickening of slabs where required for adequate encasement of raceway components.
f. Document coordination of exposed components with floor-covering materials to ensure that fittings and trim are suitable for indicated floor-covering material.
g. Revise locations from those indicated in the Contract Documents, as required to suit field conditions and to ensure a functioning layout. Identify proposed deviations from the Contract Documents.
h. Show details of connections and terminations of underfloor raceways at panelboards and communication terminal equipment in equipment rooms, wire closets, and similar spaces.
i. Identify those cells of cellular floor deck that are to be connected and fitted for the following underfloor distribution:
1) Power.
2) Voice.
3) Data.
4) Signal.
5) Communications.

3. Samples: For typical underfloor raceway products, in specified finish, including the following:
a. Service fittings and flush and recessed outlet and junction-box covers.
b. A section of each service raceway configuration with specified preset insert and service fitting installed.
c. A junction box of each size and type for use with underfloor raceway.
d. A section of each header raceway configuration, complete with provisions for connection with service raceway.
e. A section of trench-type raceway, complete with cover and required trim.
f. A junction box of each size and type, complete with cover and trim.

4. Operation and Maintenance Data: For underfloor raceways, to include in emergency, operation, and maintenance manuals. Include the following:
a. Manufacturer's written instructions for locating preset inserts and for installing afterset inserts.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. Comply with NFPA 70.

1.2 PRODUCTS

A. Flat-Top, Single-Channel, Underfloor Raceways
1. Description:
a. Material: Steel.
b. Cross-Section Shape: Rectangular.
c. Number of Levels: One **OR** Two, **as directed**.
d. Minimum Bending Radius for Communication Cables: Combination of raceways, fittings, inserts, junction boxes, service fittings, and mounting and connection arrangements for wiring devices and jacks shall provide a 2-inch- (50-mm-) minimum bending radius for communication cables.

2. Service Raceways: Fitted with preset inserts.
a. Nominal Raceway Dimensions:
1) Depth: 1-1/2 inches (38 mm).
2) Power Service Raceway Width: 3-1/2 inches (90 mm).
3) Communication Service Raceway Width: 3-1/2 inches (90 mm) **OR** 6-1/2 inches (165 mm), **as directed**.

b. Number of Single-Channel Raceways per Run: One **OR** Two **OR** Three **OR** Four **OR** Five, **as directed**, unless otherwise indicated.
c. Preset Inserts: Rectangular **OR** Round, **as directed**.
1) Spacing: 24 inches (600 mm) **OR** 12 inches (300 mm), **as directed,** o.c.
2) Size: Rectangular dimensions as required to accommodate mounting and connection of flush-mounted, duplex receptacle or dual communication-jack or connector service fitting.
3) Size: 2 inches (50 mm) in diameter.
4) Equip each insert with a disposable cover and select insert height so cover is 1/8 inch (3 mm) below surface of concrete.
5) Arrange insert for optional attachment of flush-, surface-, or wiring- extension service fitting to replace disposable cover.

3. Header Raceways: Single channel, without preset inserts (blank raceway).
a. Nominal Raceway Dimensions:
1) Depth: 1-1/2 inches (38 mm).
2) Power Header Raceway Width: 3-1/2 inches (90 mm).
3) Communication Header Raceway Width: 3-1/2 inches (90 mm) **OR** 6-1/2 inches (165 mm), **as directed**.
b. Arrangement: In same plane as **OR** Below, **as directed**, service raceways.
c. Connections: Arranged to connect with service raceways at single-level **OR** two-level, **as directed**, junction boxes.

B. Flat-Top, Multichannel, Underfloor Raceways
1. Description:
a. Material: Steel.
b. Cross-Section Shape: Rectangular.
c. Number of Longitudinal Channels: Two **OR** Three **OR** Four, **as directed**, separated by steel wall(s).
d. Number of Levels: One **OR** Two, **as directed**.
e. Minimum Bending Radius for Communication Cables: Combination of raceways, fittings, inserts, junction boxes, service fittings, and mounting and connection arrangements for wiring devices and jacks shall provide a 2-inch- (50-mm-) minimum bending radius for communication cables.

2. Service Raceways: Fitted with preset inserts.
a. Nominal Raceway Dimensions:
1) Depth: 1-3/8 inches (35 mm).
2) Power Service Channel Width: 3-1/2 inches (90 mm) **OR** 4-3/8-inches (111 mm), **as directed**.
3) Communication Service Channel Width: 3-1/2 inches (90 mm) **OR** 4 inches (102 mm) **OR** 6-1/2 inches (165 mm), **as directed**.
b. Preset Inserts:
1) Spacing: 24 inches (600 mm) **OR** 12 inches (300 mm), **as directed,** o.c.
2) Size: Dimensions as required to accommodate mounting and connection of flush- and surface-mounted, single- and multiple-system service fittings or to connect to wiring extensions for feeding wall outlets for power **OR** communications **OR** power and communications, **as directed**.
3) Equip each insert with a disposable cover arranged for installation with top 1/8 inch (3 mm) below surface of concrete.
4) Arrange inserts for optional attachment of flush-, surface-, or wiring-extension service fitting to replace disposable cover. Arrange brackets, mountings, barriers, and floor access covers to support, isolate, and provide access to flush or surface outlet-mounting connector, jack, and receptacle devices.

3. Header Raceways: Multichannel, without preset inserts (blank raceway).
a. Nominal Raceway Dimensions:
1) Header Raceway Depth: Same as service raceways **OR** 2-1/2 inches (64 mm) **OR** 2-3/4 inches (70 mm) **OR** 3 inches (76 mm) **OR** 3-1/2 inches (90 mm), **as directed**.

2) Power Header Channel Width: 3-1/2 inches (90 mm) **OR** 4-3/8-inches (111 mm), **as directed**.
3) Communication Header Channel Width: 3-1/2 inches (90 mm) **OR** 4 inches (102 mm) **OR** 6-1/2 inches (165 mm), **as directed**.

b. Arrangement: In same plane as **OR** Below, **as directed**, service raceways.
c. Connections: Arranged to connect with service raceways at single-level **OR** two-level, **as directed**, junction boxes.

C. Flush, Flat-Top Underfloor Raceways
1. Description:
a. Material: Steel.
b. Cross-Section Shape: Rectangular, single channel and multichannel, separated by steel wall(s).
c. Listed and labeled for installation with top flush with concrete floor.
d. Number of Levels: One.
2. Service Raceways: Fitted with preset inserts.
a. Number of Longitudinal Channels per Multichannel Raceway: Two **OR** Three, **as directed**.
b. Number of Single-Channel Raceways per Run: One **OR** Two **OR** Three, **as directed**, unless otherwise indicated.
c. Nominal Channel Dimensions: 3 inches (76 mm) wide by 1-1/4 inches (32 mm) deep.
d. Preset Inserts: Threaded opening with removable steel plug that is flush with top of raceway when screwed in place.
1) Spacing: 24 inches (600 mm) **OR** 12 inches (300 mm), **as directed**, o.c., full length of each service raceway.
2) Arrangement: Stagger insert locations on parallel raceways or channels to accommodate placement of adjacent service fittings.
3) Size: 1-5/8-inch (41-mm) diameter.
3. Header Raceways: Raceways same as service raceways except without preset inserts (blank raceway).
a. Nominal Channel Dimensions: Same as service raceways.
b. Arrangement: In same plane as service raceways.
c. Connections: Arranged to connect with service raceways at junction boxes.

D. Cellular Metal Underfloor Raceways
1. Service Raceways: Fitted with preset inserts.
a. Material: Steel.
b. Number of Longitudinal Cells: Three, separated by steel walls.
c. Nominal Dimensions of Cells:
1) Overall Depth: 1-1/4 inches (32 mm) unless otherwise indicated.
2) Cross-Sectional Area of Cells: Power cells: 5-1/2 sq. in. (35.5 sq. cm); communication system cells: 16 sq. in. (103 sq. cm).
d. Minimum Bending Radius for Communication Cables: Combination of raceways, fittings, inserts, junction boxes, service fittings, and mounting and connection arrangements for wiring devices and jacks shall provide a 2-inch- (50-mm-) minimum bending radius for communication cables.
e. Preset Inserts: Rectangular-shaped metal housing assemblies arranged to provide electrical outlet access to each cell of each raceway designated for service raceway use. Inserts shall be provided throughout the entire length of each such raceway.
1) Spacing: 30 inches (762 mm) **OR** 24 inches (600 mm) **OR** 12 inches (300 mm), **as directed,** o.c.
2) Include housing and connecting provisions for a flush or recessed, single-, double-, or triple-system service fitting.
3) Include mounting and connecting provisions for a surface, single- or multiple-system service fitting.

4) Include connecting provisions for a wiring-extension service fitting to feed wall outlets.
5) Equip each insert with a disposable cover plate arranged for installation with top 1/8 inch (3 mm) below surface of concrete. Arrange insert to receive a flush-, recessed-, or wiring-extension service fitting to replace disposable top.

2. Header Assembly: A junction box and raceway arrangement arranged to feed wires and cables to service raceways.
   a. Three-compartment junction box connecting blank, multicell cellular header raceway (no inserts) with cellular service raceways.
      1) Arrange junction box in the center of a 60-inch (152-cm) length of header raceway.
      2) Cellular header raceway shall have same dimensions as service raceways.
      3) Provide capability for service raceways to be run in both directions from intersection with header raceway.
   b. Three-compartment junction box preassembled with blank, flat-top, multichannel header raceway (no inserts) and fitted to connect with cellular service raceway at right angles to header raceway.
      1) Arrange junction box in the center of a 60-inch (152-cm) length of header raceway.
      2) Provide capability for service raceways to be run in both directions from intersection with header raceway.

E. Trench-Type Underfloor Raceways
1. Trench: Steel, shop or factory welded and fabricated to indicated sizes. Include the following features:
   a. Slab Depth Adjustment: Minimum of minus 1/8 inch (3 mm) to plus 5/8 inch (16 mm) before and during concrete placement.
   b. Cover Supports: Height adjustable, with leveling screws to rigidly support cover assembly.
   c. Screed Strip: Extruded aluminum along both edges at proper elevation without requiring shim material.
   d. Trim Strip: Select to accommodate floor finish material.
   e. Partitions: Arranged to separate channels and isolate wiring of different systems.
   f. Grommeted openings in active floor cells or service raceways.
   g. Manufacturer's standard corrosion-resistant finish, applied after fabrication.
2. Cover Plates: Removable, steel plates, 1/4 inch (6 mm) thick, each weighing 60 lb (27 kg) or less with full gasket attached to side units. Fabricate intermediate supports to limit unsupported spans to 15 inches (380 mm) or less. Fabricate covers with appropriate depth recess to receive indicated floor finish.

F. Electrical Connection Components For Cellular Steel Floor Deck
1. Preset Inserts: Rectangular metal-housing assemblies.
   a. Spacing: 30 inches (762 mm) **OR** 24 inches (600 mm) **OR** 12 inches (300 mm), **as directed,** o.c.
   b. Size: As required to provide electrical outlet access to each cell of each group of three cells that is designated for electrical service raceway use.
   c. Equip each insert with a disposable cover arranged for installation with top 1/8 inch (3 mm) below surface of concrete. Arrange insert to receive a flush-, recessed-, or wiring-extension service fitting to replace disposable cover.
   d. Include housing and connecting provisions for a flush or recessed, single-, double-, or triple-system service fitting.
   e. Include mounting and connecting provisions for a surface, single-, double-, or triple-system service fitting.
   f. Include connecting provisions for a wiring-extension service fitting to feed wall outlets.

G. Electrical Connection Components For Cellular Concrete Floor Deck
1. Afterset Inserts: Round metal-nipple assembly with internal and external threading, arranged to screw into plug driven into 1-7/8-inch (48-mm) hole drilled through floor fill, where present, and deck-cell wall into floor raceway cell.

a. Inserts shall be compatible with floor-mounting service fittings.
b. Inserts shall provide wiring path from cell to power **OR** communication **OR** power and communication, **as directed**, wall and ceiling outlets.
c. Inserts shall provide wiring path from cell to header raceway.

H. Supports, Fittings, And Hardware
1. Supports, fittings, and hardware shall be compatible with raceway and outlet system and shall be listed for use with raceway systems and components specified.
2. Supports: Adjustable for height and arranged to maintain alignment and spacing of raceways during concrete placement. Include hold-down straps.
3. Raceway Fittings: Couplings, expansion-joint sleeves, cross-under offsets, vertical and horizontal elbows, grounding screws, adapters, end caps, and other fittings suitable for use with basic components to form a complete installation.

I. Junction Boxes
1. Description: Manufacturer's standard enclosure for indicated type, quantity, arrangement, and configuration of raceways at each raceway junction, intersection, and access location. Include the following accessories and features:
a. Mounting brackets.
b. Escutcheons and holders to accommodate surrounding floor covering.
c. Means for leveling and height adjustment more than 3/8 inch (10 mm) before and after concrete is placed.
d. Raceway Openings: For underfloor raceways and conduits arranged to accommodate raceway layout.
e. Covers shall have appropriate depth recess to receive specific floor finish material.
f. Partitions to separate wiring of different systems.

J. Service Fittings
1. Exposed Parts Finish: Brass **OR** Brushed Aluminum, **as directed**.
2. Flush, Single-System Service Fitting for Round Inserts: Include mounting and cover to support and provide access to single connector, jack, or receptacle device; mounted flush with floor within body of insert.
a. Connector, Jack, and Receptacle Devices: Single modular type; complying with Division 26 Section(s) "Wiring Devices" AND Division 27 Section(s) "Communications Horizontal Cabling".
b. Power Receptacle Outlet: Suitable for 20-A device.
3. Flush, Single- or Multiple-System Service Fitting for Rectangular Inserts: Include mounting, hinged cover, and trim to support and provide access to connector, jack, or receptacle devices mounted flush with floor within insert.
a. Connector, Jack, and Receptacle Devices: Modular type; complying with Division 26 Section(s) "Wiring Devices" AND Division 27 Section(s) "Communications Horizontal Cabling".
b. Power Receptacle Rating: 20 A, 120 V unless otherwise indicated.
4. Recess-Mounted Service Fitting: Modular fittings compatible with preset inserts and shall include covers; provisions for receptacles, jacks, and connectors; and associated device plates for indicated systems. Include hinged flush handhole covers with recessed depth to match thickness of floor finish material. Provide for internally mounted receptacle- and communication-jack and connector assemblies complying with requirements in Division 26 Section(s) "Wiring Devices" AND Division 27 Section(s) "Communications Horizontal Cabling".
a. Duplex receptacle.
b. Duplex telephone-data jacks.
c. Double duplex receptacles.
d. Duplex receptacle and duplex telephone-data jacks.
e. Double duplex telephone-data jacks, Category 5 **OR** Category 5e **OR** Category 6, **as directed**.

f. Fiber-optic cable connector.

5. Surface-Mounted Service Fitting: Modular pedestal type, with locking attachment matched to insert floor opening.
   a. Power-outlet, double-faced, surface-mounted unit for duplex receptacle on both sides.
   b. Power-outlet, single-faced, surface-mounted unit for duplex receptacle on one side.
   c. Communication-outlet, double-faced, surface-mounted unit.
      1) Include bushed openings on both sides; 1-inch (25-mm) minimum diameter; insulated with nonconducting material.
      2) Include provisions for modular dual fiber-optic connector assembly on both sides.
      3) Include provisions for modular dual jack-connector assembly, rated for Category 5 **OR** Category 5e **OR** Category 6, **as directed**, on both sides.
   d. Communication-outlet, single-faced, surface-mounted unit with bushed opening on one side; 1-inch (25-mm) minimum diameter; insulated with nonconducting material.
   e. Combination surface-mounted unit for duplex receptacle on one side and with communication cable connection provision on opposite side.
      1) Communication Side: Include bushed opening; 1-inch (25-mm) minimum diameter; insulated with nonconducting material.
      2) Communication Side: Include provisions for modular dual fiber-optic connector assembly.
      3) Communication Side: Include provisions for modular dual jack-connector assembly, rated for Category 5 **OR** Category 5e **OR** Category 6, **as directed**.
6. Flush-Mounted Service Fittings: Modular fittings compatible with preset inserts and shall include covers, provisions for receptacles jacks and connector assemblies and wiring extensions to wall-mounted outlets, and associated device plates for indicated systems. Include flush handhole covers, recessed to suit floor finish material. Internally mounted, modular, receptacle, jack and connector assemblies shall comply with requirements in Division 26 Section(s) "Wiring Devices" AND Division 27 Section(s) "Communications Horizontal Cabling".
   a. Duplex convenience receptacle.
   b. Duplex telephone-data outlets.
   c. Double duplex convenience receptacles.
   d. Duplex convenience receptacle and duplex telephone-data outlets.
   e. Double duplex telephone-data outlets.
   f. Duplex communication jack, rated for Category 5 **OR** Category 5e **OR** Category 6, **as directed**.
   g. Duplex fiber-optic communication connector.
   h. Wiring-Extension Service Fittings: Arrangement of brackets and mountings to support, and provide access to wiring or cabling of a cell, and to connect the cable or raceway that extends the system to an individual wall outlet. Provide for connection of FMC **OR** ENT **OR** Type MC cable, **as directed**, for power extensions, and FMC **OR** ENT **OR** optical fiber/communication cable raceway, **as directed**, for communication system extensions.

1.3 EXECUTION

A. Installation
   1. Install raceways aligned and leveled and, unless otherwise indicated, parallel or perpendicular to building walls.
   2. Provide a concrete base for support of cellular metal raceway.
   3. Arrange supports to attain proper elevation, alignment, and spacing of raceways. Install supports securely at ends and at intervals not to exceed 60 inches (1500 mm), to prevent movement during concrete pour.
   4. Level raceway components with finished slab and make adjustments for floor finishes.
   5. Adjust supports to maintain a 1/16- to 3/8-inch (1.6- to 10-mm) finished concrete cover over preset inserts.
   6. Remove burrs, sharp edges, dents, and mechanical defects.
   7. Cap or plug boxes, insert- and service-fitting openings, and open ends of raceways.

8. Seal raceways, cells, junction boxes, and inserts to prevent water, concrete, or foreign matter from entering raceways before and during pouring slab or placing fill. Tape joints, or seal with compound, as recommended in writing by underfloor raceway manufacturer.
9. Junction Boxes: Install tops level and flush with finished floor. Install blank closure plates or plugs to close unused junction-box openings. Grout boxes in place to prevent movement during construction. Place top covers in inverted position during construction to prevent damage to surface of cover. Reinstall covers in proper position prior to final acceptance of Work.
10. Afterset Inserts: Cut, hole saw, and drill slab and raceways to allow for installation.
11. Ground underfloor raceway components.
12. Install a marker at the center of the last insert of each cell and channel of each straight run of metal underfloor service raceway to locate the insert and identify the system.
    a. Install markers at last inserts on both sides of permanent walls and at first inserts adjacent to each junction box.
    b. Install markers flush at screed line before pouring slab or placing fill. Extend marker with grommeted screw when floor covering is placed. Do not extend through carpet.
    c. Use slotted-head screw to identify electrical power; use Phillips-head screw to identify conventional communications.
    d. Use another distinctive screw head to identify third system such as special-purpose wiring.
13. Level raceway components with finished slab and make adjustments in raceway component elevation to accommodate indicated floor finishes.

B. Field Quality Control
1. Perform tests and inspections.
    a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
2. Tests and Inspections:
    a. Perform visual inspection of interior of each junction box **OR** section of trench raceway, **as directed**, to verify absence of dirt, dust, construction debris, and moisture. Replace damaged and malfunctioning components.
    b. Perform point-to-point tests of ground continuity and resistance of ground path between the most remote accessible fitting on each branch of each underfloor raceway system and the main electrical distribution grounding system.
        1) Determine cause and perform correction of any point-to-point resistance value that exceeds 0.05 ohms.
        2) Comply with NETA Acceptance Testing Specifications about safety, suitability of test equipment, test instrument calibration, and test report and records.

C. Cleaning
1. Clean and swab out underfloor raceways, inserts, and junction boxes after finish has been applied to floor slab, and remove foreign material, dirt, and moisture. Leave interiors clean and dry.

END OF SECTION 26 05 33 23

Task	Specification	Specification Description
26 05 33 23	26 05 33 16	Raceways And Boxes

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SECTION 26 05 36 00 - CABLE TRAYS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of cable trays. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes steel, aluminum, stainless-steel, and fiberglass cable trays and accessories.

C. Submittals
1. Product Data: Include data indicating dimensions and finishes for each type of cable tray indicated.
2. Shop Drawings: For each type of cable tray.
a. Show fabrication and installation details of cable tray, including plans, elevations, and sections of components and attachments to other construction elements. Designate components and accessories, including clamps, brackets, hanger rods, splice-plate connectors, expansion-joint assemblies, straight lengths, and fittings.
b. Seismic-Restraint Details, **as directed**: Signed and sealed by a qualified professional engineer, licensed in the state where Project is located, who is responsible for their preparation.
1) Design Calculations: Calculate requirements for selecting seismic restraints.
2) Detail fabrication, including anchorages and attachments to structure and to supported cable trays.
3. Field quality-control reports.
4. Operation and Maintenance Data.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Comply with NFPA 70.

E. Delivery, Storage, And Handling
1. Steel cable tray, hot dip galvanized after fabrication, **OR** Aluminum cable tray **OR** Stainless-steel cable tray **OR** Fiberglass cable tray, ,**as directed** may be stored outside without cover, but shall be loosely stacked, elevated off the ground, and ventilated to prevent staining during storage.
2. Store indoors to prevent water or other foreign materials from staining or adhering to cable tray. Unpack and dry wet materials before storage.
3. Steel, mill galvanized **OR** electrogalvanized **OR** factory-primed, **as directed**, cable tray shall be stored in a well-ventilated, dry location. Unpack and dry wet materials before storage.
4. PVC-coated **OR** Field-painted, **as directed**, cable tray shall be stored indoors. Protect cable tray from scratching and marring of finish. Unpack and dry wet materials before storage.

1.2 PRODUCTS

A. Materials And Finishes
1. Cable Trays, Fittings, and Accessories: Steel, complying with NEMA VE 1.

a. Factory-standard primer, ready for field painting; with cadmium-plated hardware according to ASTM B 766.
b. Mill galvanized before fabrication, complying with ASTM A 653/A 653M, G90 (Z275) coating; with hardware galvanized according to ASTM B 633 **OR** cadmium plated according to ASTM B 766, **as directed**.
c. Electrogalvanized before fabrication, complying with ASTM B 633; with hardware galvanized according to ASTM B 633.
d. Hot-dip galvanized after fabrication, complying with ASTM A 123/A 123M, Class B2; with chromium-zinc, ASTM F 1136, **OR** Type 316 stainless-steel, **as directed**, hardware.
e. PVC coating applied in a fluidized bed or by electrostatic spray; with chromium-zinc, ASTM F 1136 **OR** Type 316 stainless-steel, **as directed**, hardware.
f. Epoxy-resin paint over paint manufacturer's recommended primer and corrosion-inhibiting treatment; with cadmium-plated hardware according to ASTM B 766 **OR** Type 316 stainless-steel hardware, **as directed**.

2. Cable Trays, Fittings, and Accessories: Aluminum, complying with NEMA VE 1, Aluminum Association's Alloy 6063-T6 for rails, rungs, and cable trays, and Alloy 5052-H32 or Alloy 6061-T6 for fabricated parts; with chromium-zinc, ASTM F 1136, **OR** Type 316 stainless-steel, **as directed**, splice-plate fasteners, bolts, and screws
3. Cable Trays, Fittings, and Accessories: Stainless steel, Type 304 **OR** 316, **as directed**, complying with NEMA VE 1.
4. Cable Trays, Fittings, and Accessories: Fiberglass, complying with NEMA FG 1 and UL 568. Splice-plate fasteners, bolts, and screws shall be fiberglass-encapsulated stainless steel. Design fasteners so that no metal is visible when fully assembled and tightened. Fastener encapsulation shall not be damaged when torqued to manufacturer's recommended value.
5. Sizes and Configurations: Refer to the Cable Tray Schedule on Drawings for specific requirements for types, materials, sizes, and configurations.
   a. Center-hanger supports may be used only when specifically indicated.

B. Cable Tray Accessories
1. Fittings: Tees, crosses, risers, elbows, and other fittings as indicated, of same materials and finishes as cable tray.
2. Covers: Solid **OR** Louvered **OR** Ventilated-hat **OR** 2-in-3 pitch cover, **as directed**, type of same materials and finishes as cable tray.
3. Barrier Strips: Same materials and finishes as cable tray.
4. Cable tray supports and connectors, including bonding jumpers, as recommended by cable tray manufacturer.

C. Warning Signs
1. Lettering: 1-1/2-inch- (40-mm-) high, black letters on yellow background with legend "WARNING! NOT TO BE USED AS WALKWAY, LADDER, OR SUPPORT FOR LADDERS OR PERSONNEL."
2. Materials and fastening are specified in Division 26 Section "Identification For Electrical Systems".

1.3 EXECUTION

A. Cable Tray Installation
1. Comply with recommendations in NEMA VE 2. Install as a complete system, including all necessary fasteners, hold-down clips, splice-plate support systems, barrier strips, hinged horizontal and vertical splice plates, elbows, reducers, tees, and crosses.
2. Remove burrs and sharp edges from cable trays.
3. Fasten cable tray supports to building structure and install seismic restraints, **as directed**.

a. Design each fastener and support to carry load indicated by seismic requirements and to comply with seismic-restraint details according to Division 26 Section "Vibration And Seismic Controls For Electrical Systems".
b. Place supports so that spans do not exceed maximum spans on schedules.
c. Construct supports from channel members, threaded rods, and other appurtenances furnished by cable tray manufacturer. Arrange supports in trapeze or wall-bracket form as required by application.
d. Support bus assembly to prevent twisting from eccentric loading.
e. Manufacture center-hung support, designed for 60 percent versus 40 percent eccentric loading condition, with a safety factor of 3.
f. Locate and install supports according to NEMA FG 1 **OR** NEMA VE 1, **as directed**.

4. Make connections to equipment with flanged fittings fastened to cable tray and to equipment. Support cable tray independent of fittings. Do not carry weight of cable tray on equipment enclosure.
5. Install expansion connectors where cable tray crosses building expansion joint and in cable tray runs that exceed dimensions recommended in NEMA FG 1 **OR** NEMA VE 1, **as directed**. Space connectors and set gaps according to applicable standard.
6. Make changes in direction and elevation using standard fittings.
7. Make cable tray connections using standard fittings.
8. Seal penetrations through fire and smoke barriers according to Division 07 Section "Penetration Firestopping".
9. Sleeves for Future Cables: Install capped sleeves for future cables through firestop-sealed cable tray penetrations of fire and smoke barriers.
10. Workspace: Install cable trays with enough space to permit access for installing cables.
11. Install barriers to separate cables of different systems, such as power, communications, and data processing; or of different insulation levels, such as 600, 5000, and 15 000 V.
12. After installation of cable trays is completed, install warning signs in visible locations on or near cable trays.

B. Cable Installation
1. Install cables only when cable tray installation has been completed and inspected.
2. Fasten cables on horizontal runs with cable clamps or cable ties as recommended by NEMA VE 2. Tighten clamps only enough to secure the cable, without indenting the cable jacket. Install cable ties with a tool that includes an automatic pressure-limiting device.
3. On vertical runs, fasten cables to tray every 18 inches (457 mm). Install intermediate supports when cable weight exceeds the load-carrying capacity of the tray rungs.
4. In existing construction, remove inactive or dead cables from cable tray.
5. Install covers after installation of cable is completed.

C. Connections
1. Ground cable trays according to manufacturer's written instructions.
2. Install an insulated equipment grounding conductor with cable tray, in addition to those required by NFPA 70.

D. Field Quality Control
1. After installing cable trays and after electrical circuitry has been energized, survey for compliance with requirements. Perform the following field quality-control survey:
a. Visually inspect cable insulation for damage. Correct sharp corners, protuberances in cable tray, vibration, and thermal expansion and contraction conditions, which may cause or have caused damage.
b. Verify that the number, size, and voltage of cables in cable tray do not exceed that permitted by NFPA 70. Verify that communication or data-processing circuits are separated from power circuits by barriers.
c. Verify that there is no intrusion of such items as pipe, hangers, or other equipment that could damage cables.

d. Remove deposits of dust, industrial process materials, trash of any description, and any blockage of tray ventilation.
e. Visually inspect each cable tray joint and each ground connection for mechanical continuity. Check bolted connections between sections for corrosion. Clean and retorque in suspect areas.
f. Check for missing or damaged bolts, bolt heads, or nuts. When found, replace with specified hardware.
g. Perform visual and mechanical checks for adequacy of cable tray grounding; verify that all takeoff raceways are bonded to cable tray.

2. Report results in writing.

E. Protection

1. Protect installed cable trays.
   a. Repair damage to galvanized finishes with zinc-rich paint recommended by cable tray manufacturer.
   b. Repair damage to PVC or paint finishes with matching touchup coating recommended by cable tray manufacturer.
   c. Install temporary protection for cables in open trays to protect exposed cables from falling objects or debris during construction. Temporary protection for cables and cable tray can be constructed of wood or metal materials until the risk of damage is over.

END OF SECTION 26 05 36 00

Task	Specification	Specification Description
26 05 39 00	26 05 33 23	Underfloor Raceways For Electrical Systems
26 05 43 00	26 05 19 16	Common Work Results for Electrical
26 05 43 00	26 05 19 16a	Common Work Results for Communications
26 05 43 00	26 05 19 16b	Common Work Results for Electronic Safety and Security
26 05 43 00	26 05 19 16e	Communications Equipment Room Fittings
26 05 43 00	26 05 19 16f	Communications Backbone Cabling
26 05 43 00	26 05 19 16g	Communications Horizontal Cabling
26 05 43 00	26 05 19 16h	Conductors and Cables for Electronic Safety and Security

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SECTION 26 05 53 00 - ELECTRICAL IDENTIFICATION

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for electrical identification. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Identification for raceways.
b. Identification of power and control cables.
c. Identification for conductors.
d. Underground-line warning tape.
e. Warning labels and signs.
f. Instruction signs.
g. Equipment identification labels.
h. Miscellaneous identification products.

C. Submittals
1. Product Data: For each electrical identification product indicated.
2. Samples: For each type of label and sign to illustrate size, colors, lettering style, mounting provisions, and graphic features of identification products.
3. Identification Schedule: An index of nomenclature of electrical equipment and system components used in identification signs and labels.

D. Quality Assurance
1. Comply with ANSI A13.1 and IEEE C2, **as directed**.
2. Comply with NFPA 70.
3. Comply with 29 CFR 1910.144 and 29 CFR 1910.145.
4. Comply with ANSI Z535.4 for safety signs and labels.
5. Adhesive-attached labeling materials, including label stocks, laminating adhesives, and inks used by label printers, shall comply with UL 969.

1.2 PRODUCTS

A. Power Raceway Identification Materials
1. Comply with ANSI A13.1 for minimum size of letters for legend and for minimum length of color field for each raceway size.
2. Colors for Raceways Carrying Circuits at 600 V or Less:
a. Black letters on an orange field.
b. Legend: Indicate voltage and system or service type, **as directed**.
3. Colors for Raceways Carrying Circuits at More Than 600 V:
a. Black letters on an orange field.
b. Legend: "DANGER CONCEALED HIGH VOLTAGE WIRING" with 3-inch- (75-mm-) high letters on 20-inch (500-mm) centers.
4. Self-Adhesive Vinyl Labels for Raceways Carrying Circuits at 600 V or Less: Preprinted, flexible label laminated with a clear, weather- and chemical-resistant coating and matching wraparound adhesive tape for securing ends of legend label.

5. Snap-Around Labels for Raceways Carrying Circuits at 600 V or Less: Slit, pretensioned, flexible, preprinted, color-coded acrylic sleeve, with diameter sized to suit diameter of raceway or cable it identifies and to stay in place by gripping action.
6. Snap-Around, Color-Coding Bands for Raceways Carrying Circuits at 600 V or Less: Slit, pretensioned, flexible, solid-colored acrylic sleeve, 2 inches (50 mm) long, with diameter sized to suit diameter of raceway or cable it identifies and to stay in place by gripping action.
7. Tape and Stencil for Raceways Carrying Circuits More Than 600 V: 4-inch- (100-mm-) wide black stripes on 10-inch (250-mm) centers diagonally over orange background that extends full length of raceway or duct and is 12 inches (300 mm) wide. Stop stripes at legends.
8. Metal Tags: Brass or aluminum, 2 by 2 by 0.05 inch (50 by 50 by 1.3 mm), with stamped legend, punched for use with self-locking cable tie fastener.
9. Write-On Tags: Polyester tag, 0.010 inch (0.25 mm) **OR** 0.015 inch (0.38 mm), **as directed**, thick, with corrosion-resistant grommet and cable tie for attachment to conductor or cable.
   a. Marker for Tags: Permanent, waterproof, black ink marker recommended by tag manufacturer.
      OR
      Marker for Tags: Machine-printed, permanent, waterproof, black ink marker recommended by printer manufacturer.

B. Armored And Metal-Clad Cable Identification Materials
1. Comply with ANSI A13.1 for minimum size of letters for legend and for minimum length of color field for each raceway and cable size.
2. Colors for Raceways Carrying Circuits at 600 V and Less:
   a. Black letters on an orange field.
   b. Legend: Indicate voltage and system or service type, **as directed**.
3. Colors for Raceways Carrying Circuits at More Than 600 V:
   a. Black letters on an orange field.
   b. Legend: "DANGER CONCEALED HIGH VOLTAGE WIRING" with 3-inch- (75-mm-) high letters on 20-inch (500-mm) centers.
4. Self-Adhesive Vinyl Labels: Preprinted, flexible label laminated with a clear, weather- and chemical-resistant coating and matching wraparound adhesive tape for securing ends of legend label.
   OR
   Self-Adhesive Vinyl Tape: Colored, heavy duty, waterproof, fade resistant; 2 inches (50 mm) wide; compounded for outdoor use.

C. Power And Control Cable Identification Materials
1. Comply with ANSI A13.1 for minimum size of letters for legend and for minimum length of color field for each raceway and cable size.
2. Self-Adhesive Vinyl Labels: Preprinted, flexible label laminated with a clear, weather- and chemical-resistant coating and matching wraparound adhesive tape for securing ends of legend label.
3. Metal Tags: Brass or aluminum, 2 by 2 by 0.05 inch (50 by 50 by 1.3 mm), with stamped legend, punched for use with self-locking cable tie fastener.
4. Write-On Tags: Polyester tag, 0.010 inch (0.25 mm) **OR** 0.015 inch (0.38 mm), **as directed**, thick, with corrosion-resistant grommet and cable tie for attachment to conductor or cable.
   a. Marker for Tags: Permanent, waterproof, black ink marker recommended by tag manufacturer.
      OR
      Marker for Tags: Machine-printed, permanent, waterproof, black ink marker recommended by printer manufacturer.
5. Snap-Around Labels: Slit, pretensioned, flexible, preprinted, color-coded acrylic sleeve, with diameter sized to suit diameter of raceway or cable it identifies and to stay in place by gripping action.

6. Snap-Around, Color-Coding Bands: Slit, pretensioned, flexible, solid-colored acrylic sleeve, 2 inches (50 mm) long, with diameter sized to suit diameter of raceway or cable it identifies and to stay in place by gripping action.

D. Conductor Identification Materials
1. Color-Coding Conductor Tape: Colored, self-adhesive vinyl tape not less than 3 mils (0.08 mm) thick by 1 to 2 inches (25 to 50 mm) wide.
2. Self-Adhesive Vinyl Labels: Preprinted, flexible label laminated with a clear, weather- and chemical-resistant coating and matching wraparound adhesive tape for securing ends of legend label.
3. Snap-Around Labels: Slit, pretensioned, flexible, preprinted, color-coded acrylic sleeve, with diameter sized to suit diameter of raceway or cable it identifies and to stay in place by gripping action.
4. Snap-Around, Color-Coding Bands: Slit, pretensioned, flexible, solid-colored acrylic sleeve, 2 inches (50 mm) long, with diameter sized to suit diameter of raceway or cable it identifies and to stay in place by gripping action.
5. Marker Tapes: Vinyl or vinyl-cloth, self-adhesive wraparound type, with circuit identification legend machine printed by thermal transfer or equivalent process.
6. Write-On Tags: Polyester tag, 0.010 inch (0.25 mm) **OR** 0.015 inch (0.38 mm), **as directed**, thick, with corrosion-resistant grommet and cable tie for attachment to conductor or cable.
   a. Marker for Tags: Permanent, waterproof, black ink marker recommended by tag manufacturer.
      OR
      Marker for Tags: Machine-printed, permanent, waterproof, black ink marker recommended by printer manufacturer.

E. Floor Marking Tape
1. 2-inch- (50-mm-) wide, 5-mil (0.125-mm) pressure-sensitive vinyl tape, with black and white stripes and clear vinyl overlay.

F. Underground-Line Warning Tape
1. Tape:
   a. Recommended by manufacturer for the method of installation and suitable to identify and locate underground electrical and communications utility lines.
   b. Printing on tape shall be permanent and shall not be damaged by burial operations.
   c. Tape material and ink shall be chemically inert, and not subject to degrading when exposed to acids, alkalis, and other destructive substances commonly found in soils.
2. Color and Printing:
   a. Comply with ANSI Z535.1 through ANSI Z535.5.
   b. Inscriptions for Red-Colored Tapes: ELECTRIC LINE, HIGH VOLTAGE.
   c. Inscriptions for Orange-Colored Tapes: TELEPHONE CABLE, CATV CABLE, COMMUNICATIONS CABLE, OPTICAL FIBER CABLE.
3. Tag: Type I:
   a. Pigmented polyolefin, bright-colored, continuous-printed on one side with the inscription of the utility, compounded for direct-burial service.
   b. Thickness: 4 mils (0.1 mm).
   c. Weight: 18.5 lb/1000 sq. ft. (9.0 kg/100 sq. m).
   d. 3-Inch (75-mm) Tensile According to ASTM D 882: 30 lbf (133.4 N), and 2500 psi (17.2 MPa).
4. Tag: Type II:
   a. Multilayer laminate consisting of high-density polyethylene scrim coated with pigmented polyolefin, bright-colored, continuous-printed on one side with the inscription of the utility, compounded for direct-burial service.
   b. Thickness: 12 mils (0.3 mm).
   c. Weight: 36.1 lb/1000 sq. ft. (17.6 kg/100 sq. m).

d. 3-Inch (75-mm) Tensile According to ASTM D 882: 400 lbf (1780 N), and 11,500 psi (79.2 MPa).

5. Tag: Type ID:
   a. Detectable three-layer laminate, consisting of a printed pigmented polyolefin film, a solid aluminum-foil core, and a clear protective film that allows inspection of the continuity of the conductive core, bright-colored, continuous-printed on one side with the inscription of the utility, compounded for direct-burial service.
   b. Overall Thickness: 5 mils (0.125 mm).
   c. Foil Core Thickness: 0.35 mil (0.00889 mm).
   d. Weight: 28 lb/1000 sq. ft. (13.7 kg/100 sq. m).
   e. 3-Inch (75-mm) Tensile According to ASTM D 882: 70 lbf (311.3 N), and 4600 psi (31.7 MPa).
6. Tag: Type IID:
   a. Reinforced, detectable three-layer laminate, consisting of a printed pigmented woven scrim, a solid aluminum-foil core, and a clear protective film that allows inspection of the continuity of the conductive core, bright-colored, continuous-printed on one side with the inscription of the utility, compounded for direct-burial service.
   b. Overall Thickness: 8 mils (0.2 mm).
   c. Foil Core Thickness: 0.35 mil (0.00889 mm).
   d. Weight: 34 lb/1000 sq. ft. (16.6 kg/100 sq. m).
   e. 3-Inch (75-mm) Tensile According to ASTM D 882: 300 lbf (1334 N), and 12,500 psi (86.1 MPa).

G. Warning Labels And Signs
1. Comply with NFPA 70 and 29 CFR 1910.145.
2. Self-Adhesive Warning Labels: Factory-printed, multicolor, pressure-sensitive adhesive labels, configured for display on front cover, door, or other access to equipment unless otherwise indicated.
3. Baked-Enamel Warning Signs:
   a. Preprinted aluminum signs, punched or drilled for fasteners, with colors, legend, and size required for application.
   b. 1/4-inch (6.4-mm) grommets in corners for mounting.
   c. Nominal size, 7 by 10 inches (180 by 250 mm).
4. Metal-Backed, Butyrate Warning Signs:
   a. Weather-resistant, nonfading, preprinted, cellulose-acetate butyrate signs with 0.0396-inch (1-mm) galvanized-steel backing; and with colors, legend, and size required for application.
   b. 1/4-inch (6.4-mm) grommets in corners for mounting.
   c. Nominal size, 10 by 14 inches (250 by 360 mm).
5. Warning label and sign shall include, but are not limited to, the following legends:
   a. Multiple Power Source Warning: "DANGER - ELECTRICAL SHOCK HAZARD - EQUIPMENT HAS MULTIPLE POWER SOURCES."
   b. Workspace Clearance Warning: "WARNING - OSHA REGULATION - AREA IN FRONT OF ELECTRICAL EQUIPMENT MUST BE KEPT CLEAR FOR 36 INCHES (915 MM)."

H. Instruction Signs
1. Engraved, laminated acrylic or melamine plastic, minimum 1/16 inch (1.6 mm) thick for signs up to 20 sq. inches (129 sq. cm) and 1/8 inch (3.2 mm) thick for larger sizes.
   a. Engraved legend with black letters on white face.
   b. Punched or drilled for mechanical fasteners.
   c. Framed with mitered acrylic molding and arranged for attachment at applicable equipment.
2. Adhesive Film Label: Machine printed, in black, by thermal transfer or equivalent process. Minimum letter height shall be 3/8 inch (10 mm).
3. Adhesive Film Label with Clear Protective Overlay: Machine printed, in black, by thermal transfer or equivalent process. Minimum letter height shall be 3/8 inch (10 mm). Overlay shall provide a weatherproof and UV-resistant seal for label.

I. Equipment Identification Labels
   1. Adhesive Film Label: Machine printed, in black, by thermal transfer or equivalent process. Minimum letter height shall be 3/8 inch (10 mm).
   2. Adhesive Film Label with Clear Protective Overlay: Machine printed, in black, by thermal transfer or equivalent process. Minimum letter height shall be 3/8 inch (10 mm). Overlay shall provide a weatherproof and UV-resistant seal for label.
   3. Self-Adhesive, Engraved, Laminated Acrylic or Melamine Label: Adhesive backed, with white letters on a dark-gray background. Minimum letter height shall be 3/8 inch (10 mm).
   4. Engraved, Laminated Acrylic or Melamine Label: Punched or drilled for screw mounting. White letters on a dark-gray background. Minimum letter height shall be 3/8 inch (10 mm).
   5. Stenciled Legend: In nonfading, waterproof, black ink or paint. Minimum letter height shall be 1 inch (25 mm).

J. Cable Ties
   1. General-Purpose Cable Ties: Fungus inert, self extinguishing, one piece, self locking, Type 6/6 nylon.
      a. Minimum Width: 3/16 inch (5 mm).
      b. Tensile Strength at 73 deg F (23 deg C), According to ASTM D 638: 12,000 psi (82.7 MPa).
      c. Temperature Range: Minus 40 to plus 185 deg F (Minus 40 to plus 85 deg C).
      d. Color: Black except where used for color-coding.
   2. UV-Stabilized Cable Ties: Fungus inert, designed for continuous exposure to exterior sunlight, self extinguishing, one piece, self locking, Type 6/6 nylon.
      a. Minimum Width: 3/16 inch (5 mm).
      b. Tensile Strength at 73 deg F (23 deg C), According to ASTM D 638: 12,000 psi (82.7 MPa).
      c. Temperature Range: Minus 40 to plus 185 deg F (Minus 40 to plus 85 deg C).
      d. Color: Black.
   3. Plenum-Rated Cable Ties: Self extinguishing, UV stabilized, one piece, self locking.
      a. Minimum Width: 3/16 inch (5 mm).
      b. Tensile Strength at 73 deg F (23 deg C), According to ASTM D 638: 7000 psi (48.2 MPa).
      c. UL 94 Flame Rating: 94V-0.
      d. Temperature Range: Minus 50 to plus 284 deg F (Minus 46 to plus 140 deg C).
      e. Color: Black.

K. Miscellaneous Identification Products
   1. Paint: Comply with requirements in Division 07 for paint materials and application requirements. Select paint system applicable for surface material and location (exterior or interior).
   2. Fasteners for Labels and Signs: Self-tapping, stainless-steel screws or stainless-steel machine screws with nuts and flat and lock washers.

1.3 EXECUTION

A. Installation
   1. Verify identity of each item before installing identification products.
   2. Location: Install identification materials and devices at locations for most convenient viewing without interference with operation and maintenance of equipment.
   3. Apply identification devices to surfaces that require finish after completing finish work.
   4. Self-Adhesive Identification Products: Clean surfaces before application, using materials and methods recommended by manufacturer of identification device.
   5. Attach signs and plastic labels that are not self-adhesive type with mechanical fasteners appropriate to the location and substrate.
   6. System Identification Color-Coding Bands for Raceways and Cables: Each color-coding band shall completely encircle cable or conduit. Place adjacent bands of two-color markings in contact, side by side. Locate bands at changes in direction, at penetrations of walls and floors, at 50-foot

(15-m) maximum intervals in straight runs, and at 25-foot (7.6-m) maximum intervals in congested areas.

7. Aluminum Wraparound Marker Labels and Metal Tags: Secure tight to surface of conductor or cable at a location with high visibility and accessibility.
8. Cable Ties: For attaching tags. Use general-purpose type, except as listed below:
   a. Outdoors: UV-stabilized nylon.
   b. In Spaces Handling Environmental Air: Plenum rated.
9. Underground-Line Warning Tape: During backfilling of trenches install continuous underground-line warning tape directly above line at 6 to 8 inches (150 to 200 mm) below finished grade. Use multiple tapes where width of multiple lines installed in a common trench or concrete envelope exceeds 16 inches (400 mm) overall.
10. Painted Identification: Comply with requirements in Division 07 for surface preparation and paint application.

B. Identification Schedule
1. Concealed Raceways, Duct Banks, More Than 600 V, within Buildings: Tape and stencil 4-inch-(100-mm-) wide black stripes on 10-inch (250-mm) centers over orange background that extends full length of raceway or duct and is 12 inches (300 mm) wide. Stencil legend "DANGER CONCEALED HIGH VOLTAGE WIRING" with 3-inch- (75-mm-) high black letters on 20-inch (500-mm) centers. Stop stripes at legends. Apply to the following finished surfaces:
   a. Floor surface directly above conduits running beneath and within 12 inches (300 mm) of a floor that is in contact with earth or is framed above unexcavated space.
   b. Wall surfaces directly external to raceways concealed within wall.
   c. Accessible surfaces of concrete envelope around raceways in vertical shafts, exposed in the building, or concealed above suspended ceilings.
2. Accessible Raceways, Armored and Metal-Clad Cables, More Than 600 V: Self-adhesive vinyl **OR** Snap-around, **as directed**, labels. Install labels at 10-foot (3-m) **OR** 30-foot (10-m), **as directed**, maximum intervals.
3. Accessible Raceways and Metal-Clad Cables, 600 V or Less, for Service, Feeder, and Branch Circuits More Than 30 A, and 120 V to ground: Identify with self-adhesive vinyl label **OR** self-adhesive vinyl tape applied in bands, **as directed**. Install labels at 10-foot (3-m) **OR** 30-foot (10-m), **as directed**, maximum intervals.
4. Accessible Raceways and Cables within Buildings: Identify the covers of each junction and pull box of the following systems with self-adhesive vinyl labels with the wiring system legend and system voltage. System legends shall be as follows:
   a. Emergency Power.
   b. Power.
   c. UPS.
5. Power-Circuit Conductor Identification, 600 V or Less: For conductors in vaults, pull and junction boxes, manholes, and handholes, use color-coding conductor tape to identify the phase.
   a. Color-Coding for Phase and Voltage Level Identification, 600 V or Less: Use colors listed below for ungrounded service, feeder, and branch-circuit conductors.
      1) Color shall be factory applied or field applied for sizes larger than No. 8 AWG, if authorities having jurisdiction permit.
      2) Colors for 208/120-V Circuits:
         a) Phase A: Black.
         b) Phase B: Red.
         c) Phase C: Blue.
      3) Colors for 480/277-V Circuits:
         a) Phase A: Brown.
         b) Phase B: Orange.
         c) Phase C: Yellow.
      4) Field-Applied, Color-Coding Conductor Tape: Apply in half-lapped turns for a minimum distance of 6 inches (150 mm) from terminal points and in boxes where

splices or taps are made. Apply last two turns of tape with no tension to prevent possible unwinding. Locate bands to avoid obscuring factory cable markings.

6. Power-Circuit Conductor Identification, More than 600 V: For conductors in vaults, pull and junction boxes, manholes, and handholes, use write-on tags **OR** nonmetallic plastic tag holder with adhesive-backed phase tags, and a separate tag with the circuit designation, **as directed**.
7. Install instructional sign including the color-code for grounded and ungrounded conductors using adhesive-film-type labels.
8. Conductors to Be Extended in the Future: Attach write-on tags **OR** marker tape, **as directed**, to conductors and list source.
9. Auxiliary Electrical Systems Conductor Identification: Identify field-installed alarm, control, and signal connections.
   a. Identify conductors, cables, and terminals in enclosures and at junctions, terminals, and pull points. Identify by system and circuit designation.
   b. Use system of marker tape designations that is uniform and consistent with system used by manufacturer for factory-installed connections.
   c. Coordinate identification with Project Drawings, manufacturer's wiring diagrams, and the Operation and Maintenance Manual.
10. Locations of Underground Lines: Identify with underground-line warning tape for power, lighting, communication, and control wiring and optical fiber cable.
    a. Limit use of underground-line warning tape to direct-buried cables.
    b. Install underground-line warning tape for both direct-buried cables and cables in raceway.
11. Workspace Indication: Install floor marking tape to show working clearances in the direction of access to live parts. Workspace shall be as required by NFPA 70 and 29 CFR 1926.403 unless otherwise indicated. Do not install at flush-mounted panelboards and similar equipment in finished spaces.
12. Warning Labels for Indoor Cabinets, Boxes, and Enclosures for Power and Lighting: Self-adhesive warning labels **OR** Baked-enamel warning signs **OR** Metal-backed, butyrate warning signs, **as directed**.
    a. Comply with 29 CFR 1910.145.
    b. Identify system voltage with black letters on an orange background.
    c. Apply to exterior of door, cover, or other access.
    d. For equipment with multiple power or control sources, apply to door or cover of equipment including, but not limited to, the following:
       1) Power transfer switches.
       2) Controls with external control power connections.
13. Operating Instruction Signs: Install instruction signs to facilitate proper operation and maintenance of electrical systems and items to which they connect. Install instruction signs with approved legend where instructions are needed for system or equipment operation.
14. Emergency Operating Instruction Signs: Install instruction signs with white legend on a red background with minimum 3/8-inch- (10-mm-) high letters for emergency instructions at equipment used for power transfer **OR** load shedding, **as directed**.
15. Equipment Identification Labels: On each unit of equipment, install unique designation label that is consistent with wiring diagrams, schedules, and the Operation and Maintenance Manual. Apply labels to disconnect switches and protection equipment, central or master units, control panels, control stations, terminal cabinets, and racks of each system. Systems include power, lighting, control, communication, signal, monitoring, and alarm systems unless equipment is provided with its own identification.
    a. Labeling Instructions:
       1) Indoor Equipment: Adhesive film label **OR** Adhesive film label with clear protective overlay **OR** Self-adhesive, engraved, laminated acrylic or melamine label **OR** Engraved, laminated acrylic or melamine label, **as directed**. Unless otherwise indicated, provide a single line of text with 1/2-inch- (13-mm-) high letters on 1-1/2-inch- (38-mm-) high label; where two lines of text are required, use labels 2 inches (50 mm) high.
       2) Outdoor Equipment: Engraved, laminated acrylic or melamine label **OR** Stenciled legend 4 inches (100 mm) high, **as directed**.

3) Elevated Components: Increase sizes of labels and letters to those appropriate for viewing from the floor.
4) Unless provided with self-adhesive means of attachment, fasten labels with appropriate mechanical fasteners that do not change the NEMA or NRTL rating of the enclosure.

b. Equipment to Be Labeled:
1) Panelboards: Typewritten directory of circuits in the location provided by panelboard manufacturer. Panelboard identification shall be self-adhesive, engraved **OR** engraved, **as directed**, laminated acrylic or melamine label.
2) Enclosures and electrical cabinets.
3) Access doors and panels for concealed electrical items.
4) Switchgear.
5) Switchboards.
6) Transformers: Label that includes tag designation shown on Drawings for the transformer, feeder, and panelboards or equipment supplied by the secondary.
7) Substations.
8) Emergency system boxes and enclosures.
9) Motor-control centers.
10) Enclosed switches.
11) Enclosed circuit breakers.
12) Enclosed controllers.
13) Variable-speed controllers.
14) Push-button stations.
15) Power transfer equipment.
16) Contactors.
17) Remote-controlled switches, dimmer modules, and control devices.
18) Battery-inverter units.
19) Battery racks.
20) Power-generating units.
21) Monitoring and control equipment.
22) UPS equipment.

END OF SECTION 26 05 53 00

Task	Specification	Specification Description
26 05 83 00	26 05 13 00	Conductors And Cables
26 05 83 00	26 05 13 00a	Undercarpet Cables
26 05 83 00	26 05 13 00b	Medium-Voltage Cables

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SECTION 26 09 23 00 - LIGHTING CONTROLS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for lighting controls. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes manually operated lighting controls with relays, electrically operated circuit breakers, and control module.
2. This Section includes manually operated, PC-based, digital lighting controls with external signal source, relays, electrically operated circuit breakers, and control module.
3. This Section includes individually addressable lighting control devices communicating with data-entry and -retrieval devices using DALI protocol.

C. Definitions
1. BACnet: A networking communication protocol that complies with ASHRAE 135.
2. BAS: Building automation system.
3. DALI: Digital addressable lighting interface.
4. LonWorks: A control network technology platform for designing and implementing interoperable control devices and networks.
5. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling and power-limited circuits.
6. Monitoring: Acquisition, processing, communication, and display of equipment status data, metered electrical parameter values, power quality evaluation data, event and alarm signals, tabulated reports, and event logs.
7. PC: Personal computer; sometimes plural as "PCs."
8. Power Line Carrier: Use of radio-frequency energy to transmit information over transmission lines whose primary purpose is the transmission of power.
9. RS-485: A serial network protocol, similar to RS-232, complying with TIA/EIA-485-A.

D. Submittals
1. Product Data: For control modules, power distribution components, DALI network materials, manual switches and plates, and conductors and cables.
2. Shop Drawings: Detail assemblies of standard components, custom assembled for specific application on this Project.
   a. Outline Drawings: Indicate dimensions, weights, arrangement of components, and clearance and access requirements.
   b. Block Diagram: Show interconnections between components specified in this Section and devices furnished with power distribution system components. Indicate data communication paths and identify networks, data buses, data gateways, concentrators, and other devices to be used. Describe characteristics of network and other data communication lines.
   c. Wiring Diagrams: Power, signal, and control wiring. Coordinate nomenclature and presentation with a block diagram.
3. Coordination Drawings: Submit evidence that lighting controls are compatible with connected monitoring and control devices and systems specified in other Sections.
   a. Show interconnecting signal and control wiring and interfacing devices that prove compatibility of inputs and outputs.
   b. For networked controls, list network protocols and provide statements from manufacturers that input and output devices meet interoperability requirements of the network protocol.

4. Software and Firmware Operational Documentation:
   a. Software operating and upgrade manuals.
   b. Program Software Backup: On a magnetic media or compact disc, complete with data files.
   c. Device address list.
   d. Printout of software application and graphic screens.
5. Field quality-control test reports.
6. Software licenses and upgrades required by and installed for operation and programming of digital and analog devices.
7. Operation and maintenance data.
8. Warranty: Special warranty specified in this Section.

E. Quality Assurance
1. Source Limitations: Obtain lighting control module and power distribution components through one source from a single manufacturer.
2. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
3. Comply with 47 CFR, Subparts A and B, for Class A digital devices.
4. Comply with protocol described in IEC 60929, Annex E, for DALI lighting control devices, wiring, and computer hardware and software.
5. Comply with NFPA 70.

F. Coordination
1. Coordinate lighting control components to form an integrated interconnection of compatible components. Match components and interconnections for optimum performance of lighting control functions.
   a. Coordinate lighting controls with BAS **OR** HVAC controls, **as directed**. Design display graphics showing building areas controlled; include the status of lighting controls in each area.
   b. Coordinate lighting controls with that in Sections specifying distribution components that are monitored or controlled by power monitoring and control equipment.
2. Coordinate lighting control components specified in this Section with components specified in Division 26 Section "Panelboards".

G. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of lighting controls that fail in materials or workmanship or from transient voltage surges within specified warranty period.
   a. Failures include, but are not limited to, the following:
      1) Failure of software input/output to execute switching or dimming commands.
      2) Failure of modular relays to operate under manual or software commands.
      3) Damage of electronic components due to transient voltage surges.
   b. Warranty Period: Two years from date of Final Completion.
   c. Extended Warranty Period Failure Due to Transient Voltage Surges: Eight years.
   d. Extended Warranty Period for Electrically Held Relays: 10 years from date of Final Completion.

H. Software Service Agreement (May Not Be Allowed For Publicly Funded Projects)
1. Technical Support: Beginning with Final Completion, provide software support for two years.
2. Upgrade Service: Update software to latest version at Project completion. Install and program software upgrades that become available within two years from date of Final Completion. Upgrading software shall include operating system. Upgrade shall include new or revise licenses for use of the software.

a. Provide 30-day notice to the Owner to allow scheduling and access to system and to allow the Owner to upgrade computer equipment, if necessary.

1.2 PRODUCTS

A. System Requirements

1. Expandability: System shall be capable of increasing the number of control functions in the future by 25 percent of current capacity; to include equipment ratings, housing capacities, spare relays, terminals, number of conductors in control cables, and control software.
2. Performance Requirements (for programmable system that controls manual and automatic operation that is not PC based): Manual switch operation sends a signal to programmable-system control module that processes the signal according to its programming and routes an open or close command to one or more relays **OR** electrically operated circuit breakers, **as directed**, in the power-supply circuits to groups of lighting fixtures or other loads.
3. Performance Requirements (for PC-based programmable system that controls manual and automatic operation): Manual switches, an internal timing and control unit, and external sensors or other control signal sources send a signal to a PC-based programmable-system control module that processes the signal according to its programming and routes an open or close command to one or more relays **OR** electrically operated circuit breakers, **as directed**, in the power-supply circuits, or routes variable commands to one or more dimmers, for groups of lighting fixtures or other loads.
4. Performance Requirements (for DALI-compliant program): Individually addressable devices (such as electronic ballasts, dimmers, and manual switches) are operated from digital signals received through a DALI-compliant bus, from data-entry and -retrieval devices (such as PCs, personal digital assistants (PDAs), hand-held infrared programming devices, wired Ethernet hubs, wireless IEEE 802.11 hubs). Devices also report status to data-entry and -retrieval devices though the bus.
5. BAS Interface: Provide hardware and software to enable the BAS to monitor, control, display, and record data for use in processing reports.
   a. Hardwired Points:
      1) Monitoring: On-off status, <**Insert monitoring point**>.
      2) Control: On-off operation, <**Insert control point**>.
   b. ASHRAE 135 (BACnet) **OR** LonTalk **OR** Modbus **OR** Industry-accepted, open-protocol, **as directed**, communication interface with the BAS shall enable the BAS operator to remotely control and monitor lighting from a BAS operator workstation. Control features and monitoring points displayed locally at lighting panel shall be available through the BAS.

B. Control Module

1. Control Module Description: (This is a generic, nonproprietary control module that is not PC based.) Comply with UL 916 (CSA C22.2, No. 205); microprocessor-based, solid-state, 365-day timing and control unit. Output circuits shall be switched on or off by internally programmed time signals or by program-controlled analog or digital signals from external sources. Output circuits shall be pilot-duty relays compatible with power switching devices. An integral keypad shall provide local programming and control capability. A key-locked cover and a programmed security access code shall protect keypad use. An integral alphanumeric LCD or LED shall display menu-assisted programming and control.
2. Control Module Description: (These are typical systems developed by time-switch manufacturers as an expansion and refinement of their microprocessor-based, digital, time-switch product lines - controls are not PC based.) Comply with UL 916 (CSA C22.2, No. 205); microprocessor-based, solid-state, 365-day timing and control unit. Unit shall be programmable for control of indicated number of output circuits. Output circuits shall be switched on or off by internally programmed time signals or by program-controlled analog or digital signals from external sources. Output circuits shall be pilot-duty relays compatible with power switching devices, all located in other enclosures. An integral keypad shall provide local programming and control capability. A key-locked cover and a programmed security access code shall protect keypad use. An integral

alphanumeric LCD shall display manual-control and programming steps. Modules and their associated control panels shall include the following features:

a. Multichannel output with <**Insert number**> channels.

OR

Multiple inputs and multichannel output arranged for <**Insert number**> channels.

b. Multiple inputs for indicated occupancy sensors and hand-held programming device.

3. Control Module Description: (These are low-voltage control systems developed by high-end, remote-control dimmer system manufacturers - controls are not PC based.) Comply with UL 916 (CSA C22.2, No. 205); microprocessor-based, solid-state, 365-day timing and control unit. Control units shall be programmable and capable of receiving inputs from indicated sensors and hand-held programmer. Output circuits shall be pilot-duty relays compatible with power switching devices. Output circuits shall include digital circuits arranged to transmit control commands to remote preset dimmers. Modules and their associated control panels shall include the following features:

a. Multichannel output with <**Insert number**> channels.

OR

Multiple inputs and multichannel output arranged for <**Insert number**> channels.

b. Multiple inputs for occupancy sensors, daylight sensors, and dimming systems with associated daylight sensors.

4. Control Module Description: (This is a low-voltage control system developed around panelboards with electrically operated, molded-case circuit breakers and control module installed in panelboard - controls are not PC based.) Panelboard mounted; comply with UL 916 (CSA C22.2, No. 205); microprocessor based, solid-state, 365-day timing and control unit. Control units shall be programmable and capable of receiving inputs from sensors and other sources. Panelboard shall use low-voltage-controlled, electrically operated, molded-case branch circuit breakers as prime power-circuit switching devices. Circuit breakers and a limited number of digital or analog, low-voltage control-circuit outputs shall be individually controlled by control module. Line-voltage components and wiring shall be separated from low-voltage components and wiring by barriers. Control module shall be locally programmable. Panelboard shall also comply with Division 26 Section "Panelboards".

5. Control Module Description: (This is a refinement of classic low-voltage control system originally developed for manual, multipoint lighting control using latching-type, single-pole relays to switch 120- and 277-V circuits - controls are not PC based.) Comply with UL 508 (CSA C22.2, No. 14); microprocessor-based, programmable, control unit; mounted in preassembled, modular relay panel. Low-voltage-controlled, latching-type, single-pole lighting circuit relays shall be prime output circuit devices. Where indicated, a limited number of digital or analog, low-voltage control-circuit outputs shall be supported by control unit and circuit boards associated with relays. Control units shall be capable of receiving inputs from sensors and other sources. Line-voltage components and wiring shall be separated from low-voltage components and wiring by barriers. Control module shall be locally programmable.

6. Control Module Description: (This is a typical PC-based software control system developed to operate panelboards with electrically operated circuit breakers, relay boards with latching-type control relays, and individually addressable DALI-compliant devices. This control scheme is also suitable for integrating one or more of these boards to a PC-based control network (such as BAS, detention monitoring and control system, and HVAC control system) specified in another Section.) Programmable, PC-based unit with 17-inch color video monitor **OR** 15-inch color LCD, **as directed**, and keyboard for graphic display and programming of system status and to override breaker status; and to display status of local override controls and diagnostic information. If the control module is applied to emergency lighting units, control unit shall indicate failure of normal power and that the lighting units are, or are not, powered by the alternate power source.

a. Display: Single graphic display for programming lighting control panelboards.

OR

Display: Separate graphic displays for programming each lighting control panelboard.

b. Interoperability: Control module shall be configured to connect with other control systems using RS-485 network to enable remote workstations to use control module functions.

OR

Interoperability: Control module shall be configured to connect to LonWorks-compliant **OR** BACnet-compliant, **as directed**, network, resulting in extending control to any network-compliant devices such as occupancy switches.

OR

Interoperability: Lighting control shall be configured to allow individual users to turn lighting on and off with their PCs. Software shall be written for Windows operating system, with Web page as the display and ActiveX controls that can be accessed through an Internet browser. Include at least three levels of password protection. Include an egress lighting option that will provide each user with a lighted path for exiting the building after normal working hours.

OR

Interoperability: Lighting control shall be configured to allow individual users to turn lighting on and off with DALI-compliant, digital-communication devices. Software shall be written for Windows operating system, with the full suite of DALI commands and device parameter settings.

c. System Memory: Nonvolatile. System shall reboot program and reset time automatically without errors after power outages up to 90 days' duration.

d. Software: Lighting control software shall be capable of linking switch inputs to relay outputs, retrieving links, viewing relay output status, controlling relay outputs, simulating switch inputs, setting device addresses, and assigning switch input and relay output modes.

e. Automatic Time Adjustment: System shall automatically adjust for leap year and daylight saving time and shall provide weekly routine and annual holiday scheduling.

f. Astronomic Control: Automatic adjustment of dawn and dusk switching.

g. Demand Control: Demand shall be monitored through pulses from a remote meter and shall be controlled by programmed switching of loads. System capability shall include sliding window averaging and programming of load priorities and characteristics. Minimum of two different time-of-day demand schedules shall execute load-management control actions by switching output circuits or by transmitting other types of load-control signals.

h. Confirmation: Each relay or contactor device operated by system shall have auxiliary contacts that provide a confirmation signal to the system of on or off status of device. On or off status confirmation for each electrically operated circuit breaker shall be provided by an auxiliary contact or by a sensing device at load terminal.

   1) Software shall interpret status signals, provide for their display, and initiate failure signals.

      OR

      Lamp or LED at control module or display panel shall identify status of each controlled circuit.

i. Remote Communication Capability: Allow programming, data-gathering interrogation, status display, and controlled command override from a PC at a remote location over telephone lines **OR** data links **OR** DALI networks **OR** power line carrier, **as directed**. System shall include modem, communications and control software, and remote computer compatibility verification for this purpose.

j. Telephone Override Capability: Override programmed lighting shutdown commands by telephoning computer and shall enter a voice-menu-guided, override touch-tone code specific to zone being controlled.

k. Local Override Capability: Manual, low-voltage control devices shall override programmed shutdown of lighting and shall override other programmed control for intervals that may be duration programmed.

l. Automatic Control of Local Override: Automatic control shall switch lighting off if lighting has been switched on by local override. Comply with provisions in California Code of Regulations, Title 24, Part 6, **as directed**.

m. Automatic battery backup shall provide power to maintain program and system clock operation for 90 days' minimum duration when power is off.

n. Programmed time signals shall change preset scenes and dimmer settings.

o. Daylight Balancing Dimming Control: Control module shall interpret variable analog signal from photoelectric sensor and shall route dimming signals to dimming fluorescent ballast control circuits. Signal shall control dimming of fixture so illumination level remains constant as daylight contribution varies.

p. Daylight Compensating Switch Control: Control module shall interpret a preset threshold illumination-level signal from a photoelectric relay and shall activate relays controlling power to selected groups of lighting fixtures to turn them on and off to maintain adjustable minimum illumination level as daylight contribution varies.

q. Energy Conservation: Bilevel control of special ballasts or dimming circuits to comply with local energy codes.

r. Flick Warning: Programmable momentary turnoff of lights shall warn that programmed shutoff will occur after a preset interval. Warning shall be repeated after a second preset interval before end of programmed override period.

s. Diagnostics: When system operates improperly, software shall initiate factory-programmed diagnosis of failure and display messages identifying problem and possible causes.

t. Additional Programming: In addition to system programming by the PC, individual control modules shall be programmable using data-entry and -retrieval (such as PCs, personal digital assistants (PDAs), hand-held infrared programming devices, wired Ethernet hubs, wireless IEEE 802.11 hubs).

C. Power Distribution Components (For DALI-Compliant Networks)

1. Modular Relay Panel: Comply with UL 508 (CSA C22.2, No. 14) and UL 916 (CSA C22.2, No. 205); factory assembled with modular single-pole relays, power supplies, and accessory components required for specified performance.

a. Cabinet: Steel with hinged, locking door.

1) Barriers separate low-voltage and line-voltage components.

2) Directory: Mounted on back of door. Identifies each relay as to load groups controlled and each programmed pilot device if any.

3) Control Power Supply: Transformer and full-wave rectifier with filtered dc output.

b. Single-Pole Relays: Mechanically held unless otherwise indicated; split-coil, momentary-pulsed type.

1) Low-Voltage Leads: Plug connector to the connector strip in cabinet and pilot light power where indicated.

2) Rated Capacity (Mounted in Relay Panel): 20 A, 125-V ac for tungsten filaments; 20 A, 277-V ac for ballasts.

3) Endurance: 50,000 cycles at rated capacity.

4) Mounting: Provision for easy removal and installation in relay cabinet.

2. Electrically Operated, Molded-Case Circuit-Breaker Panelboard: Comply with NEMA PB 1 and UL 50 (CSA C22.2, No. 94), UL 67 (CSA C22.2, No. 29), UL 489 (CSA C22.2, No. 65), and UL 916 (CSA C22.2, No. 205).

a. Cabinets: In addition to requirements specified below, comply with Division 26 Section "Panelboards".

b. Electrically Operated, Molded-Case Circuit Breakers: Bolt-on type.

1) Switching Endurance Ratings: Certified by manufacturer or by a nationally recognized testing laboratory (NRTL) for at least 20,000 open and close operations under rated load at 0.8 power factor.

2) Minimum 30,000 open and close operations with load equal to circuit-breaker trip rating and consisting of 100 percent tungsten filament load.

3) Minimum 30,000 open and close operations with load equal to circuit-breaker trip rating and consisting of 100 percent fluorescent ballasts rated for 10 percent total harmonic distortion.

4) Listed and labeled as complying with UL SWD, HCAR, and HID ratings by a national recognized testing laboratory (NRTL) acceptable to authorities having jurisdiction.

3. Line-Voltage Surge Suppression: Factory installed as an integral part of 120- and 277-V ac, solid-state control panels.

OR
Line-Voltage Surge Suppression: Field-mounting surge suppressors that comply with Division 26 Section "Transient-voltage Suppression For Low-voltage Electrical Power Circuits" for Category A locations.
OR
Line-Voltage Surge Suppression: Factory installed as an integral part of 120- and 277-V ac, solid-state control panels or field-mounting surge suppressors that comply with Division 26 Section "Transient-voltage Suppression For Low-voltage Electrical Power Circuits" for Category A locations.

D. DALI Network Materials
1. Network Power Supply and Router: Interface device connecting TCP/IP control networks to DALI-compliant network.
   a. DALI-Compliant Network Power Rating: One full-rated network for **OR** Two full-rated networks, each capable of, **as directed**, powering up to 64 addressable devices for each network; suitable for use with NFPA 70, Class 1 and Class 2 control circuits; and 16 V dc, 250 mA.
   b. Primary Power: 120 or 277 V, field selectable; 12 VA.
   c. 10basT Ethernet port.
   d. LED indicator lights for Ethernet status (link, send, and receive), power-on, and DALI network failure.
2. Lighting Control Software:
   a. Five-tier hierarchical architecture; high-speed, parallel query; and distributed-logic processing scalable from single rooms to full campuses.
   b. Automatic backup for all settings and parameters.
   c. TCP/IP network protocol.
   d. Interactive with other building management systems at TCP/IP level.
   e. At least three security levels.
   f. Support the full suite of DALI commands and device parameter settings.
   g. Scheduling modules to provide building-wide scene scheduling.
   h. Billing modules to track energy use for multiple tenants and able to produce monthly billing statements.
   i. Support load shedding, peak shaving, sweeps with local override, and other energy-conservation measures.
   j. Able to report individual device status, including inoperative lamps, ballast failure detection, and dimmer position.

E. Manual Switches And Plates
1. Push-Button Switches: Modular, momentary-contact, low-voltage type.
   a. Match color specified in Division 26 Section "Wiring Devices".
   b. Integral green LED **OR** neon, **as directed**, pilot light to indicate when circuit is on.
   c. Internal white LED **OR** neon, **as directed**, locator light to illuminate when circuit is off.
2. Manual, Maintained Contact, Full- or Low-Voltage Switch: Comply with Division 26 Section "Wiring Devices".
3. Wall-Box Dimmers: Comply with Division 26 Section "Wiring Devices".
4. Wall Plates: Single and multigang plates as specified in Division 26 Section "Wiring Devices"
5. Legend: Engraved or permanently silk-screened on wall plate where indicated. Use designations indicated on Drawings.

F. Conductors And Cables
1. Power Wiring to Supply Side of Class 2 Power Source: Not smaller than No. 12 AWG, complying with Division 26 Section "Low-voltage Electrical Power Conductors And Cables".
2. Classes 2 and 3 Control Cables: Multiconductor cable with copper conductors not smaller than No. 18 **OR** 22 **OR** 24, **as directed**, AWG, complying with Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

3. Class 1 Control Cables: Multiconductor cable with copper conductors not smaller than No. 14 **OR** 16 **OR** 18, **as directed**, AWG, complying with Division 26 Section "Low-voltage Electrical Power Conductors And Cables".
4. Digital and Multiplexed Signal Cables: Unshielded, twisted-pair cable with copper conductors, complying with TIA/EIA-568-B.2, Category 5e **OR** 6, **as directed**, for horizontal copper cable and with Division 28 Section "Conductors And Cables For Electronic Safety And Security".

1.3 EXECUTION

A. Wiring Installation
1. Comply with NECA 1.
2. Wiring Method: Install wiring in raceways except where installed in accessible ceilings and gypsum board partitions. Comply with Division 26 Section "Low-voltage Electrical Power Conductors And Cables". Minimum conduit size shall be 1/2 inch (13 mm).
3. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points. Separate power-limited and non-power-limited conductors according to conductor manufacturer's written instructions.
4. Install field-mounting transient voltage suppressors for lighting control devices in Category A locations that do not have integral line-voltage surge protection.
5. Size conductors according to lighting control device manufacturer's written instructions, unless otherwise indicated.
6. Splices, Taps, and Terminations: Make connections only on numbered terminal strips in terminal cabinets, equipment enclosures, and in junction, pull, and outlet boxes.
7. Identify components and power and control wiring according to Division 26 Section "Identification For Electrical Systems".

B. Field Quality Control
1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and assist in field testing. Report results in writing.
2. Perform the following field tests and inspections and prepare test reports:
   a. Test for circuit continuity.
   b. Verify that the control module features are operational.
   c. Check operation of local override controls.
   d. Test system diagnostics by simulating improper operation of several components selected by the Owner.

C. Software Installation
1. Install and program software with initial settings of adjustable values. Make backup copies of software and user-supplied values. Provide current licenses for software.

D. Adjusting
1. Occupancy Adjustments: When requested within 12 months of date of Final Completion, provide on-site assistance in adjusting sensors and to assist the Owner's personnel in making program changes to suit actual occupied conditions. Provide up to two visits to Project during other than normal occupancy hours for this purpose.

E. Demonstration
1. Engage a factory-authorized service representative to train the Owner's maintenance personnel to adjust, operate, and maintain lighting controls and software training for PC-based control systems.

END OF SECTION 26 09 23 00

SECTION 26 09 23 00a - LIGHTING CONTROL DEVICES

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for lighting control devices. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following lighting control devices:
a. Time switches.
b. Outdoor and Indoor photoelectric switches.
c. Indoor occupancy sensors.
d. Outdoor motion sensors.
e. Lighting contactors.
f. Emergency shunt relays.

C. Definitions
1. LED: Light-emitting diode.
2. PIR: Passive infrared.

D. Submittals
1. Product Data: For each type of product indicated.
2. Field quality-control test reports.
3. Operation and maintenance data.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

1.2 PRODUCTS

A. Time Switches
1. Electronic Time Switches: Electronic, solid-state programmable units with alphanumeric display; complying with UL 917.
a. Contact Configuration: SPST **OR** DPST **OR** DPDT, **as directed**.
b. Contact Rating: 30-A inductive or resistive, 240-V ac **OR** 20-A ballast load, 120/240-V ac, **as directed**.
c. Program: 8 on-off set points on a 24-hour schedule and an annual holiday schedule that overrides the weekly operation on holidays, **as directed**.
OR
Program: 2 on-off set points on a 24-hour schedule, allowing different set points for each day of the week and an annual holiday schedule that overrides the weekly operation on holidays, **as directed**.
OR
Programs: channels; each channel shall be individually programmable with 8 on-off set points on a 24-hour schedule.
OR
Programs: channels; each channel shall be individually programmable with 2 on-off set points on a 24-hour schedule with skip-a-day weekly schedule.

OR

Programs: channels; each channel shall be individually programmable with 2 on-off set points on a 24-hour schedule, allowing different set points for each day of the week.

OR

Programs: channels; each channel shall be individually programmable with 40 on-off operations per week and an annual holiday schedule that overrides the weekly operation on holidays.

OR

Programs: channels; each channel shall be individually programmable with 40 on-off operations per week, plus 4 seasonal schedules that modify the basic program, and an annual holiday schedule that overrides the weekly operation on holidays.

OR

Program: Configuration, as directed by the Owner and an annual holiday schedule that overrides the weekly operation on holidays, **as directed**.

d. Circuitry: Allow connection of a photoelectric relay as substitute for on-off function of a program on selected channels, **as directed**.

e. Astronomic Time: All **OR** Selected, **as directed**, channels.

f. Battery Backup: For schedules and time clock.

2. Electromechanical-Dial Time Switches: Type complying with UL 917.

a. Contact Configuration: SPST **OR** DPST **OR** SPDT **OR** DPDT, **as directed**.

b. Contact Rating: 30-A inductive or resistive, 240-V ac **OR** 20-A ballast load, 120/240-V ac, **as directed**.

c. Circuitry: Allow connection of a photoelectric relay as substitute for on-off function of a program.

d. Astronomic time dial.

e. Eight-Day Program: Uniquely programmable for each weekday and holidays.

f. Skip-a-day mode.

g. Wound-spring reserve carryover mechanism to keep time during power failures, minimum of 16 hours.

B. Outdoor Photoelectric Switches

1. Description: Solid state, with SPST **OR** DPST, **as directed**, dry contacts rated for 1800-VA tungsten or 1000-VA inductive, to operate connected relay, contactor coils, or microprocessor input; complying with UL 773A.

a. Light-Level Monitoring Range: 1.5 to 10 fc (16.14 to 108 lx), with an adjustment for turn-on and turn-off levels within that range, and a directional lens in front of photocell to prevent fixed light sources from causing turn-off, **as directed**.

b. Time Delay: 15-second minimum, to prevent false operation.

c. Surge Protection: Metal-oxide varistor, complying with IEEE C62.41.1, IEEE C62.41.2, and IEEE 62.45 for Category A1 locations.

d. Mounting: Twist lock complying with IEEE C136.10, with base-and-stem mounting or stem-and-swivel mounting accessories as required to direct sensor to the north sky exposure.

OR

Description: Solid state, with SPST **OR** DPST, **as directed**, dry contacts rated for 1800 VA to operate connected load, relay, or contactor coils; complying with UL 773.

a. Light-Level Monitoring Range: 1.5 to 10 fc (16.14 to 108 lx), with an adjustment for turn-on and turn-off levels within that range.

b. Time Delay: 30-second minimum, to prevent false operation.

c. Lightning Arrester: Air-gap type.

d. Mounting: Twist lock complying with IEEE C136.10, with base.

C. Indoor Photoelectric Switches

1. Ceiling-Mounted Photoelectric Switch: Solid-state, light-level sensor unit, with separate relay unit mounted on luminaire, **as directed**, to detect changes in lighting levels that are perceived by the eye. Cadmium sulfide photoresistors are not acceptable.
   a. Sensor Output: Contacts rated to operate the associated relay, complying with UL 773A. Sensor shall be powered from the relay unit.
   b. Relay Unit: Dry contacts rated for 20-A ballast load at 120- and 277-V ac, for 13-A tungsten at 120-V ac, and for 1 hp at 120-V ac. Power supply to sensor shall be 24-V dc, 150-mA, Class 2 power source as defined by NFPA 70.
   c. Light-Level Monitoring Range: 10 to 200 fc (108 to 2152 lx) **OR** 100 to 1000 fc (1080 to 10 800 lx), **as directed**, with an adjustment for turn-on and turn-off levels within that range.
   d. Time Delay: Adjustable from 5 to 300 seconds to prevent cycling, with deadband adjustment.
   e. Indicator: Two LEDs to indicate the beginning of on-off cycles.
2. Skylight Photoelectric Sensors: Solid-state, light-level sensor; housed in a threaded, plastic fitting for mounting under skylight, facing up at skylight; with separate relay unit mounted on luminaire, **as directed**, to detect changes in lighting levels that are perceived by the eye. Cadmium sulfide photoresistors are not acceptable.
   a. Sensor Output: Contacts rated to operate the associated relay, complying with UL 773A. Sensor shall be powered from the relay unit.
   b. Relay Unit: Dry contacts rated for 20-A ballast load at 120- and 277-V ac, for 13-A tungsten at 120-V ac, and for 1 hp at 120-V ac. Power supply to sensor shall be 24-V dc, 150-mA, Class 2 power source as defined by NFPA 70.
   c. Light-Level Monitoring Range: 1000 to 10,000 fc (10 800 to 108 000 lx), with an adjustment for turn-on and turn-off levels within that range.
   d. Time Delay: Adjustable from 5 to 300 seconds to prevent cycling, with deadband adjustment.
   e. Indicator: Two LEDs to indicate the beginning of on-off cycles.

D. Indoor Occupancy Sensors
1. General Description: Wall- or ceiling-mounting, solid-state units with a separate relay unit.
   a. Operation: Unless otherwise indicated, turn lights on when covered area is occupied and off when unoccupied; with a time delay for turning lights off, adjustable over a minimum range of 1 to 15 minutes.
   b. Sensor Output: Contacts rated to operate the connected relay, complying with UL 773A. Sensor shall be powered from the relay unit.
   c. Relay Unit: Dry contacts rated for 20-A ballast load at 120- and 277-V ac, for 13-A tungsten at 120-V ac, and for 1 hp at 120-V ac. Power supply to sensor shall be 24-V dc, 150-mA, Class 2 power source as defined by NFPA 70.
   d. Mounting:
      1) Sensor: Suitable for mounting in any position on a standard outlet box.
      2) Relay: Externally mounted through a 1/2-inch (13-mm) knockout in a standard electrical enclosure.
      3) Time-Delay and Sensitivity Adjustments: Recessed and concealed behind hinged door.
   e. Indicator: LED, to show when motion is being detected during testing and normal operation of the sensor.
   f. Bypass Switch: Override the on function in case of sensor failure.
   g. Automatic Light-Level Sensor: Adjustable from 2 to 200 fc (21.5 to 2152 lx); keep lighting off when selected lighting level is present.
2. PIR Type: Ceiling mounting; detect occupancy by sensing a combination of heat and movement in area of coverage.
   a. Detector Sensitivity: Detect occurrences of 6-inch- (150-mm-) minimum movement of any portion of a human body that presents a target of not less than 36 sq. in. (232 sq. cm).
   b. Detection Coverage (Room): Detect occupancy anywhere in a circular area of 1000 sq. ft. (93 sq. m) when mounted on a 96-inch- (2440-mm-) high ceiling.

c. Detection Coverage (Corridor): Detect occupancy within 90 feet (27.4 m) when mounted on a 10-foot- (3-m-) high ceiling.

3. Ultrasonic Type: Ceiling mounting; detect occupancy by sensing a change in pattern of reflected ultrasonic energy in area of coverage.
   a. Detector Sensitivity: Detect a person of average size and weight moving not less than 12 inches (305 mm) in either a horizontal or a vertical manner at an approximate speed of 12 inches/s (305 mm/s).
   b. Detection Coverage (Small Room): Detect occupancy anywhere within a circular area of 600 sq. ft. (56 sq. m) when mounted on a 96-inch- (2440-mm-) high ceiling.
   c. Detection Coverage (Standard Room): Detect occupancy anywhere within a circular area of 1000 sq. ft. (93 sq. m) when mounted on a 96-inch- (2440-mm-) high ceiling.
   d. Detection Coverage (Large Room): Detect occupancy anywhere within a circular area of 2000 sq. ft. (186 sq. m) when mounted on a 96-inch- (2440-mm-) high ceiling.
   e. Detection Coverage (Corridor): Detect occupancy anywhere within 90 feet (27.4 m) when mounted on a 10-foot- (3-m-) high ceiling in a corridor not wider than 14 feet (4.3 m).
4. Dual-Technology Type: Ceiling mounting; detect occupancy by using a combination of PIR and ultrasonic detection methods in area of coverage. Particular technology or combination of technologies that controls on-off functions shall be selectable in the field by operating controls on unit.
   a. Sensitivity Adjustment: Separate for each sensing technology.
   b. Detector Sensitivity: Detect occurrences of 6-inch- (150-mm-) minimum movement of any portion of a human body that presents a target of not less than 36 sq. in. (232 sq. cm), and detect a person of average size and weight moving not less than 12 inches (305 mm) in either a horizontal or a vertical manner at an approximate speed of 12 inches/s (305 mm/s).
   c. Detection Coverage (Standard Room): Detect occupancy anywhere within a circular area of 1000 sq. ft. (93 sq. m) when mounted on a 96-inch- (2440-mm-) high ceiling.

E. Outdoor Motion Sensors (PIR)
1. Performance Requirements: Suitable for operation in ambient temperatures ranging from minus 40 to plus 130 deg F (minus 40 to plus 54 deg C), rated as raintight according to UL 773A.
   a. Operation: Turn lights on when sensing infrared energy changes between background and moving body in area of coverage; with a time delay for turning lights off, adjustable over a minimum range of 1 to 15 minutes.
   b. Mounting:
      1) Sensor: Suitable for mounting in any position on a standard outdoor junction box.
      2) Relay: Internally mounted in a standard weatherproof electrical enclosure.
      3) Time-Delay and Sensitivity Adjustments: Recessed and concealed behind hinged door.
   c. Bypass Switch: Override the on function in case of sensor failure.
   d. Automatic Light-Level Sensor: Adjustable from 1 to 20 fc (11 to 215 lx); keep lighting off during daylight hours.
2. Detector Sensitivity: Detect occurrences of 6-inch- (150-mm-) minimum movement of any portion of a human body that presents a target of not less than 36 sq. in. (232 sq. cm).
3. Detection Coverage: Up to 35 feet (11 m), with a field of view of 90 degrees **OR** Up to 100 feet (30 m), with a field of view of 60 degrees **OR** Up to 35 feet (11 m), with a field of view of 180 degrees **OR** Up to 52.5 feet (16 m), with a field of view of 270 degrees, **as directed**.
4. Lighting Fixture Mounted Sensor: Suitable for switching 300 W of tungsten load at 120- or 277-V ac.
5. Individually Mounted Sensor: Contacts rated to operate the connected relay, complying with UL 773A. Sensor shall be powered from the relay unit.
   a. Relay Unit: Dry contacts rated for 20-A ballast load at 120- and 277-V ac, for 13-A tungsten at 120-V ac, and for 1 hp at 120-V ac. Power supply to sensor shall be 24-V dc, 150-mA, Class 2 power source as defined by NFPA 70.

b. Indicator: LED, to show when motion is being detected during testing and normal operation of the sensor.

F. Lighting Contactors
1. Description: Electrically operated and mechanically **OR** electrically, **as directed**, held, combination type with fusible switch **OR** nonfused disconnect, **as directed**, complying with NEMA ICS 2 and UL 508.
a. Current Rating for Switching: Listing or rating consistent with type of load served, including tungsten filament, inductive, and high-inrush ballast (ballast with 15 percent or less total harmonic distortion of normal load current).
b. Fault Current Withstand Rating: Equal to or exceeding the available fault current at the point of installation.
c. Enclosure: Comply with NEMA 250.
d. Provide with control and pilot devices as indicated on Drawings **OR** scheduled, **as directed**, matching the NEMA type specified for the enclosure.
2. BAS Interface: Provide hardware interface to enable the BAS to monitor and control lighting contactors.
a. Monitoring: On-off status, as directed by the Owner.
b. Control: On-off operation, as directed by the Owner.

G. Emergency Shunt Relay
1. Description: Normally closed, electrically held relay, arranged for wiring in parallel with manual or automatic, **as directed**, switching contacts; complying with UL 924.
a. Coil Rating: 120 **OR** 277, **as directed**, V.

H. Conductors And Cables
1. Power Wiring to Supply Side of Remote-Control Power Sources: Not smaller than No. 12 AWG. Comply with requirements in Division 26 Section "Low-voltage Electrical Power Conductors And Cables".
2. Classes 2 and 3 Control Cable: Multiconductor cable with stranded-copper conductors not smaller than No. 18 **OR** 22 **OR** 24, **as directed**, AWG. Comply with requirements in Division 26 Section "Low-voltage Electrical Power Conductors And Cables".
3. Class 1 Control Cable: Multiconductor cable with stranded-copper conductors not smaller than No. 14 **OR** 16 **OR** 18, **as directed**, AWG. Comply with requirements in Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

1.3 EXECUTION

A. Sensor Installation
1. Install and aim sensors in locations to achieve not less than 90 percent coverage of areas indicated. Do not exceed coverage limits specified in manufacturer's written instructions.

B. Contactor Installation
1. Mount electrically held lighting contactors with elastomeric isolator pads, to eliminate structure-borne vibration, unless contactors are installed in an enclosure with factory-installed vibration isolators.

C. Wiring Installation
1. Wiring Method: Comply with Division 26 Section "Low-voltage Electrical Power Conductors And Cables". Minimum conduit size shall be 1/2 inch (13 mm).
2. Wiring within Enclosures: Comply with NECA 1. Separate power-limited and nonpower-limited conductors according to conductor manufacturer's written instructions.
3. Size conductors according to lighting control device manufacturer's written instructions, unless otherwise indicated.

4. Splices, Taps, and Terminations: Make connections only on numbered terminal strips in junction, pull, and outlet boxes; terminal cabinets; and equipment enclosures.

D. Identification
1. Identify components and power and control wiring according to Division 26 Section "Identification For Electrical Systems".
   a. Identify controlled circuits in lighting contactors.
   b. Identify circuits or luminaries controlled by photoelectric and occupancy sensors at each sensor.
2. Label time switches and contactors with a unique designation.

E. Field Quality Control
1. Perform the following field tests and inspections and prepare test reports:
   a. After installing time switches and sensors, and after electrical circuitry has been energized, adjust and test for compliance with requirements.
   b. Operational Test: Verify operation of each lighting control device, and adjust time delays.
2. Lighting control devices that fail tests and inspections are defective work.

END OF SECTION 26 09 23 00a

SECTION 26 09 23 00b - ELECTRICAL POWER MONITORING AND CONTROL

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for electrical power monitoring and control. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following for monitoring and control of electrical power system:
   a. PC-based workstation(s) and software.
   b. Communication network and interface modules for RS-232; RS-485, Modbus TCP/IP; and IEEE 802.3 data transmission protocols.

C. Definitions
1. Ethernet: Local area network based on IEEE 802.3 standards.
2. Firmware: Software (programs or data) that has been written onto read-only memory (ROM). Firmware is a combination of software and hardware. Storage media with ROMs that have data or programs recorded on them are firmware.
3. HTML: Hypertext markup language.
4. I/O: Input/output.
5. KB: Short for kilobyte. When used to describe data storage, "KB" represents 1024 bytes.
6. KY Pulse: A term used by the metering industry to describe a method of measuring consumption of electricity that is based on a relay changing status in response to the rotation of the disk in the meter.
7. LAN: Local area network; sometimes plural as "LANs."
8. LCD: Liquid crystal display.
9. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less that 50 V or remote-control, signaling and power-limited circuits.
10. Modbus TCP/IP: An open protocol for exchange of process data.
11. Monitoring: Acquisition, processing, communication, and display of equipment status data, metered electrical parameter values, power quality evaluation data, event and alarm signals, tabulated reports, and event logs.
12. PC: Personal computer; sometimes plural as "PCs."
13. rms: Root-mean-square value of alternating voltage, which is the square root of the mean value of the square of the voltage values during a complete cycle.
14. RS-232: A TIA standard for asynchronous serial data communications between terminal devices.
15. RS-485: A TIA standard for multipoint communications using two twisted-pairs.
16. TCP/IP: Transport control protocol/Internet protocol incorporated into Microsoft Windows.
17. THD: Total harmonic distortion.
18. UPS: Uninterruptible power supply; used both in singular and plural context.
19. WAN: Wide area network.

D. Submittals
1. Product Data: For each type of product indicated.
   a. Attach copies of approved Product Data submittals for products (such as switchboards and switchgear) that describe power monitoring and control features to illustrate coordination among related equipment and power monitoring and control.
2. Shop Drawings: For power monitoring and control equipment. Include plans, elevations, sections, details, and attachments to other work.
   a. Outline Drawings: Indicate arrangement of components and clearance and access requirements.

b. Block Diagram: Show interconnections between components specified in this Section and devices furnished with power distribution system components. Indicate data communication paths and identify networks, data buses, data gateways, concentrators, and other devices to be used. Describe characteristics of network and other data communication lines.
c. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
d. Wiring Diagrams: Power, signal, and control wiring. Coordinate nomenclature and presentation with a block diagram.
e. UPS sizing calculations for workstation.

3. Software and Firmware Operational Documentation:
   a. Self-study guide describing the process for setting equipment's network address; setting the Owner's options; procedures to ensure data access from any PC on the network, using a standard Web browser; and recommended firewall setup.
   b. Software operating and upgrade manuals.
   c. Software Backup: On a magnetic media or compact disc, complete with the Owner-selected options.
   d. Device address list and the set point of each device and operator option, as set in applications software.
   e. Graphic file and printout of graphic screens and related icons, with legend.
4. Software Upgrade Kit: For the Owner to use in modifying software to suit future power system revisions or power monitoring and control revisions.
5. Software licenses and upgrades required by and installed for operating and programming digital and analog devices.
6. Field quality-control test reports.
7. Operation and Maintenance Data: For power monitoring and control units, to include in emergency, operation, and maintenance manuals. Include the following:
   a. Operating and applications software documentation.
   b. Software licenses.
   c. Software service agreement.
   d. PC installation and operating documentation, manuals, and software for the PC and all installed peripherals. Software shall include system restore, emergency boot diskettes, and drivers for all installed hardware. Provide separately for each PC.
   e. Hard copies of manufacturer's specification sheets, operating specifications, design guides, user's guides for software and hardware, and PDF files on CD-ROM of the hard-copy submittal.
8. Other Informational Submittals:
   a. System installation and setup guides, with data forms to plan and record options and setup decisions.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

F. Software Service Agreement
1. Technical Support: Beginning with Final Completion, provide software support for two years.
2. Upgrade Service: Update software to latest version at Project completion. Install and program software upgrades that become available within two years from date of Final Completion. Upgrading software shall include the operating systems. Upgrade shall include new or revised licenses for use of software.
   a. Provide 30-day notice to the Owner to allow scheduling and access to system and to allow the Owner to upgrade computer equipment if necessary.

1.2 PRODUCTS

A. Functional Description
1. Instrumentation and Recording Devices: Monitor and record load profiles and chart energy consumption patterns.
   a. Calculate and Record the Following:
      1) Load factor.
      2) Peak demand periods.
      3) Consumption correlated with facility activities.
   b. Measure and Record Metering Data for the Following:
      1) Electricity.
      2) Domestic water.
      3) Natural gas.
2. Software: Calculate allocation of utility costs.
   a. Automatically Import Energy Usage Records to Allocate Energy Costs for the Following:
      1) At least 15 departments.
      2) At least 30 tenants.
      3) At least five processes.
      4) At least five buildings.
   b. Verify utility bills and analyze alternate energy rates, **as directed**.
3. Power Quality Monitoring: Identify power system anomalies and measure, display, and record trends and alarms of the following power quality parameters:
   a. Voltage regulation and unbalance.
   b. Continuous three-phase rms voltage.
   c. Periodic max./min./avg. samples.
   d. Harmonics.
   e. Voltage excursions.
4. Emergency Load Shedding. Preserve critical loads or avoid total shutdown due to unforeseen loss of power sources according to the following logic:
   a. Determine system topology.
   b. Evaluate remaining loads and sources.
   c. Shed loads in less than 100 ms.
5. Demand Management:
   a. Peaking or co-generator control.
   b. Load interlocking.
   c. Load shedding.
   d. Load trimming.
6. System: Report equipment status and power system control.

B. System Requirements
1. Monitoring and Control System: Include PC-based workstation **OR** multiple PC-based workstations **OR** multiple PC-based workstations with graphics capability and Web access, **as directed**, with its operating system and application software, connected to data transmission network.
2. Surge Protection: For external wiring of each conductor entry connection to components to protect components from voltage surges originating external to equipment housing and entering through power, communication, signal, control, or sensing leads.
   a. Minimum Protection for Power Lines 120 V and More: Auxiliary panel suppressors complying with requirements in Division 26 Section "Transient-voltage Suppression For Low-voltage Electrical Power Circuits".
   b. Minimum Protection for Communication, Signal, Control, and Low-Voltage Power Lines: Comply with requirements as recommended by manufacturer for type of line being protected.
3. Addressable Devices: All transmitters and receivers shall communicate unique device identification and status reports to monitoring and control clients.

4. BAS Interface: Provide factory-installed hardware and software to enable the BAS to monitor, display, and record data for use in processing reports.
   a. Hardwired Monitoring Points: Electrical power demand (kilowatts), electrical power consumption (kilowatt-hours), power factor, **as directed**.
      OR
      ASHRAE 135 (BACnet) **OR** LonTalk **OR** Modbus **OR** Industry-accepted, open-protocol, **as directed**, communication interface with the BAS shall enable the BAS operator to remotely monitor meter information from a BAS operator workstation. Control features and monitoring points displayed locally at metering panel shall be available through the BAS.

C. Operating System
1. Software: Configured to run on a portable laptop computer, a single PC, or a palm computer, with capability for accessing a single meter at a time. System is not connected to a LAN. Modbus TCP/IP, RS-232, and RS-485 digital communications.
   OR
   Software: Configured to run on a single PC, with capability for accessing multiple devices simultaneously. Modbus TCP/IP, RS-232, and RS-485 digital communications.
   OR
   Software: Configured for a server and multiple client PCs, each with capability for accessing multiple devices simultaneously. Ethernet, Modbus TCP/IP, RS-232, and RS-485 digital communications.
   OR
   Software: Configured for a server and multiple client PCs, each with capability for accessing multiple devices simultaneously. Software shall include interactive graphics client and shall be Web enabled. Workstations and portable computers shall not require any software except for an Internet browser to provide connectivity and full functionality. Include a firewall recommended by manufacturer. 100 Base-T Ethernet, Modbus TCP/IP RS-232, and RS-485 digital communications.
2. Operating System Software: Based on 32-bit, Microsoft Windows workstation operating system. Software shall have the following features:
   a. Multiuser and multitasking to allow independent activities and monitoring to occur simultaneously at different workstations.
   b. Graphical user interface to show pull-down menus and a menu tree format.
   c. Capability for future additions within the indicated system size limits.
3. Peer Computer Control Software: Shall detect a failure of workstation and associated server, **as directed**, and shall cause other workstation and associated server, **as directed**, to assume control of all system functions without interruption of operation. Drivers shall be provided in both central computers to support this mode of operation.

D. Applications Software
1. Basic Requirements:
   a. Fully compatible with and based on the approved operating system.
   b. Password-protected operator login and access; three levels, minimum.
   c. Password-protected setup functions.
   d. Context sensitive on-line help.
   e. Capability of creating, deleting, and copying files; and automatically maintaining a directory of all files, including size and location of each sequential and random-ordered record.
   f. Capability for importing custom icons into graphic views to represent alarms and I/O devices.
   g. Automatic and encrypted backups for database and history; automatically stored at central control PC **OR** selected workstation, **as directed**, and encrypted with a nine-character alphanumeric password, which must be used to restore or read data contained in backup.
   h. Operator audit trail for recording and reporting all changes made to user-defined system options.
2. Workstation Server Functions:

a. Support other client PCs on the LAN and WAN, **as directed**.
b. Maintain recorded data in databases accessible from other PCs on the LAN and WAN, **as directed**.

3. Data Formats:
   a. User-programmable export and import of data to and from commonly used Microsoft Windows spreadsheet, database, billing, and other applications; using dynamic data exchange technology.
   b. Option to convert reports and graphics to HTML format.
   c. Interactive graphics.
   d. Option to send preprogrammed or operator designed e-mail reports.
4. Metered Data: Display metered values in real time.
5. Remote Control:
   a. Display circuit-breaker status and allow breaker control.
   b. User defined with load-shedding automatically initiated and executed schemes responding to programmed time schedules, set points of metered demands, utility contracted load shedding, or combinations of these.
6. Equipment Documentation: Database for recording of equipment ratings and characteristics; with capability for graphic display on monitors.
7. Graphics: Interactive color-graphics platform with pull-down menus and mouse-driven generation of power system graphics, in formats widely used for such drafting; to include the following:
   a. Site plan.
   b. Floor plans.
   c. Equipment elevations.
   d. Single-line diagrams.
8. User-Defined Monitoring and Control Events: Display and record with date and time stamps accurate to 0.1 second, and including the following:
   a. Operator log on/off.
   b. Attempted operator log on/off.
   c. All alarms.
   d. Equipment operation counters.
   e. Out-of-limit, pickup, trip, and no-response events.
9. Trending Reports: Display data acquired in real-time from different meters or devices, in historical format over user-defined time; unlimited as to interval, duration, or quantity of trends.
   a. Spreadsheet functions of sum, delta, percent, average, mean, standard deviation, and related functions applied to recorded data.
   b. Charting, statistical, and display functions of standard Windows-based spreadsheet.
10. Alarms: Display and record alarm messages from discrete input and controls outputs, according to user programmable protocol.
    a. Functions requiring user acknowledgment shall run in background during computer use for other applications and override other presentations when they occur.
11. Waveform Data: Display and record waveforms on demand or automatically on an alarm or programmed event; include the graphic displays of the following, based on user-specified criteria:
    a. Phase voltages, phase currents, and residual current.
    b. Overlay of three-phase currents, and overlay each phase voltage and current.
    c. Waveforms ranging in length from 2 cycles to 5 minutes.
    d. Disturbance and steady-state waveforms up to 512 points per cycle.
    e. Transient waveforms up to 83,333 points per cycle on 60-Hz base.
    f. Calculated waveform on a minimum of four cycles of data of the following:
       1) THD.
       2) rms magnitudes.
       3) Peak values.
       4) Crest factors.
       5) Magnitude of individual harmonics.
12. Data Sharing: Allow export of recorded displays and tabular data to third-party applications software.
13. Tenant or Activity Billing Software:

a. Automatically compute and prepare tenant bills **OR** activity demand and energy-use statements, **as directed**, based on metering of energy use and peak demand integrated over user-defined interval.
b. Intervals shall be same as used by electric utilities, including current vendor.
c. Import metered data from saved records that were generated by metering and monitoring software.
d. Maintain separate directory for each tenant's historical billing information.
e. Prepare summary reports in user-defined formats and time intervals.

14. Reporting: User commands initiate the reporting of a list of current alarm, supervisory, and trouble conditions in system or a log of past events.
    a. Print a record of user-defined alarm, supervisory, and trouble events on workstation printer.
    b. Sort and report by device name and by function.
    c. Report type of signal (alarm, supervisory, or trouble), description, date, and time of occurrence.
    d. Differentiate alarm signals from other indications.
    e. When system is reset, report reset event with same information concerning device, location, date, and time.

E. Communication Components And Networks
1. Transient Voltage Surge Suppression and Electromagnetic-Interference Immunity: Include in solid-state equipment. Comply with IEEE C37.90.
2. Network Configuration: High-speed, multi-access, open nonproprietary, industry standard communication protocol; LANs complying with EIA 485, 100 Base-T Ethernet, and Modbus TCP/IP.

F. Power Monitors
1. Separately mounted, permanently installed instrument for power monitoring and control.
    a. Enclosure: NEMA 250, Type 1 **OR** 12, **as directed**.
2. Environmental Conditions: System components shall be capable of withstanding the following environmental conditions without mechanical or electrical damage or degradation of operating capability:
    a. Indoor installation in non-air-conditioned **OR** nontemperature-controlled, **as directed**, spaces that have environmental controls to maintain ambient conditions of 0 to 122 deg F (minus 18 to plus 50 deg C) dry bulb and 20 to 90 percent relative humidity, noncondensing.
3. rms Real-Time Measurements:
    a. Current: Each phase, neutral, average of three phases, percent unbalance.
    b. Voltage: Line-to-line each phase, line-to-line average of three phases, line-to-neutral each phase, line-to-neutral average of three phases, line-to-neutral percent unbalance.
    c. Power: Per phase and three-phase total.
    d. Reactive Power: Per phase and three-phase total.
    e. Apparent Power: Per phase and three-phase total.
    f. Power Factor: Per phase and three-phase total.
    g. Displacement Power Factor: Per phase and three-phase total.
    h. Frequency.
    i. THD: Current and voltage.
    j. Accumulated Energy: Real kWh, reactive kVARh, apparent kVAh (signed/absolute).
    k. Incremental Energy: Real kWh, reactive kVARh, apparent kVAh (signed/absolute).
    l. Conditional Energy: Real kWh, reactive kVARh, apparent kVAh (signed/absolute).
4. Demand Current Calculations, per Phase, Three-Phase Average and Neutral:
    a. Present.
    b. Running average.
    c. Last completed interval.
    d. Peak.
5. Demand Real Power Calculations, Three-Phase Total:

a. Present.
b. Running average.
c. Last completed interval.
d. Predicted.
e. Peak.
f. Coincident with peak kVA demand.
g. Coincident with kVAR demand.

6. Demand Reactive Power Calculations, Three-Phase Total:
   a. Present.
   b. Running average.
   c. Last completed interval.
   d. Predicted.
   e. Peak.
   f. Coincident with peak kVA demand.
   g. Coincident with kVAR demand.
7. Demand Apparent Power Calculations, Three-Phase Total:
   a. Present.
   b. Running average.
   c. Last completed interval.
   d. Predicted.
   e. Peak.
   f. Coincident with peak kVA demand.
   g. Coincident with kVAR demand.
8. Average Power Factor Calculations, Demand Coincident, Three-Phase Total:
   a. Last completed interval.
   b. Coincident with kW peak.
   c. Coincident with kVAR peak.
   d. Coincident with kVA peak.
9. Power Analysis Values:
   a. THD, Voltage and Current: Per phase, three phase, and neutral.
   b. Displacement Power Factor: Per phase, three phase.
   c. Fundamental Voltage, Magnitude and Angle: Per phase.
   d. Fundamental Currents, Magnitude and Angle: Per phase.
   e. Fundamental Real Power: Per phase, three phase.
   f. Fundamental Reactive Power: Per phase.
   g. Harmonic Power: Per phase, three phase.
   h. Phase rotation.
   i. Unbalance: Current and voltage.
   j. Harmonic Magnitudes and Angles for Current and Voltages: Per phase, up to 31st **OR** 63rd, **as directed**, harmonic.
10. Power Demand Calculations: According to one of the following calculation methods, selectable by the user:
    a. Thermal Demand: Sliding window updated every second for the present demand and at end of the interval for the last interval. Adjustable window that can be set in 1-minute intervals, from 1 to 60 minutes.
    b. Block Interval with Optional Subintervals: Adjustable for 1-minute intervals, from 1 to 60 minutes. User-defined parameters for the following block intervals:
       1) Sliding block that calculates demand every second, with intervals less than 15 minutes, and every 15 seconds with an interval between 15 and 60 minutes.
       2) Fixed block that calculates demand at end of the interval.
       3) Rolling block subinterval that calculates demand at end of each subinterval and displays it at end of the interval.
    c. Demand Calculation Initiated by a Synchronization Signal:
       1) Signal is a pulse from an external source. Demand period begins with every pulse. Calculation shall be configurable as either a block or rolling block calculation.

2) Signal is a communication signal. Calculation shall be configurable as either a block or rolling block calculation.
3) Demand can be synchronized with clock in the power meter.

11. Sampling:
    a. Current and voltage shall be digitally sampled at a rate high enough to provide accuracy to 63rd harmonic of 60-Hz fundamental.
    b. Power monitor shall provide continuous sampling at a rate of 128 samples per cycle on all voltage and current channels in the meter.
12. Minimum and Maximum Values: Record monthly minimum and maximum values, including date and time of record. For three-phase measurements, identify phase of recorded value. Record the following parameters:
    a. Line-to-line voltage.
    b. Line-to-neutral voltage.
    c. Current per phase.
    d. Line-to-line voltage unbalance.
    e. Line-to-neutral voltage unbalance.
    f. Power factor.
    g. Displacement power factor.
    h. Total power.
    i. Total reactive power.
    j. Total apparent power.
    k. THD voltage L-L.
    l. THD voltage L-N.
    m. THD current.
    n. Frequency.
13. Harmonic Calculation: Display and record the following:
    a. Harmonic magnitudes and angles for each phase voltage and current through 31st **OR** 63rd, **as directed**, harmonic. Calculate for all three phases, current and voltage, and residual current. Current and voltage information for all phases shall be obtained simultaneously from same cycle.
    b. Harmonic magnitude reported as a percentage of the fundamental or as a percentage of rms values, as selected by user.
14. Current and Voltage Ratings:
    a. Designed for use with current inputs from standard instrument current transformers with 5-A secondary and shall have a metering range of 0-10 A.
    b. Withstand ratings shall be not less than 15 A, continuous; 50 A, lasting over 10 seconds, no more frequently than once per hour; 500 A, lasting 1 second, no more frequently than once per hour.
    c. Designed for use with voltage inputs from standard instrument potential transformers with a 120-V secondary.
15. Accuracy:
    a. Comply with ANSI C12.20, Class 0.5; and IEC 60687, Class 0.5 for revenue meters.
    b. Accuracy from Light to Full Rating:
        1) Power: Accurate to 0.25 percent of reading, plus 0.025 percent of full scale.
        2) Voltage and Current: Accurate to 0.075 percent of reading, plus 0.025 percent of full scale.
        3) Power Factor: Plus or minus 0.002, from 0.5 leading to 0.5 lagging.
        4) Frequency: Plus or minus 0.01 Hz at 45 to 67 Hz.
16. Waveform Capture:
    a. Capture and store steady-state waveforms of voltage and current channels; initiated manually. Each capture shall be for 3 cycles, 128 data points for each cycle, allowing resolution of harmonics to 31st harmonic of basic 60 Hz.
    b. Store captured waveforms in internal nonvolatile memory; available for PC display, archiving, and analysis.
17. Input: One digital input signal(s).

a. Normal mode for on/off signal.
b. Demand interval synchronization pulse, accepting a demand synchronization pulse from a utility demand meter.
c. Conditional energy signal to control conditional energy accumulation.

18. Outputs:
    a. Operated either by user command sent via communication link, or set to operate in response to user-defined alarm or event.
    b. Closed in either a momentary or latched mode as defined by user.
    c. Each output relay used in a momentary contact mode shall have an independent timer that can be set by user.
    d. One digital KY pulse to a user-definable increment of energy measurement. Output ratings shall be up to 120-V ac, 300-V dc, 50 mA, and provide 3500-V rms isolation.
    e. One relay output module(s), providing a load voltage range from 20- to 240-V ac or from 20- to 30-V dc, supporting a load current of 2 A.
    f. Output Relay Control:
        1) Relay outputs shall operate either by user command sent via communication link or in response to user-defined alarm or event.
        2) Normally open and normally closed contacts, field configured to operate as follows:
            a) Normal contact closure where contacts change state for as long as signal exists.
            b) Latched mode when contacts change state on receipts of a pickup signal; changed state is held until a dropout signal is received.
            c) Timed mode when contacts change state on receipt of a pickup signal; changed state is held for a preprogrammed duration.
            d) End of power demand interval when relay operates as synchronization pulse for other devices.
            e) Energy Pulse Output: Relay pulses quantities used for absolute kWh, absolute kVARh, kVAh, kWh In, kVARh In, kWh Out, and kVARh Out.
            f) Output controlled by multiple alarms using Boolean-type logic.
19. Onboard Data Logging:
    a. Store logged data, alarms, events, and waveforms in 80 **OR** 800, **as directed**, KB of onboard nonvolatile memory.
    b. Stored Data:
        1) Billing Log: User configurable; data shall be recorded every 15 minutes, identified by month, day, and 15-minute interval. Accumulate 24 months of monthly data, 32 days of daily data, and between 2 to 52 days of 15-minute interval data, depending on number of quantities selected.
        2) Custom Data Logs: One **OR** Three, **as directed**, user-defined log(s) holding up to 96 parameters. Date and time stamp each entry to the second and include the following user definitions:
            a) Schedule interval.
            b) Event definition.
            c) Configured as "fill-and-hold" or "circular, first-in first-out."
        3) Alarm Log: Include time, date, event information, and coincident information for each defined alarm or event.
        4) Waveform Log: Store captured waveforms configured as "fill-and-hold" or "circular, first-in first-out."
    c. Default values for all logs shall be initially set at factory, with logging to begin on device power up.
20. Alarms.
    a. User Options:
        1) Define pickup, dropout, and delay.
        2) Assign one of four severity levels to make it easier for user to respond to the most important events first.
        3) Allow for combining up to four alarms using Boolean-type logic statements for outputting a single alarm.

b. Alarm Events:
   1) Over/undercurrent.
   2) Over/undervoltage.
   3) Current imbalance.
   4) Phase loss, current.
   5) Phase loss, voltage.
   6) Voltage imbalance.
   7) Over kW demand.
   8) Phase reversal.
   9) Digital input off/on.
   10) End of incremental energy interval.
   11) End of demand interval.

21. Control Power: 90- to 457-V ac or 100- to 300-V dc.
22. Communications:
   a. Power monitor shall be permanently connected to communicate via Modbus TCP via a 100 Base-T Ethernet **OR** RS-485 Modbus TCP/IP, **as directed**.
   b. Local plug-in connections shall be for RS-232 and 100 Base-T Ethernet.
23. Display Monitor:
   a. Backlighted LCD to display metered data with touch-screen **OR** touch-pad, **as directed**, selecting device.
   b. Touch-screen display shall be a minimum 12-inch diagonal, resolution of 800 by 600 RGB pixels, 256 colors; NEMA 250, Type 1 display enclosure.
   c. Display four values on one screen at same time.
      1) Current, per phase rms, three-phase average and neutral, **as directed**.
      2) Voltage, phase to phase, phase to neutral, and three-phase averages of phase to phase and phase to neutral.
      3) Real power, per phase and three-phase total.
      4) Reactive power, per phase and three-phase total.
      5) Apparent power, per phase and three-phase total.
      6) Power factor, per phase and three-phase total.
      7) Frequency.
      8) Demand current, per phase and three-phase average.
      9) Demand real power, three-phase total.
      10) Demand apparent power, three-phase total.
      11) Accumulated energy (MWh and MVARh).
      12) THD, current and voltage, per phase.
   d. Reset: Allow reset of the following parameters at the display:
      1) Peak demand current.
      2) Peak demand power (kW) and peak demand apparent power (kVA).
      3) Energy (MWh) and reactive energy (MVARh).

G. Standalone, Web-Enabled Monitoring And Control Instrument
1. Separately mounted, permanently installed instrument for power monitoring and control.
   a. Enclosure: NEMA 250, Type 1 **OR** 12, **as directed**.
2. Environmental Conditions: System components shall be capable of withstanding the following environmental conditions without mechanical or electrical damage or degradation of operating capability.
   a. Indoor installation in non-air-conditioned **OR** nontemperature-controlled, **as directed**, spaces that have environmental controls to maintain ambient conditions of 0 to 122 deg F (minus 18 to plus 50 deg C) dry bulb and 20 to 90 percent relative humidity, noncondensing.
3. Power-Distribution Equipment Monitor: Web enabled, with integral network port and embedded Web server with factory-configured firmware and HTML-formatted Web pages for viewing of power monitoring and equipment status information from connected devices equipped with digital communication ports.

4. LAN Connectivity: Multipoint, RS-485 Modbus serial communication network, interconnecting all breaker trip units, protective relays, drives, and metering devices equipped with communications. Serial communication network connected to Ethernet server that functions as a gateway and server, providing data access via 10 Base-T **OR** 100 Base-T **OR** 100 Base-FX, **as directed**, LAN.
5. Communication Devices within the Equipment: Addressed at factory and tested to verify reliable communication with network server.
6. Server Configuration:
   a. Initial network parameters set using a standard Web browser. Connect via a local operator interface, or an RJ-45 port accessible from front of equipment.
   b. Network server shall be factory programmed with embedded HTML-formatted Web pages that are user configurable and that provide detailed communication diagnostic information for serial and Ethernet ports as status of RS-485 network; with internal memory management information pages for viewing using a standard Web browser.
   c. Login: Password protected; password administration accessible from the LAN using a standard Web browser.
   d. Operating Software: Suitable for local access; firewall protected.
7. Data Access:
   a. Network server shall include embedded HTML pages providing real-time information from devices connected to RS-485 network ports via a standard Web browser.
8. Equipment Monitoring Options: Login shall be followed by a main menu for selecting summary Web pages that follow.
9. Summary Web pages shall be factory configured to display the following information for each communicating device within the power equipment lineup:
   a. User-Configured Custom Home Page: Provide for the lineup, showing status-at-a-glance of key operating values, **as directed**.
   b. Circuit Summary Page: Circuit name, three-phase average rms current, power (kW), power factor, and breaker status.
   c. Load Current Summary Page: Circuit name, Phase A, B, and C rms current values.
   d. Demand Current Summary Page: Circuit name, Phase A, B, and C average demand current values.
   e. Power Summary Page: Circuit name, present demand power (kW), peak demand power (kW), and recorded time and date.
   f. Energy Summary Page: Circuit name, energy (kWh), reactive energy (kVARh), and time/date of last reset.
   g. Transformer Status Page: Transformer tag, coil temperatures, and cooling fan status.
   h. Motor-Control Center Status Page: Circuit name, three-phase average rms current, thermal capacity (percentage), and drive output frequency (Hz) contactor status.
   i. Specific Device Pages: Each individual communicating device shall display detailed, real-time information, as appropriate for device type.
      1) Display historical energy data that shall be logged automatically for each device, as appropriate for device type.
      2) Display historical data logged from each device in graphical time-trend plots. Value to be displayed on time-trend plot shall be user selectable. Time interval to be displayed on scale shall be for previous day or week.
   j. Export historical energy data to a PC or workstation through network using FTP (File Transfer Protocol). Format exported data in a CSV (Comma Separated Variable) file format for importing into spreadsheet applications.
10. Communications:
    a. Power monitor: Permanently connected to communicate via RS-485 Modbus TCP/IP **OR** Modbus TCP via an 100 Base-T Ethernet, **as directed**.
    b. Local Plug-in Connections: RS-232 and 100 Base-T Ethernet.
    c. Monitor Display: Backlighted LCD to display metered data with touch-screen **OR** touch-pad, **as directed**, selecting device.

H. Workstation Hardware

1. Environmental Conditions: System components shall be capable of withstanding the following environmental conditions without mechanical or electrical damage or degradation of operating capability:
   a. Indoor installation in spaces that have environmental controls to maintain ambient conditions of 36 to 122 deg F (2 to 50 deg C) dry bulb and 20 to 90 percent relative humidity, noncondensing.
2. Computer: Standard unmodified PC of modular design. CPU word size shall be 32 bytes or larger; CPU operating speed shall be at least 66 MHz **OR** GHz, **as directed**.
   a. Memory: 256 MB of usable installed memory, expandable to a minimum of 1024 MB without additional chassis or power supplies.
   b. Real-Time Clock:
      1) Accuracy: Plus or minus 1 minute per month.
      2) Time Keeping Format: 24-hour time format including seconds, minutes, hours, date, day, and month; automatic reset by software.
      3) Clock shall function for one year without power.
      4) Provide automatic time correction once every 24 hours by synchronizing clock with the Time Service Department of the U.S. Naval Observatory.
   c. Serial Ports: Two RS-232-F serial ports for general use, with additional ports as required. Data transmission rates shall be selectable under program control.
   d. Parallel Port: Enhanced.
   e. LAN Adapter Card: 10/100-Mbps PCI bus, internal network interface card.
   f. Sound Card: For playback and recording of digital WAV sound files associated with audible warning and alarm functions.
   g. Color Monitor: PC compatible, not less than 18 inches (455 mm), LCD type, with a minimum resolution of 1280 by 1024 pixels, noninterlaced, and a maximum dot pitch of 0.28 mm.
   h. Keyboard: Minimum of 64 characters, standard ASCII character set based on ANSI INCITS 154.
   i. Mouse: Standard, compatible with installed software.
   j. Disk Storage: Include the following, each with appropriate controller:
      1) Minimum 80-GB hard disk, maximum average access time of 10 ms.
      2) Floppy Disk Drive: High density, 3-1/2-inch (90-mm) size.
      3) PCMCIA slot with removable 500-MB media.
      4) 100-MB Iomega Zip drive.
      5) 250-MB Iomega Jaz drive.
   k. Magnetic Tape System, **as directed**: 4-mm cartridge magnetic tape system with minimum 2 **OR** 4 **OR** 12 **OR** 20, **as directed**,-GB formatted capacity per tape. Provide 10 tapes, each in a rigid cartridge with spring-loaded cover and operator-selectable write-protect feature.
   l. Modem: 56,600 bps, full duplex for asynchronous communications. With error detection, auto answer/autodial, and call-in-progress detection. Modem shall comply with requirements in ITU-T v.34, ITU-T v.42, ITU-T v.42 Appendix VI for error correction, and ITU-T v.42 BIS for data compression standards; and shall be suitable for operating on unconditioned voice-grade telephone lines complying with 47 CFR 68.
   m. Audible Alarm: Manufacturer's standard.
   n. CD-ROM Drive:
      1) Nominal Storage Capacity: 650 MB.
      2) Data Transfer Rate: 1.2 Mbps.
      3) Average Access Time: 150 ms.
      4) Cache Memory: 256 KB.
      5) Data Throughput: 1 MB/second, minimum.
   o. Report Printer: Minimum resolution 600 dpi laser printer.
      1) Connected to central station and designated workstations.
      2) RAM: 2 MB, minimum.
      3) Printing Speed: Minimum 12 pages per minute.

4) Paper Handling: Automatic sheet feeder with 250-sheet paper cassette and with automatic feed.

p. Interface: Bidirectional parallel and universal serial bus.

q. LAN Adapter Card: 10/100-Mbps internal network interface card.

3. Redundant Central Computer: Connected in a hot standby, peer configuration; automatically maintains copies of system software, application software, and data files. System transactions and other activities that alter system data files shall be updated to system files of redundant computer in near real-time. If central computer fails, redundant computer shall assume control immediately and automatically.

4. UPS: Self-contained; complying with requirements in Division 26 Section "Static Uninterruptible Power Supply".

a. Size: Provide a minimum of 6 hours of operation of workstation station equipment, including 2 hours of alarm printer operation, **as directed**.

b. Batteries: Sealed, valve regulated, recombinant, lead calcium.

c. Accessories:

1) Transient voltage suppression.

2) Input-harmonics reduction.

3) Rectifier/charger.

4) Battery disconnect device.

5) Static bypass transfer switch.

6) Internal maintenance bypass/isolation switch.

7) External maintenance bypass/isolation switch.

8) Output isolation transformer.

9) Remote UPS monitoring.

10) Battery monitoring.

11) Remote battery monitoring.

I. RS-232 ASCII Interface

1. ASCII interface shall allow RS-232 connections to be made between a meter or circuit monitor operating as the host PC and any equipment that will accept RS-232 ASCII command strings, such as local display panels **OR** dial-up modems **OR** alarm transmitters, **as directed**.

2. Pager System Interface: Alarms shall be able to activate a pager system with customized message for each input alarm.

a. RS-232 output shall be capable of connection to a pager interface that can be used to call a paging system or service and send a signal to a portable pager. System shall allow an individual alphanumeric message per alarm input to be sent to paging system. This interface shall support both numeric and alphanumeric pagers.

3. Alarm System Interface:

a. RS-232 output shall be capable of transmitting alarms from other monitoring and alarm systems to workstation software.

4. Cables:

a. PVC-Jacketed, RS-232 Cable: Paired, 2 pairs, No. 22 AWG, stranded (7x30) tinned copper conductors, polypropylene insulation, and individual aluminum foil-polyester tape shielded pairs with 100 percent shield coverage; PVC jacket. Pairs are cabled on common axis with No. 24 AWG, stranded (7x32) tinned copper drain wire.

1) NFPA 70, Type CM.

2) Flame Resistance: UL 1581, Vertical Tray.

b. Plenum-Type, RS-232 Cable: Paired, 2 pairs, No. 22 AWG, stranded (7x30) tinned copper conductors, plastic insulation, and individual aluminum foil-polyester tape shielded pairs with 100 percent shield coverage; plastic jacket. Pairs are cabled on common axis with No. 24 AWG, stranded (7x32) tinned copper drain wire.

1) NFPA 70, Type CMP.

2) Flame Resistance: NFPA 262, Flame Test.

J. LAN Cables

1. Comply with Division 27 Section "Communications Horizontal Cabling".

2. RS-485 Cable:
   a. PVC-Jacketed, RS-485 Cable: Paired, 2 pairs, twisted, No. 22 AWG, stranded (7x30) tinned copper conductors, PVC insulation, unshielded, PVC jacket, and NFPA 70, Type CMG.
   b. Plenum-Type, RS-485 Cable: Paired, 2 pairs, No. 22 AWG, stranded (7x30) tinned copper conductors, fluorinated-ethylene-propylene insulation, unshielded, and fluorinated-ethylene-propylene jacket, and NFPA 70, Type CMP.
3. Unshielded Twisted Pair Cables: Category 5e **OR** 6, **as directed**, as specified for horizontal cable for data service in Division 27 Section "Communications Horizontal Cabling".

K. Low-Voltage Wiring
1. Low-Voltage Control Cable: Multiple conductor, color-coded, No. 20 AWG copper, minimum.
   a. Sheath: PVC; except in plenum-type spaces, use sheath listed for plenums.
   b. Ordinary Switching Circuits: Three conductors, unless otherwise indicated.
   c. Switching Circuits with Pilot Lights or Locator Feature: Five conductors, unless otherwise indicated.

1.3 EXECUTION

A. Cabling
1. Comply with NECA 1.
2. Install cables and wiring according to requirements in Division 27 Section "Communications Horizontal Cabling".
3. Wiring Method: Install wiring in raceway and cable tray except within consoles, cabinets, desks, and counters. Conceal raceway and wiring except in unfinished spaces.
   OR
   Wiring Method: Install wiring in raceway and cable tray except within consoles, cabinets, desks, and counters and except in accessible ceiling spaces and in gypsum board partitions where unenclosed wiring method may be used. Use NRTL-listed plenum cable in environmental air spaces, including plenum ceilings. Conceal raceway and cables except in unfinished spaces.
4. Install LAN cables using techniques, practices, and methods that are consistent with specified category rating of components and that ensure specified category performance of completed and linked signal paths, end to end.
5. Install cables without damaging conductors, shield, or jacket.

B. Identification
1. Identify components and power and control wiring according to Division 26 Section "Identification For Electrical Systems".
2. Label each power monitoring and control module with a unique designation.

C. Grounding
1. Comply with IEEE 1100, "Power and Grounding Sensitive Electronic Equipment."

D. Field Quality Control
1. Perform tests and inspections and prepare test reports.
   a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
2. Tests and Inspections:
   a. Electrical Tests: Use caution when testing devices containing solid-state components.
   b. Continuity tests of circuits.
   c. Operational Tests: Set and operate controls at workstation and at monitored and controlled devices to demonstrate their functions and capabilities. Use a methodical sequence that cues and reproduces actual operating functions as recommended by

manufacturer. Submit sequences for approval. Note response to each test command and operation. Note time intervals between initiation of alarm conditions and registration of alarms at central-processing workstation.

1) Coordinate testing required by this Section with that required by Sections specifying equipment being monitored and controlled.
2) Test LANs according to requirements in Division 27 Section "Communications Horizontal Cabling".
3) System components with battery backup shall be operated on battery power for a period of not less than 10 percent of calculated battery operating time.
4) Verify accuracy of graphic screens and icons.
5) Metering Test: Load feeders, measure loads on feeder conductor with an rms reading clamp-on ammeter, and simultaneously read indicated current on the same phase at central-processing workstation. Record and compare values measured at the two locations. Resolve discrepancies greater than 5 percent and record resolution method and results.
6) Record metered values, control settings, operations, cues, time intervals, and functional observations and submit test reports printed by workstation printer.

3. Correct deficiencies, make necessary adjustments, and retest. Verify that specified requirements are met.
4. Test Labeling: After satisfactory completion of tests and inspections, apply a label to tested components indicating test results, date, and responsible agency and representative.
5. Reports: Written reports of tests and observations. Record defective materials and workmanship and unsatisfactory test results. Record repairs and adjustments.
6. Remove and replace malfunctioning devices and circuits and retest as specified above.

E. Demonstration

1. Engage a factory-authorized service representative to train the Owner's maintenance personnel to adjust, operate, and maintain systems.
   a. Train the Owner's management and maintenance personnel in interpreting and using monitoring displays and in configuring and using software and reports. Include troubleshooting, servicing, adjusting, and maintaining equipment. Provide a minimum of 12 hours' training.
   b. Training Aid: Use approved final versions of software and maintenance manuals as training aids.

END OF SECTION 26 09 23 00b

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SECTION 26 09 23 00c - MOTOR-CONTROL CENTERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for motor-control centers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section includes MCCs for use with ac circuits rated 600 V and less and having the following factory-installed components:
   a. Incoming main lugs and OCPDs.
   b. Full-voltage magnetic controllers.
   c. Reduced-voltage magnetic controllers.
   d. Reduced-voltage, solid-state controllers.
   e. Multispeed controllers.
   f. VFCs.
   g. Feeder-tap units.
   h. TVSS.
   i. Instrumentation.
   j. Auxiliary devices.

C. Definitions
1. BAS: Building automation system.
2. CE: Conformite Europeene (European Compliance).
3. CPT: Control power transformer.
4. EMI: Electromagnetic interference.
5. GFCI: Ground fault circuit interrupting.
6. IGBT: Insulated-gate bipolar transistor.
7. LAN: Local area network.
8. LED: Light-emitting diode.
9. MCC: Motor-control center.
10. MCCB: Molded-case circuit breaker.
11. MCP: Motor-circuit protector.
12. NC: Normally closed.
13. NO: Normally open.
14. OCPD: Overcurrent protective device.
15. PCC: Point of common coupling.
16. PID: Control action, proportional plus integral plus derivative.
17. PT: Potential transformer.
18. PWM: Pulse-width modulated.
19. RFI: Radio-frequency interference.
20. SCR: Silicon-controlled rectifier.
21. TDD: Total demand (harmonic current) distortion.
22. THD(V): Total harmonic voltage demand.
23. TVSS: Transient voltage surge suppressor.
24. VFC: Variable-frequency controller.

D. Performance Requirements
1. Seismic Performance: MCCs shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.

a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

E. Submittals

1. Product Data: For each type of controller and each type of MCC. Include shipping and operating weights, features, performance, electrical ratings, operating characteristics, and furnished specialties and accessories.
2. LEED Submittals:
   a. Product Data for Credit EA 5: For continuous metering equipment for energy consumption.
3. Shop Drawings: For each MCC, manufacturer's approval, custom and production drawings as defined in UL 845. In addition to requirements specified in UL 845, include dimensioned plans, elevations, and sections; and conduit entry locations and sizes, mounting arrangements, and details, including required clearances and service space around equipment.
   a. Show tabulations of installed devices, equipment features, and ratings. Include the following:
      1) Each installed unit's type and details.
      2) Factory-installed devices.
      3) Enclosure types and details.
      4) Nameplate legends.
      5) Short-circuit current (withstand) rating of complete MCC, and for bus structure and each unit.
      6) Features, characteristics, ratings, and factory settings of each installed controller and feeder device, and installed devices.
      7) Specified optional features and accessories.
   b. Schematic and Connection Wiring Diagrams: For power, signal, and control wiring for each installed controller.
   c. Nameplate legends.
   d. Vertical and horizontal bus capacities.
   e. Features, characteristics, ratings, and factory settings of each installed unit.
4. Harmonic Analysis Study and Report: Comply with IEEE 399 and NETA Acceptance Testing Specification; identify the effects of nonlinear loads and their associated harmonic contributions on the voltages and currents throughout the electrical system. Analyze possible **OR** designated, **as directed**, operating scenarios, including recommendations for VFC input filtering to limit TDD and THD(V) at each VFC **OR** at the defined PCC, **as directed**, to specified levels.
5. Standard Drawings: For each MCC, as defined in UL 845.
6. Production Drawings: For each MCC, as defined in UL 845.
7. Coordination Drawings: Floor plans, drawn to scale, showing dimensioned layout, required working clearances, and required area above and around MCCs where pipe and ducts are prohibited. Show MCC layout and relationships between electrical components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate field measurements.
8. Seismic Qualification Certificates: For MCCs, accessories, and components, from manufacturer.
   a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
   c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
9. Qualification Data: For qualified testing agency.
10. Product Certificates: For each MCC, from manufacturer.
11. Source quality-control reports.
12. Field quality-control reports.
13. Operation and Maintenance Data: For MCCs, all installed devices, and components to include in emergency, operation, and maintenance manuals. Include the following:

a. Manufacturer's Record Drawings: As defined in UL 845. In addition to requirements specified in UL 845, include field modifications and field-assigned wiring identification incorporated during construction by manufacturer, Contractor, or both.
b. Manufacturer's written instructions for testing and adjusting circuit breaker and MCP trip settings.
c. Manufacturer's written instructions for setting field-adjustable overload relays.
d. Manufacturer's written instructions for testing, adjusting, and reprogramming reduced-voltage, solid-state controllers.
e. Manufacturer's written instructions for testing, adjusting, and reprogramming microprocessor control modules.
f. Manufacturer's written instructions for setting field-adjustable timers, controls, and status and alarm points.

14. Load-Current and Overload-Relay Heater List: Compile after motors have been installed, and arrange to demonstrate that selection of heaters suits actual motor nameplate full-load currents.
15. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed, and arrange to demonstrate that switch settings for motor running overload protection suit actual motors to be protected.
16. Warranty: Sample of special warranty.

F. Quality Assurance
1. Testing Agency Qualifications: Member company of NETA or an NRTL.
   a. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.
2. Source Limitations: Obtain MCCs and controllers of a single type from single source from single manufacturer.
3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
4. Comply with NFPA 70.
5. IEEE Compliance: Fabricate and test enclosed controllers according to IEEE 344 to withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".

G. Delivery, Storage, And Handling
1. Deliver MCCs in shipping splits of lengths that can be moved past obstructions in delivery paths.
2. Handle MCCs according to the following:
   a. NEMA ICS 2.3, "Instructions for the Handling, Installation, Operation, and Maintenance of Motor Control Centers Rated Not More Than 600 Volts."
   b. NECA 402, "Recommended Practice for Installing and Maintaining Motor Control Centers."
3. If stored in space that is not permanently enclosed and air conditioned, remove loose packing and flammable materials from inside MCCs; install temporary electric heating, with at least 250 W per vertical section **OR** connect factory-installed space heaters to temporary electrical service, **as directed**.

H. Project Conditions
1. Environmental Limitations: Rate equipment for continuous operation under the following conditions unless otherwise indicated:
   a. Ambient Temperature: Less than 0 deg F (minus 18 deg C) or exceeding 104 deg F (40 deg C), with an average value exceeding 95 deg F (35 deg C) over a 24-hour period.
   b. Ambient Storage Temperature: Not less than minus 4 deg F (minus 20 deg C) and not exceeding 140 deg F (60 deg C).
   c. Humidity: Less than 95 percent (noncondensing).
   d. Altitude: Exceeding 6600 feet (2000 m), or 3300 feet (1000 m) if MCC includes solid-state devices.
2. Interruption of Existing Electrical Service or Distribution Systems: Do not interrupt electrical service to, or distribution systems within, a facility occupied by the Owner or others unless

permitted under the following conditions, and then only after arranging to provide temporary electrical service according to requirements indicated:
a. Notify the Owner no fewer than two days in advance of proposed interruption of electrical service.
b. Indicate method of providing temporary electrical service.
c. Do not proceed with interruption of electrical service without the Owner's written permission.
d. Comply with NFPA 70E.
3. Product Selection for Restricted Space: Drawings indicate maximum dimensions for MCCs, including clearances between MCCs and adjacent surfaces and other items.

I. Coordination
1. Coordinate sizes and locations of concrete bases. Cast anchor-bolt inserts into bases.
2. Coordinate features of MCCs, installed units, and accessory devices with remote pilot devices and control circuits to which they connect.
3. Coordinate features, accessories, and functions of each MCC, each controller, and each installed unit with ratings and characteristics of supply circuits, motors, required control sequences, and duty cycle of motors and loads.

J. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace TVSS **OR** VFCs, **as directed**, that fail in materials or workmanship within specified warranty period.
a. Warranty Period: Five years from date of Final Completion.

1.2 PRODUCTS

A. Manufactured Units
1. General Requirements for MCCs: Comply with NEMA ICS 18 and UL 845, **as directed**.

B. Functional Features
1. Description: Modular arrangement of main units, controller units, control devices, feeder-tap units, instruments, metering, auxiliary devices, and other items mounted in vertical sections of MCC.
2. Controller Units: Combination controller units.
a. Install units up to and including Size 3 on drawout mountings with connectors that automatically line up and connect with vertical-section buses while being racked into their normal, energized positions.
b. Equip units in Type B and Type C MCCs with pull-apart terminal strips for external control connections.
3. Feeder-Tap Units: Through 225-A rating shall have drawout mountings with connectors that automatically line up and connect with vertical-section buses while being racked into their normal, energized positions.
4. Future Units: Compartments fully bused and equipped with guide rails or equivalent, ready for insertion of drawout units.
5. Spare Units: Installed in compartments indicated "spare."

C. Incoming Mains
1. Incoming Mains Location: Top and bottom, **as directed**.
2. Main Lugs Only: Conductor connectors suitable for use with conductor material and sizes.
a. Material: Tin-plated aluminum **OR** Hard-drawn copper, 98 percent conductivity, **as directed**.
b. Main and Neutral Lugs: Compression **OR** Mechanical, **as directed**, type.

3. MCCB: Comply with UL 489, with series-connected rating **OR** interrupting capacity, **as directed**, to meet available fault currents.
   a. Thermal-Magnetic Circuit Breakers: Inverse time-current element for low-level overloads, and instantaneous magnetic trip element for short circuits. Adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
   b. Adjustable Instantaneous-Trip Circuit Breakers: Magnetic trip element with front-mounted, field-adjustable trip setting.
   c. Electronic trip circuit breakers with rms sensing; field-replaceable rating plug or field-replicable electronic trip; and the following field-adjustable settings:
      1) Instantaneous trip.
      2) Long- and short-time pickup levels.
      3) Long- and short-time time adjustments.
      4) Ground-fault pickup level, time delay, and I^2t response.
   d. Current-Limiting Circuit Breakers: Frame sizes 400 A and smaller; let-through ratings less than NEMA FU 1, RK-5.
   e. Integrally Fused Circuit Breakers: Thermal-magnetic trip element with integral limiter-style fuse listed for use with circuit breaker; trip activation on fuse opening or on opening of fuse compartment door.
   f. MCCB Features and Accessories:
      1) Standard frame sizes, trip ratings, and number of poles.
      2) Lugs: Mechanical **OR** Compression, **as directed**, style, suitable for number, size, trip ratings, and conductor material.
      3) Application Listing: Appropriate for application; Type SWD for switching fluorescent lighting loads; Type HID for feeding fluorescent and high-intensity discharge (HID) lighting circuits.
      4) Ground-Fault Protection: Integrally mounted **OR** Remote-mounted, **as directed**, relay and trip unit with adjustable pickup and time-delay settings, push-to-test feature, and ground-fault indicator.
      5) Zone-Selective Interlocking: Integral with electronic trip unit; for interlocking ground-fault protection function.
      6) Communication Capability: Circuit-breaker-mounted **OR** Universal-mounted **OR** Integral **OR** Din-rail-mounted, **as directed**, communication module with functions and features compatible with power monitoring and control system specified in Division 16 Section "Electrical Power Monitoring and Control."
      7) Shunt Trip: 120-V trip coil energized from separate circuit, set to trip at 55 **OR** 75, **as directed**, percent of rated voltage.
      8) Undervoltage Trip: Set to operate at 35 to 75 percent of rated voltage without intentional time delay.
      9) Auxiliary Contacts: One SPDT switch **OR** Two SPDT switches, **as directed**, with "a" and "b" contacts; "a" contacts mimic circuit-breaker contacts, "b" contacts operate in reverse of circuit-breaker contacts.
      10) Key Interlock Kit: Externally mounted to prohibit circuit-breaker operation; key shall be removable only when circuit breaker is in off position.
4. Insulated-Case Circuit Breaker: 80 **OR** 100, **as directed**, percent rated, sealed, insulated-case power circuit breaker with interrupting capacity rating to meet available fault current.
   a. Fixed **OR** Drawout, **as directed**, circuit-breaker mounting.
   b. Two-step, stored-energy closing.
   c. Standard **OR** Full, **as directed**,-function, microprocessor-based trip units with interchangeable rating plug, trip indicators, and the following field-adjustable settings:
      1) Instantaneous trip.
      2) Long- and short-time time adjustments.
      3) Ground-fault pickup level, time delay, and I^2t response.
   d. Zone-Selective Interlocking: Integral with electronic trip unit; for interlocking ground-fault protection function.
   e. Remote trip indication and control.

f. Communication Capability: Integral communication module with functions and features compatible with power monitoring and control system specified in Division 16 Section "Electrical Power Monitoring and Control."
g. Key Interlock Kit: Externally mounted to prohibit circuit-breaker operation; key shall be removable only when circuit breaker is in off position.
h. Control Voltage: 40-V dc **OR** 125-V dc **OR** 250-V dc **OR** 120-V ac, **as directed**.

D. Combination Controllers
1. Full-Voltage Controllers:
a. General Requirements for Full-Voltage Enclosed Controllers: Comply with NEMA ICS 2, general purpose, Class A.
b. Magnetic Controllers: Full voltage, across the line, electrically held.
1) Configuration: Nonreversing and reversing.
2. Reduced-Voltage Magnetic Controllers:
a. General Requirements for Reduced-Voltage Magnetic Controllers: Comply with NEMA ICS 2, general purpose, Class A; closed transition; adjustable time delay on transition.
b. Reduced-Voltage Magnetic Controllers: Reduced voltage, electrically held.
1) Configuration:
a) Wye-Delta Controller: Four contactors, with a three-phase starting resistor/reactor bank.
b) Part-Winding Controller: Separate START and RUN contactors, field-selectable for one-half or two-thirds winding start mode, with either six- or nine-lead motors; with separate overload relays for starting and running sequences.
c) Autotransformer Reduced-Voltage Controller: Medium-duty service, with integral overtemperature protection; taps for starting at 50, 65, and 80 percent of line voltage; two START and one RUN contactors.
3. Reduced-Voltage, Solid-State Controllers:
a. General Requirements for Reduced-Voltage, Solid-State Controllers: Comply with UL 508.
b. Reduced-Voltage, Solid-State Controllers: An integrated unit with power SCRs, heat sink, microprocessor logic board, door-mounted digital display and keypad, bypass contactor, and overload relay; suitable for use with NEMA MG 1, Design B, polyphase, medium-induction motors.
1) Configuration: Standard duty **OR** Severe duty, **as directed**; nonreversible **OR** reversible, **as directed**.
2) Starting Mode: Voltage ramping **OR** Current limit **OR** Torque control **OR** Torque control with voltage boost, **as directed**; field selectable, **as directed**.
3) Stopping Mode: Coast to stop **OR** Adjustable torque deceleration **OR** Adjustable braking, **as directed**; field selectable, **as directed**.
4) Shorting (Bypass) Contactor: Operates automatically when full voltage is applied to motor, and bypasses the SCRs. Solid-state controller protective features shall remain active when the shorting contactor is in the bypass mode.
5) Shorting and Input Isolation, **as directed**, Contactor Coils: Pressure-encapsulated type; manufacturer's standard operating voltage, matching control power or line voltage, depending on contactor size and line-voltage rating. Provide coil transient suppressors, **as directed**.
6) Logic Board: Identical for all ampere ratings and voltage classes, with environmental protective coating.
7) Adjustable acceleration-rate control using voltage or current ramp, and adjustable starting torque control with up to 400 percent current limitation for 20 seconds.
8) SCR bridge shall consist of at least two SCRs per phase, providing stable and smooth acceleration with **OR** without, **as directed**, external feedback from the motor or driven equipment.

9) Keypad, front accessible; for programming the controller parameters, functions, and features; shall be manufacturer's standard and include not less than the following functions:
   a) Adjusting motor full-load amperes, as a percentage of the controller's rating.
   b) Adjusting current limitation on starting, as a percentage of the motor full-load current rating.
   c) Adjusting linear acceleration and deceleration ramps, in seconds.
   d) Initial torque, as a percentage of the nominal motor torque.
   e) Adjusting torque limit, as a percentage of the nominal motor torque.
   f) Adjusting maximum start time, in seconds.
   g) Adjusting voltage boost, as a percentage of the nominal supply voltage.
   h) Selecting stopping mode, and adjusting parameters.
   i) Selecting motor thermal-overload protection class between 5 and 30.
   j) Activating and de-activating protection modes.
   k) Selecting or activating communications modes.
10) Digital display, front accessible; for showing motor, controller, and fault status; shall be manufacturer's standard and include not less than the following:
   a) Controller Condition: Ready, starting, running, stopping.
   b) Motor Condition: Amperes, voltage, power factor, power, and thermal state.
   c) Fault Conditions: Controller thermal fault, motor overload alarm and trip, motor underload, overcurrent, shorted SCRs, line or phase loss, phase reversal, and line frequency over or under normal.
11) Controller Diagnostics and Protection:
   a) Microprocessor-based thermal protection system for monitoring SCR and motor thermal characteristics, and providing controller overtemperature and motor overload alarm and trip; settings selectable via the keypad.
   b) Protection from line-side reverse phasing; line-side and motor-side phase loss; motor jam, stall, and underload conditions; and line frequency over or under normal.
   c) Input isolation contactor that opens when the controller diagnostics detect a faulted solid-state component, or when the motor is stopped.
      OR
      Shunt trip that opens the disconnecting means when the controller diagnostics detect a faulted solid-state component.
12) Remote Output Features:
   a) All outputs prewired to terminal blocks.
   b) Form C status contacts that change state when controller is running.
   c) Form C alarm contacts that change state when a fault condition occurs.
13) Optional Features:
   a) Analog output for field-selectable assignment of motor operating characteristics; 0 to 10-V dc **OR** 4 to 20-mA dc, **as directed**.
   b) Additional field-assignable Form C contacts for alarm outputs.
   c) Surge suppressors in solid-state power circuits providing three-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.
   d) Full-voltage bypass contactor operating automatically **OR** manually, with NORMAL/BYPASS selector switch, **as directed**. Power contacts shall be totally enclosed, double break, and silver-cadmium oxide; and assembled to allow inspection and replacement without disturbing line or load wiring.

4. Multispeed Magnetic Controllers:
   a. General Requirements for Multispeed Magnetic Controllers: Comply with NEMA ICS 2, general purpose, Class A.
   b. Multispeed Magnetic Controllers: Two speed, full voltage, across the line, electrically held. Compelling relay to ensure that motor will start only at low speed.
      1) Configuration: Nonreversing **OR** Reversing, **as directed**; consequent pole **OR** two winding, **as directed**.

2) Compelling relays shall ensure that motor starts only at low speed.
3) Accelerating timer relays shall ensure properly timed acceleration through speeds lower than that selected.
4) Decelerating timer relays shall ensure automatically timed deceleration through each speed.
5) Antiplugging timer relays shall ensure a time delay when transferring from FORWARD to REVERSE and back.

5. Disconnecting Means and OCPDs:
   a. Fusible Disconnecting Means:
      1) NEMA KS 1, heavy-duty, horsepower-rated, fusible switch with clips or bolt pads to accommodate Class J **OR** Class L, **as directed**, fuses.
      2) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
      3) Auxiliary Contacts: NO/NC, arranged to activate before switch blades open.
   b. MCP Disconnecting Means:
      1) UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents, instantaneous-only circuit breaker with front-mounted, field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
      2) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
      3) Auxiliary contacts "a" and "b" arranged to activate with MCP handle.
      4) NC **OR** NO, **as directed**, alarm contact that operates only when MCP has tripped.
      5) Current-limiting module to increase controller short-circuit current (withstand) rating to 100 kA.
   c. MCCB Disconnecting Means:
      1) UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents; thermal-magnetic MCCB, with inverse time-current element for low-level overloads and instantaneous magnetic trip element for short circuits.
      2) Front-mounted, adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
      3) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
      4) Auxiliary contacts "a" and "b" arranged to activate with MCCB handle.
      5) NC **OR** NO, **as directed**, alarm contact that operates only when MCCB has tripped.
   d. Molded-Case Switch Disconnecting Means:
      1) UL 489, NEMA AB 1, and NEMA AB 3, with in-line fuse block for Class J or L power fuses (depending on ampere rating), providing an interrupting capacity to comply with available fault currents; MCCB with fixed, high-set instantaneous trip only.
      2) Lockable Handle: Accepts three padlocks and interlocks with cover in closed position.
      3) Auxiliary contacts "a" and "b" arranged to activate with molded-case switch handle.
      4) NC **OR** NO, **as directed**, alarm contact that operates only when molded-case switch has tripped.
6. Overload Relays:
   a. Melting-Alloy Overload Relays:
      1) Inverse-time-current characteristic.
      2) Class 10 **OR** Class 20 **OR** Class 30, **as directed**, tripping characteristic.
      3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
   b. Bimetallic Overload Relays:
      1) Inverse-time-current characteristic.
      2) Class 10 **OR** Class 20 **OR** Class 30, **as directed**, tripping characteristic.
      3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
      4) Ambient compensated.

5) Automatic resetting.

c. Solid-State Overload Relays:

1) Switch or dial selectable for motor running overload protection.

2) Sensors in each phase.

3) Class 10 **OR** Class 20 **OR** Class 10/20 selectable, **as directed**, tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.

a) Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.

b) Analog communication module.

d. NC **OR** NO, **as directed**, isolated overload alarm contact.

e. External overload reset push button.

7. Control Power:

a. Control Circuits: 24 **OR** 120, **as directed**,-V ac; obtained from integral CPT, with primary and secondary fuses, with CPT **OR** control power source, **as directed**, of sufficient capacity to operate integral devices and remotely located pilot, indicating, and control devices.

1) CPT Spare Capacity: 50 **OR** 100 **OR** 200, **as directed**, VA.

E. VFCS

1. General Requirements for VFCs: Comply with NEMA ICS 7, NEMA ICS 61800-2, and UL 508C, **as directed**.

2. Application: Constant torque and variable torque, **as directed**.

3. VFC Description: Variable-frequency power converter (rectifier, dc bus, and IGBT PWM inverter) factory packaged in an enclosure, with integral disconnecting means and overcurrent and overload protection; listed and labeled by an NRTL as a complete unit; arranged to provide self-protection, protection, and variable-speed control of one or more three-phase induction motors by adjusting output voltage and frequency.

a. Units suitable for operation of NEMA MG 1, Design A and Design B motors as defined by NEMA MG 1, Section IV, Part 30, "Application Considerations for Constant Speed Motors Used on a Sinusoidal Bus with Harmonic Content and General Purpose Motors Used with Adjustable-Voltage or Adjustable-Frequency Controls or Both."

b. Units suitable for operation of inverter-duty motors as defined by NEMA MG 1, Section IV, Part 31, "Definite-Purpose Inverter-Fed Polyphase Motors."

c. Listed and labeled for integrated short-circuit current (withstand) rating by an NRTL acceptable to authorities having jurisdiction.

d. Listed and labeled for single-phase use by an NRTL acceptable to authorities having jurisdiction.

4. Design and Rating: Match load type such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.

5. Output Rating: Three-phase; 10 to 60 Hz, with voltage proportional to frequency throughout voltage range **OR** 66 Hz, with torque constant as speed changes, **as directed**; maximum voltage equals input voltage.

6. Unit Operating Requirements:

a. Input AC Voltage Tolerance: Plus 10 and minus 10 **OR** 15, **as directed**, percent of VFC input voltage rating.

b. Input AC Voltage Unbalance: Not exceeding 3 **OR** 5, **as directed**, percent.

c. Input Frequency Tolerance: Plus or minus 3 percent of VFC frequency rating.

d. Minimum Efficiency: 96 **OR** 97, **as directed**, percent at 60 Hz, full load.

e. Minimum Displacement Primary-Side Power Factor: 96 **OR** 98, **as directed**, percent under any load or speed condition.

f. Overload Capability: 1.1 **OR** 1.5, **as directed**, times the base load current for 60 seconds; minimum of 1.8 times the base load current for three seconds.

g. Starting Torque: Minimum of 100 percent of rated torque from 3 to 60 Hz.

h. Speed Regulation: Plus or minus 5 **OR** 10, **as directed**, percent.

i. Output Carrier Frequency: Selectable; 0.5 to 15 kHz.

j. Stop Modes: Programmable; includes fast, free-wheel, and dc injection braking.

7. Inverter Logic: Microprocessor based, 16 **OR** 32, **as directed**, bit, isolated from all power circuits.
8. Isolated Control Interface: Allows VFCs to follow remote-control signal over a minimum 40:1 speed range.
   a. Signal: Electrical.
      OR
      Signal: Pneumatic.
9. Internal Adjustability Capabilities:
   a. Minimum Speed: 5 to 25 percent of maximum rpm.
   b. Maximum Speed: 80 to 100 percent of maximum rpm.
   c. Acceleration: 0.1 to 999.9 seconds.
   d. Deceleration: 0.1 to 999.9 seconds.
   e. Current Limit: 30 to a minimum of 150 percent of maximum rating.
10. Self-Protection and Reliability Features:
   a. Input transient protection by means of surge suppressors to provide three-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.
   b. Loss of Input Signal Protection: Selectable response strategy including speed default to a percent of the most recent speed, a preset speed, or stop; with alarm.
   c. Under- and overvoltage trips.
   d. Inverter overcurrent trips.
   e. VFC and Motor Overload/Overtemperature Protection: Microprocessor-based thermal protection system for monitoring VFCs and motor thermal characteristics, and for providing VFC overtemperature and motor overload alarm and trip; settings selectable via the keypad; NRTL approved.
   f. Critical frequency rejection, with three selectable, adjustable deadbands.
   g. Instantaneous line-to-line and line-to-ground overcurrent trips.
   h. Loss-of-phase protection.
   i. Reverse-phase protection.
   j. Short-circuit protection.
   k. Motor overtemperature fault.
11. Automatic Reset/Restart: Attempt three restarts after drive fault or on return of power after an interruption and before shutting down for manual reset or fault correction; adjustable delay time between restart attempts.
12. Power-Interruption Protection: To prevent motor from re-energizing after a power interruption until motor has stopped, unless "Bidirectional Autospeed Search" feature is available and engaged.
13. Bidirectional Autospeed Search: Capable of starting VFC into rotating loads spinning in either direction and returning motor to set speed in proper direction, without causing damage to drive, motor, or load.
14. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.
15. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.
16. Integral Input Disconnecting Means and OCPD: NEMA AB 1, instantaneous-trip circuit breaker **OR** NEMA AB 1, molded-case switch, with power fuse block and current-limiting fuses **OR** NEMA AB 1, thermal-magnetic circuit breaker **OR** NEMA KS 1, nonfusible switch, with power fuse block and current-limiting fuses **OR** NEMA KS 1, fusible switch, **as directed**, with pad-lockable, door-mounted handle mechanism.
   a. Disconnect Rating (for VFCs without bypass systems): Not less than 115 percent of VFC input current rating.
   b. Disconnect Rating (for VFCs with bypass systems): Not less than 115 percent of NFPA 70 motor full-load current rating or VFC input current rating, whichever is larger.
   c. Auxiliary Contacts: NO/NC, arranged to activate before switch blades open.

d. Auxiliary contacts "a" and "b" arranged to activate with circuit-breaker handle.
e. NC **OR** NO, **as directed**, alarm contact that operates only when circuit breaker has tripped.

F. VFC Controls And Indication
1. Status Lights: Door-mounted LED indicators displaying the following conditions:
   a. Power on.
   b. Run.
   c. Overvoltage.
   d. Line fault.
   e. Overcurrent.
   f. External fault.
2. Panel-Mounted Operator Station: Manufacturer's standard front-accessible, sealed keypad and plain-English language digital display; allows complete programming, program copying, operating, monitoring, and diagnostic capability.
   a. Keypad: In addition to required programming and control keys, include keys for HAND, OFF, and AUTO modes.
   b. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: View only; view and operate; and view, operate, and service.
      1) Control Authority: Supports at least four conditions: Off, local manual control at VFC, local automatic control at VFC, and automatic control through a remote source.
3. Historical Logging Information and Displays:
   a. Running log of total power versus time.
   b. Total run time.
   c. Fault log, maintaining last four faults with time and date stamp for each.
4. Indicating Devices: Digital display and additional readout devices as required, mounted flush in VFC door and connected to display VFC parameters, including, but not limited to:
   a. Output frequency (Hz).
   b. Motor speed (rpm).
   c. Motor status (running, stop, fault).
   d. Motor current (amperes).
   e. Motor torque (percent).
   f. Fault or alarming status (code).
   g. PID feedback signal (percent).
   h. DC-link voltage (V dc).
   i. Set point frequency (Hz).
   j. Motor output voltage (V ac).
5. Control Signal Interfaces:
   a. Electric Input Signal Interface:
      1) A minimum of two programmable analog inputs: 0- to 10-V dc **OR** 4- to 20-mA dc **OR** Operator-selectable "x"- to "y"-mA dc, **as directed**.
      2) A minimum of six multifunction programmable digital inputs.
   b. Pneumatic Input Signal Interface: 3 to 15 psig (20 to 104 kPa).
   c. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the BAS or other control systems:
      1) 0- to 10-V dc.
      2) 4- to 20-mA dc.
      3) Potentiometer using up/down digital inputs.
      4) Fixed frequencies using digital inputs.
   d. Output Signal Interface: A minimum of one programmable analog output signal(s) (0- to 10-V dc **OR** 4- to 20-mA dc **OR** operator-selectable "x"- to "y"-mA dc, **as directed**), which can be configured for any of the following:
      1) Output frequency (Hz).
      2) Output current (load).

3) DC-link voltage (V dc).
4) Motor torque (percent).
5) Motor speed (rpm).
6) Set point frequency (Hz).

e. Remote Indication Interface: A minimum of two programmable dry-circuit relay outputs (120-V ac, 1 A) for remote indication of the following:
1) Motor running.
2) Set point speed reached.
3) Fault and warning indication (overtemperature or overcurrent).
4) PID high- or low-speed limits reached.

6. PID Control Interface: Provides closed-loop set point, differential feedback control in response to dual feedback signals. Allows for closed-loop control of fans and pumps for pressure, flow, or temperature regulation.
a. Number of Loops: One **OR** Two, **as directed**.

7. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display VFC status and alarms and energy usage, **as directed**. Allows VFC to be used with an external system within a multidrop LAN configuration; settings retained within VFC's nonvolatile memory.
a. Network Communications Ports: Ethernet and RS-422/485.
b. Embedded BAS Protocols for Network Communications: ASHRAE 135 BACnet **OR** Echelon LonWorks **OR** Ethernet TCP/IP **OR** Johnson Metasys N2 **OR** Modbus/Memobus **OR** Siemens System 600 APOGEE, **as directed**; protocols accessible via the communications ports.

G. VFC Line Conditioning And Filtering
1. Input Line Conditioning: Based on the harmonic analysis study and report, provide input filtering, as required, to limit TDD at input terminals of VFCs to less than 5 **OR** 8, **as directed**, percent and THD(V) to 3 **OR** 5, **as directed**, percent.
2. Input Line Conditioning: Based on the harmonic analysis study and report, provide input filtering, as required, to limit TDD and THD(V) at the defined PCC per IEEE 519.
3. Input Line Conditioning: <**Insert requirements**>.
4. VFC Output Filtering: <**Insert requirements**>.
5. EMI/RFI Filtering: CE marked; certify compliance with IEC 61800-3 for Category C2.

H. VFC Bypass Systems
1. Bypass Operation: Safely transfers motor between power converter output and bypass circuit, manually, automatically, or both. Selector switches set modes, and indicator lights indicate mode selected. Unit is capable of stable operation (starting, stopping, and running) with motor completely disconnected from power converter.
2. Bypass Mode: Manual operation only; requires local operator selection at VFC. Transfer between power converter and bypass contactor and retransfer shall only be allowed with the motor at zero speed.
OR
Bypass Mode: Field-selectable automatic or manual, allows local and remote transfer between power converter and bypass contactor and retransfer, either via manual operator interface or automatic control system feedback.
3. Bypass Controller: Two-contactor-style bypass allows motor operation via the power converter or the bypass controller; with input isolating switch and barrier arranged to isolate the power converter and permit safe troubleshooting and testing, both energized and de-energized, while motor is operating in bypass mode, **as directed**.
a. Bypass Contactor: Load-break, IEC **OR** NEMA, **as directed**,-rated contactor.
b. Output Isolating Contactor: Non-load-break, IEC **OR** NEMA, **as directed**,-rated contactor.
c. Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.

OR
Bypass Controller: Three-contactor-style bypass allows motor operation via the power converter or the bypass controller; with input isolating switch and barrier, **as directed**, arranged to isolate the power converter input and output and permit safe testing and troubleshooting of the power converter, both energized and de-energized, while motor is operating in bypass mode.
a. Bypass Contactor: Load-break, IEC **OR** NEMA, **as directed**,-rated contactor.
b. Input and Output Isolating Contactors: Non-load-break, IEC **OR** NEMA, **as directed**,-rated contactors.
c. Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.

4. Bypass Contactor Configuration: Full-voltage (across-the-line) **OR** Reduced-voltage (autotransformer), **as directed**, type.
a. NORMAL/BYPASS selector switch.
b. HAND/OFF/AUTO selector switch.
c. NORMAL/TEST Selector Switch: Allows testing and adjusting of VFC while the motor is running in the bypass mode.
d. Contactor Coils: Pressure-encapsulated type with coil transient suppressors, **as directed**.
1) Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.
2) Power Contacts: Totally enclosed, double break, and silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.
e. Control Circuits: 120-V ac; obtained from integral CPT, with primary and secondary fuses **as directed**, with CPT **OR** control power source, **as directed**, of sufficient capacity to operate all integral devices and remotely located pilot, indicating, and control devices.
f. CPT Spare Capacity: 50 **OR** 100 **OR** 200, **as directed**, VA.

5. Overload Relays: NEMA ICS 2.
a. Melting-Alloy Overload Relays:
1) Inverse-time-current characteristic.
2) Class 10 **OR** Class 20 **OR** Class 30, **as directed**, tripping characteristic.
3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
b. Bimetallic Overload Relays:
1) Inverse-time-current characteristic.
2) Class 10 **OR** Class 20 **OR** Class 30, **as directed**, tripping characteristic.
3) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
4) Ambient compensated.
5) Automatic resetting.
c. Solid-State Overload Relays:
1) Switch or dial selectable for motor-running overload protection.
2) Sensors in each phase.
3) Class 10 **OR** Class 20 **OR** Class 10/20 selectable, **as directed**, tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.
4) Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
5) Analog communication module.
6) NC **OR** NO, **as directed**, isolated overload alarm contact.
7) External overload reset push button.

I. Optional VFC Features
1. Multiple-Motor Capability: VFC suitable for variable-speed service to multiple motors. Overload protection shuts down VFC and motors served by it, and generates fault indications, when overload protection activates.

a. Configure to allow two or more motors to operate simultaneously at the same speed; separate overload relay for each controlled motor.
b. Configure to allow two motors to operate separately; operator selectable via local or remote switch or contact closures; single overload relay for both motors; separate output magnetic contactors for each motor.
c. Configure to allow two motors to operate simultaneously and in a lead/lag mode, with one motor operated at variable speed via the power converter and the other at constant speed via the bypass controller; separate overload relay for each controlled motor.

2. Damper control circuit with end of travel feedback capability.
3. Sleep Function: Senses a minimal deviation of a feedback signal and stops the motor. On an increase in speed-command signal deviation, VFC resumes normal operation.
4. Motor Preheat Function: Preheats motor when idle to prevent moisture accumulation in the motor.
5. Firefighter's Override (Smoke Purge) Input: On a remote contact closure from the firefighter's control station **OR** smoke-control fan controller, **as directed**, this password-protected input:
   a. Overrides all other local and external inputs (analog/digital, serial communication, and all keypad commands).
   b. Forces VFC to operate motor, without any other run or speed command, at a field-adjustable, preset speed.
      OR
      Forces VFC to transfer to Bypass Mode and operate motor at full speed.
   c. Causes display of Override Mode on the VFC display.
   d. Reset VFC to normal operation on removal of override signal automatically **OR** manually, **as directed**.
6. Remote Indicating Circuit Terminals: Mode selection, controller status, and controller fault.
7. Remote digital operator kit.
8. Communication Port: RS-232 port, USB 2.0 port, or equivalent connection capable of connecting a printer and a notebook computer.

J. Feeder-Tap Units
1. MCCB: Comply with UL 489, with series-connected rating **OR** interrupting capacity, **as directed**, to meet available fault currents.
   a. Thermal-Magnetic Circuit Breakers: Inverse time-current element for low-level overloads, and instantaneous magnetic trip element for short circuits. Adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
   b. Adjustable Instantaneous-Trip Circuit Breakers: Magnetic trip element with front-mounted, field-adjustable trip setting.
   c. Electronic trip circuit breakers with rms sensing; field-replaceable rating plug or field-replicable electronic trip; and the following field-adjustable settings:
      1) Instantaneous trip.
      2) Long- and short-time pickup levels.
      3) Long- and short-time time adjustments.
      4) Ground-fault pickup level, time delay, and I^2t response.
   d. Current-Limiting Circuit Breakers: Frame sizes 400 A and smaller; let-through ratings less than NEMA FU 1, RK-5.
   e. Integrally Fused Circuit Breakers: Thermal-magnetic trip element with integral limiter-style fuse listed for use with circuit breaker; trip activation on fuse opening or on opening of fuse compartment door.
   f. MCCB Features and Accessories:
      1) Standard frame sizes, trip ratings, and number of poles.
      2) Lugs: Mechanical **OR** Compression, **as directed**, style, suitable for number, size, trip ratings, and conductor material.
      3) Application Listing: Appropriate for application; Type SWD for switching fluorescent lighting loads; Type HID for feeding fluorescent and high-intensity discharge (HID) lighting circuits.

4) Ground-Fault Protection: Integrally mounted **OR** Remote-mounted, **as directed**, relay and trip unit with adjustable pickup and time-delay settings, push-to-test feature, and ground-fault indicator.
5) Zone-Selective Interlocking: Integral with electronic trip unit; for interlocking ground-fault protection function.
6) Communication Capability: Circuit-breaker-mounted **OR** Universal-mounted **OR** Integral **OR** Din-rail-mounted, **as directed**, communication module with functions and features compatible with power monitoring and control system specified in Division 26 Section "Electrical Power Monitoring And Control".
7) Shunt Trip: 120-V trip coil energized from separate circuit, set to trip at 55 **OR** 75, **as directed**, percent of rated voltage.
8) Undervoltage Trip: Set to operate at 35 to 75 percent of rated voltage without intentional time delay.
9) Auxiliary Contacts: One SPDT switch **OR** Two SPDT switches, **as directed**, with "a" and "b" contacts; "a" contacts mimic circuit-breaker contacts, "b" contacts operate in reverse of circuit-breaker contacts.
10) Key Interlock Kit: Externally mounted to prohibit circuit-breaker operation; key shall be removable only when circuit breaker is in off position.

2. Fusible Switch: NEMA KS 1, Type HD, clips to accommodate specified fuses with lockable handle.
3. Fuses are specified in Division 26 Section "Fuses".

K. Transient Voltage Suppression Devices
1. Surge Protection Device Description: IEEE C62.41-compliant, integrally mounted, wired-in **OR** plug-in **OR** bolt-on, **as directed**, solid-state, parallel-connected, modular (with field-replaceable modules) **OR** non-modular, **as directed**, type, with sine-wave tracking suppression and filtering modules, UL 1449, second edition, short-circuit current rating matching or exceeding the MCC short-circuit rating, and with the following features and accessories:
   a. Fuses, rated at 200-kA interrupting capacity.
   b. Fabrication using bolted compression lugs for internal wiring.
   c. Integral disconnect switch.
   d. Redundant suppression circuits.
   e. Redundant replaceable modules.
   f. Arrangement with wire connections to phase buses, neutral bus, and ground bus.
   g. LED indicator lights for power and protection status.
   h. Audible alarm, with silencing switch, to indicate when protection has failed.
   i. Form-C contacts rated at 5 A and 250-V ac, one NO and one NC, for remote monitoring of system operation. Contacts shall reverse position on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.
   j. Four **OR** Six, **as directed**,-digit, transient-event counter set to totalize transient surges.
2. Peak Single-Impulse Surge Current Rating: 160 kA per mode/320 kA per phase **OR** 120 kA per mode/240 kA per phase **OR** 80 kA per mode/160 kA per phase, **as directed**.
3. Withstand Capabilities: 12,000 IEEE C62.41, Category C3 (10 kA), 8-by-20-mic.sec. surges with less than 5 percent change in clamping voltage.
4. Protection modes and UL 1449 SVR for grounded wye circuits with 480Y/277 **OR** 208Y/120 **OR** 600Y/347, **as directed**,-V, three-phase, four-wire circuits shall be as follows:
   a. Line to Neutral: 800 V for 480Y/277 **OR** 400 V for 208Y/120 **OR** 1200 V for 600Y/347, **as directed**.
   b. Line to Ground: 800 V for 480Y/277 **OR** 400 V for 208Y/120 **OR** 1200 V for 600Y/347, **as directed**.
   c. Neutral to Ground: 800 V for 480Y/277 **OR** 400 V for 208Y/120 **OR** 1200 V for 600Y/347, **as directed**.

   OR

   Protection modes and UL 1449 SVR for 240/120-V, three-phase, four-wire circuits with high leg shall be as follows:

a. Line to Neutral: 400 V, 800 V from high leg.
b. Line to Ground: 400 V.
c. Neutral to Ground: 400 V.

OR

Protection modes and UL 1449 SVR for 240-, 480-, or 600-V, three-phase, three-wire, delta circuits shall be as follows:

a. Line to Line: 2000 V for 480 V **OR** 1000 V for 240 V **OR** 2500 V for 600 V, **as directed**.
b. Line to Ground: 1500 V for 480 V **OR** 800 V for 240 V **OR** 2500 V for 600 V, **as directed**.

L. Instrumentation

1. Instrument Transformers (for the Owner metering): IEEE C57.13, NEMA EI 21.1, and the following:
   a. PTs: IEEE C57.13; 120 V, 60 Hz, single **OR** tapped **OR** double, **as directed**, secondary; disconnecting type with integral fuse mountings. Burden and accuracy shall be consistent with connected metering and relay devices.
   b. Current Transformers: IEEE C57.13; 5 A, 60 Hz, secondary; wound **OR** bushing **OR** bar or window, **as directed**, type; single **OR** double, **as directed**, secondary winding and secondary shorting device. Burden and accuracy shall be consistent with connected metering and relay devices.
   c. CPTs: Dry type, mounted in separate compartments for units larger than 3 kVA.
   d. Current Transformers for Neutral and Ground-Fault Current Sensing: Connect secondary wiring to ground overcurrent relays, via shorting terminals, to provide selective tripping of main and tie circuit breaker. Coordinate with feeder circuit-breaker, ground-fault protection.
2. Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three- or four-wire systems and with the following features:
   a. Listed or recognized by a nationally recognized testing laboratory.
   b. Inputs from sensors or 5-A current-transformer secondaries, and potential terminals rated to 600 V.
   c. Switch-selectable digital display of the following values with the indicated maximum accuracy tolerances:
      1) Phase Currents, Each Phase: Plus or minus 1 percent.
      2) Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent.
      3) Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 percent.
      4) Three-Phase Real Power (Megawatts): Plus or minus 2 percent.
      5) Three-Phase Reactive Power (Megavars): Plus or minus 2 percent.
      6) Power Factor: Plus or minus 2 percent.
      7) Frequency: Plus or minus 0.5 percent.
      8) Accumulated Energy, Megawatt Hours: Plus or minus 2 percent; accumulated values unaffected by power outages up to 72 hours.
      9) Megawatt Demand: Plus or minus 2 percent; demand interval programmable from five to 60 minutes.
      10) Contact devices to operate remote impulse-totalizing demand meter.
   d. Mounting: Display and control unit flush or semiflush mounted in instrument compartment door.
3. Ammeters, Voltmeters, and Power-Factor Meters: ANSI C39.1.
   a. Meters: 4-inch (100-mm) diameter or 6 inches (150 mm) square, flush or semiflush, with antiparallax 250-degree scale and external zero adjustment.
   b. Voltmeters: Cover an expanded-scale range of nominal voltage plus 10 percent.
4. Instrument Switches: Rotary type with off position.
   a. Voltmeter Switches: Permit reading of all phase-to-phase voltages and phase-to-neutral voltages where a neutral is included.
   b. Ammeter Switches: Permit reading of current in each phase and maintain current-transformer secondaries in a closed-circuit condition at all times.

5. Feeder Ammeters: 2-1/2-inch (64-mm) minimum size with 90- or 120-degree scale. Meter and transfer device with off position, located on overcurrent device door for feeder circuits, unless otherwise indicated.
6. Watt-Hour Meters and Wattmeters:
   a. Comply with ANSI C12.1.
   b. Three-phase induction type with two stators, each with current and potential coil, rated 5 A, 120 V, 60 Hz.
   c. Suitable for connection to three- and four-wire circuits.
   d. Potential indicating lamps.
   e. Adjustments for light and full load, phase balance, and power factor.
   f. Four-dial clock register.
   g. Integral demand indicator.
      OR
      Contact devices to operate remote impulse-totalizing demand meter.
   h. Ratchets to prevent reverse rotation.
   i. Removable meter with drawout test plug.
   j. Semiflush mounted case with matching cover.
   k. Appropriate multiplier tag.
7. Impulse-Totalizing Demand Meter:
   a. Comply with ANSI C12.1.
   b. Suitable for use with MCC watt-hour meter, including two-circuit totalizing relay.
   c. Cyclometer.
   d. Four-dial, totalizing kilowatt-hour register.
   e. Positive chart drive mechanism.
   f. Capillary pen holding a minimum of one month's ink supply.
   g. Roll chart with minimum 31-day capacity; appropriate multiplier tag.
   h. Capable of indicating and recording five **OR** 15 **OR** 30, **as directed**,-minute integrated demand of totalized system.

M. MCC Control Power
1. Control Circuits: 120-V ac, supplied through secondary disconnecting devices from CPT.
   OR
   Control Circuits: 120-V ac, supplied from remote branch circuit.
2. Electrically Interlocked Main and Tie Circuit Breakers: Two CPTs in separate compartments, with interlocking relays, connected to the primary side of each CPT at the line side of the associated main circuit breaker. 120-V secondaries connected through automatic transfer relays to ensure a fail-safe automatic transfer scheme.
3. Control Power Fuses: Primary and secondary fuses for current-limiting and overload protection of transformer and fuses for protection of control circuits.
4. Control Wiring: Factory installed, with bundling, lacing, and protection included. Provide flexible conductors for No. 8 AWG and smaller, for conductors across hinges, and for conductors for interconnections between shipping units.

N. Enclosures
1. Indoor Enclosures: Freestanding steel cabinets unless otherwise indicated. NEMA 250, Type 1 **OR** Type 1A **OR** Type 2 **OR** Type 12, **as directed**, unless otherwise indicated to comply with environmental conditions at installed location.
2. Space Heaters: Factory-installed electric space heaters of sufficient wattage in each vertical section to maintain enclosure temperature above expected dew point.
   a. Space-Heater Control: Thermostats to maintain temperature of each section above expected dew point **OR** Manual switching of branch-circuit protective device, **as directed**.
   b. Space-Heater Power Source: Transformer, factory installed in MCC **OR** 120-V external branch circuit, **as directed**.
3. Enclosure Finish for Indoor Units: Factory-applied finish in manufacturer's standard gray **OR** custom color, **as directed**, finish over a rust-inhibiting primer on treated metal surface.

4. Outdoor Enclosures: Type 3R, non-walk-in aisle **OR** Type 3R, with interior-lighted walk-in aisle, **as directed**.
   a. Finish: Factory-applied finish in manufacturer's standard **OR** custom, **as directed**, color; undersurfaces treated with corrosion-resistant undercoating.
   b. Enclosure: Flat **OR** Downward, rearward sloping, **as directed**, roof; bolt-on rear covers **OR** rear hinged doors, **as directed**, for each section, with provisions for padlocking.
   c. Doors: Personnel door at each end of aisle, minimum width of 30 inches (762 mm); opening outwards; with panic hardware and provisions for padlocking **OR** cylinder lock, **as directed**.
   d. Accessories: Fluorescent lighting fixtures, ceiling mounted; wired to a three-way light switch at each end of aisle; GFCI duplex receptacle; emergency battery pack lighting fixture installed on wall of aisle midway between personnel doors.
   e. Walk-in Aisle Heating and Ventilating:
      1) Factory-installed electric unit heater(s), wall or ceiling mounted, with integral thermostat and disconnect and with capacities to maintain switchboard interior temperature of 40 deg F (5 deg C) with outside design temperature of 104 deg F (40 deg C).
      2) Factory-installed exhaust fan with capacities to maintain switchboard interior temperature of 100 deg F (38 deg C) with outside design temperature of 23 deg F (minus 5 deg C).
      3) Ventilating openings complete with replaceable fiberglass air filters, **as directed**.
      4) Thermostat: Single stage; wired to control heat and exhaust fan.
   f. Power for Space Heaters, Ventilation, Lighting, and Receptacle: Include a CPT within the switchboard. Supply voltage shall be 120 **OR** 120/240 **OR** 120/208, **as directed**,-V ac.
      OR
      Power for space heaters, ventilation, lighting, and receptacle provided by a remote source.
5. Compartments: Modular; individual lift-off, **as directed**, doors with concealed hinges and quick-captive screw fasteners. Interlocks on units requiring disconnecting means in off position before door can be opened or closed, except by operating a permissive release device.
6. Interchangeability: Compartments constructed to allow for removal of units without opening adjacent doors, disconnecting adjacent compartments, or disturbing operation of other units in MCC; same size compartments to permit interchangeability and ready rearrangement of units, such as replacing three single units with a unit requiring three spaces, without cutting or welding.
7. Wiring Spaces:
   a. Vertical wireways in each vertical section for vertical wiring to each unit compartment; supports to hold wiring in place.
   b. Horizontal wireways in bottom **OR** top **OR** bottom and top, **as directed**, of each vertical section for horizontal wiring between vertical sections; supports to hold wiring in place.

O. Auxiliary Devices
1. General Requirements for Control-Circuit and Pilot Devices: NEMA ICS 5; factory installed in controller enclosure cover unless otherwise indicated.
   a. Push Buttons, Pilot Lights, and Selector Switches: Heavy **OR** Standard, **as directed**,-duty, oiltight, **as directed**, type.
      1) Push Buttons: Covered **OR** Lockable **OR** Recessed **OR** Shielded **OR** Shrouded **OR** Unguarded, **as directed**, types; maintained **OR** momentary, **as directed**, contact unless otherwise indicated.
      2) Pilot Lights: Incandescent **OR** LED **OR** Neon **OR** Resistor **OR** Transformer, **as directed**, types; <**Insert color(s)**>; push to test, **as directed**.
      3) Selector Switches: Rotary type.
   b. Elapsed-Time Meters: Heavy duty with digital readout in hours; nonresettable **OR** resettable, **as directed**.
   c. Meters: Panel type, 2-1/2-inch (64-mm) minimum size with 90- or 120-degree scale and plus or minus 2 percent accuracy with selector switches having an off position.
2. NC **OR** NO **OR** Reversible NC/NO, **as directed**, contactor auxiliary contact(s).

3. Control Relays: Auxiliary and adjustable pneumatic **OR** solid-state, **as directed**, time-delay relays.
4. Phase-Failure, Phase-Reversal, and Undervoltage and Overvoltage Relays: Solid-state sensing circuit with isolated output contacts for hard-wired connections. Provide adjustable undervoltage, overvoltage, and time-delay settings.
5. Space heaters, with NC auxiliary contacts, to mitigate condensation in enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.
6. Sun shields installed on fronts, sides, and tops of enclosures installed outdoors and subject to direct and extended sun exposure.
7. Cover gaskets for Type 1 enclosures.
8. Terminals for connecting power factor correction capacitors to the line **OR** load, **as directed**, side of overload relays.
9. Spare control-wiring terminal blocks; unwired **OR** wired, **as directed**.
10. Spare-Fuse Cabinet: Identified and compartmented steel box **OR** cabinet with hinged lockable door, **as directed**.

P. Characteristics And Ratings
1. Wiring: NEMA ICS 18, Class I **OR** Class I-S, **as directed**, Type A **OR** Type B, for starters above Size 3 **OR** Type B-D, for starter Size 3 and below **OR** Type B-T, for starter Size 3 and below **OR** Type C, **as directed**.
   OR
   Wiring: NEMA ICS 18, Class II **OR** Class II-S, **as directed**, Type B, for starters above Size 3 **OR** Type B-D, for starter Size 3 and below **OR** Type B-T, for starter Size 3 and below **OR** Type C, **as directed**.
2. Control and Load Wiring: Factory installed, with bundling, lacing, and protection included. Provide flexible conductors for No. 8 AWG and smaller, for conductors across hinges, and for conductors for interconnections between shipping units.
3. Nominal System Voltage: 480 V, three phase, three wire **OR** 480Y/277 V, three phase, four wire, **as directed**.
   OR
   Nominal System Voltage: 208 V, three phase, three wire **OR** 208/120 V, three phase, four wire, **as directed**.
4. Short-Circuit Current Rating for Each Unit: Combination series rated **OR** Fully rated, **as directed**; 22 **OR** 42 **OR** 65 **OR** 100, **as directed**, kA.
5. Short-Circuit Current Rating of MCC: Combination series rated **OR** Fully rated, **as directed**, with its main overcurrent device; 22 **OR** 42 **OR** 65 **OR** 100, **as directed**, kA.
6. Environmental Ratings:
   a. Ambient Temperature Rating: Not less than 0 deg F (minus 18 deg C) and not exceeding 104 deg F (40 deg C), with an average value not exceeding 95 deg F (35 deg C) over a 24-hour period.
   b. Ambient Storage Temperature Rating: Not less than minus 4 deg F (minus 20 deg C) and not exceeding 140 deg F (60 deg C)
   c. Humidity Rating: Less than 95 percent (noncondensing).
   d. Altitude Rating: Not exceeding 6600 feet (2000 m), or 3300 feet (1000 m) if MCC includes solid-state devices.
7. Main-Bus Continuous Rating: 600 **OR** 800 **OR** 1000 **OR** 1200 **OR** 1600 **OR** 2000, **as directed**, A.
8. Vertical-Bus Minimum, **as directed**, Continuous Rating: 300 **OR** 600 **OR** 1200, **as directed**, A.
9. Horizontal and Vertical Bus Bracing (Short-Circuit Current Rating): Match MCC short-circuit current rating.
10. Main Horizontal and Equipment Ground Buses: Uniform capacity for entire length of MCC's main and vertical sections. Provide for future extensions from both ends, **as directed**. Brace bus extensions for busway feeder bus, **as directed**.
11. Vertical Phase and Equipment Ground Buses: Uniform capacity for entire usable height of vertical sections, except for sections incorporating single units.

12. Phase- and Neutral-, **as directed**,Bus Material: Hard-drawn copper of 98 percent conductivity, silver **OR** tin, **as directed**, plated.
    OR
    Phase- and Neutral-, **as directed**,Bus Material: Tin-plated, high-strength, electrical-grade aluminum alloy.
13. Neutral Buses: 50 percent of the ampacity of phase buses unless otherwise indicated, equipped with mechanical **OR** compression, **as directed**, connectors for outgoing circuit neutral cables. Brace bus extensions for busway feeder neutral bus, **as directed**.
    OR
    Neutral Buses: 100 percent of the ampacity of phase buses unless otherwise indicated, equipped with mechanical **OR** compression, **as directed**, connectors for outgoing circuit neutral cables. Brace bus extensions for busway feeder neutral bus, **as directed**.
14. Ground Bus: Minimum size required by UL 845, hard-drawn copper of 98 percent conductivity, equipped with mechanical **OR** compression, **as directed**, connectors for feeder and branch-circuit equipment grounding conductors. For busway feeders, extend insulated equipment grounding cable to busway ground connection and support cable at intervals in vertical run, **as directed**.
15. Front-Connected, Front-Accessible MCCs:
    a. Main Devices: Drawout **OR** Fixed, **as directed**, mounted.
    b. Controller Units: Drawout and fixed, **as directed**, mounted.
    c. Feeder-Tap Units: Drawout and fixed, **as directed**, mounted.
    d. Sections front and rear aligned.
16. Utility Metering Compartment: Fabricated, barrier compartment and section complying with utility company's requirements; hinged sealed door; buses provisioned for mounting utility company's current transformers and potential transformers or potential taps as required by utility company. If separate vertical section is required for utility metering, match and align with basic MCC. Provide service entrance label and necessary applicable service entrance features.
17. the Owner Metering Compartment: A separate customer metering compartment and section with front hinged door, metering, and current transformers for each meter. Current transformer secondary wiring shall be terminated on shorting-type terminal blocks. Include potential transformers having primary and secondary fuses with disconnecting means and secondary wiring terminated on terminal blocks, **as directed**.
18. Bus Transition and Incoming Pull Sections: Matched and aligned with basic MCC.
19. Pull Box on Top of an MCC:
    a. Adequate ventilation to maintain temperature in pull box within same limits as MCC.
    b. Set back from front to clear circuit-breaker removal mechanism.
    c. Removable covers forming top, front, and sides. Top covers at rear easily removable for drilling and cutting.
    d. Insulated bottom of fire-resistive material with separate holes for cable drops into MCC.
    e. Cable supports arranged to facilitate cabling and adequate to support cables, including those for future installation.
    f. Isolation Barrier Access Provisions: Permit checking of bus-bolt tightness.
20. Future Devices: Equip compartments with mounting brackets, supports, bus connections, and appurtenances at full rating of unit.
21. Bus-Bar Insulation: Factory-applied, flame-retardant, tape wrapping of individual bus bars or flame-retardant, spray-applied insulation. Minimum insulation temperature rating of 105 deg C.
22. Fungus Proofing: Permanent fungicidal treatment for OCPDs and other components including instruments and instrument transformers.

Q. Source Quality Control
1. MCC Testing: Inspect and test MCCs according to requirements in NEMA ICS 18.
2. VFC Testing: Test and inspect VFCs according to requirements in NEMA ICS 61800-2.
    a. Test each VFC while connected to its specified motor **OR** a motor that is comparable to that for which the VFC is rated, **as directed**.

b. Verification of Performance: Rate VFCs according to operation of functions and features specified.

3. MCCs will be considered defective if they do not pass tests and inspections.
4. Prepare test and inspection reports.

1.3 EXECUTION

A. Examination
1. Examine areas and surfaces to receive MCCs, with Installer present, for compliance with requirements for installation tolerances, and other conditions affecting performance of the Work.
2. Examine enclosed controllers before installation. Reject enclosed controllers that are wet, moisture damaged, or mold damaged.
3. Proceed with installation only after unsatisfactory conditions have been corrected.

B. Harmonic Analysis Study
1. Perform a harmonic analysis study to identify the effects of nonlinear loads and their associated harmonic contributions on the voltages and currents throughout the electrical system. Analyze possible **OR** designated, **as directed**, operating scenarios, including recommendations for VFC input filtering to limit TDD and THD(V) at the defined PCC to specified levels.
2. Prepare a harmonic analysis study report complying with IEEE 399 and NETA Acceptance Testing Specification.

C. Installation
1. Coordinate layout and installation of MCCs with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.
2. Floor-Mounting Controllers: Install MCCs on 4-inch (100-mm) nominal thickness concrete base. Comply with requirements for concrete base specified in Division 03 Section "Cast-in-place Concrete".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   d. Install anchor bolts to elevations required for proper attachment to supported equipment.
3. Seismic Bracing: Comply with requirements specified in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".
4. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.
5. Install fuses in each fusible switch.
6. Install fuses in control circuits if not factory installed. Comply with requirements in Division 26 Section "Fuses".
7. Install heaters in thermal-overload relays. Select heaters based on actual nameplate full-load amperes after motors have been installed.
8. Install, connect, and fuse thermal-protector monitoring relays furnished with motor-driven equipment.
9. Install power factor correction capacitors. Connect to the line **OR** load, **as directed**, side of overload relays. If connected to the load side of overload relays, adjust overload heater sizes to accommodate the reduced motor full-load currents.
10. Comply with NECA 1.

D. Identification
1. Comply with requirements in Division 26 Section "Identification For Electrical Systems" for identification of MCC, MCC components, and control wiring.

a. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
b. Label MCC and each cubicle with engraved nameplate.
c. Label each enclosure-mounted control and pilot device.
d. Mark up a set of manufacturer's connection wiring diagrams with field-assigned wiring identifications and return to manufacturer for inclusion in Record Drawings.

2. Operating Instructions: Frame printed operating instructions for MCCs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of MCCs.

E. Control Wiring Installation
1. Install wiring between enclosed controllers **OR** master terminal boards, **as directed**, and remote devices and facility's BAS **OR** and facility's central-control system, **as directed**. Comply with requirements in Division 26 Section "Control-voltage Electrical Power Cables".
2. Bundle, train, and support wiring in enclosures.
3. Connect selector switches and other automatic-control selection devices where applicable.
a. Connect selector switches to bypass only those manual- and automatic-control devices that have no safety functions when switch is in manual-control position.
b. Connect selector switches within enclosed controller circuit in both manual and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor overload protectors.

F. Connections
1. Comply with requirements for installation of conduit in Division 26 Section "Raceway And Boxes For Electrical Systems". Drawings indicate general arrangement of conduit, fittings, and specialties.
2. Comply with requirements in Division 26 Section "Grounding And Bonding For Electrical Systems".

G. Field Quality Control
1. Perform tests and inspections.
2. Acceptance Testing Preparation:
a. Test insulation resistance for each enclosed controller, component, connecting supply, feeder, and control circuit.
b. Test continuity of each circuit.
3. Tests and Inspections:
a. Inspect controllers, wiring, components, connections, and equipment installation. Test and adjust controllers, components, and equipment.
b. Test insulation resistance for each enclosed controller element, component, connecting motor supply, feeder, and control circuits.
c. Test continuity of each circuit.
d. Verify that voltages at controller locations are within 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify the Owner before starting the motor(s).
e. Test each motor for proper phase rotation.
f. Perform each electrical test and visual and mechanical inspection stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
g. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
h. Perform the following infrared (thermographic) scan tests and inspections and prepare reports:
1) Initial Infrared Scanning: After Final Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each multipole enclosed controller. Remove front panels so joints and connections are accessible to portable scanner.
2) Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each multipole enclosed controller 11 months after date of Final Completion.

3) Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

i. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

j. Mark up a set of manufacturer's drawings with all field modifications incorporated during construction and return to manufacturer for inclusion in Record Drawings.

4. Enclosed controllers will be considered defective if they do not pass tests and inspections.

5. Prepare test and inspection reports, including a certified report that identifies enclosed controllers and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

H. Startup Service

1. Perform startup service.

a. Complete installation and startup checks according to manufacturer's written instructions.

I. Adjusting

1. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.

2. Adjust overload relay heaters or settings if power factor correction capacitors are connected to the load side of the overload relays.

3. Adjust the trip settings of MCPs and thermal-magnetic circuit breakers with adjustable, instantaneous trip elements. Initially adjust to six times the motor nameplate full-load amperes and attempt to start motors several times, allowing for motor cool-down between starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping. Do not exceed eight times the motor full-load amperes (or 11 times for NEMA Premium Efficient motors if required). Where these maximum settings do not allow starting of a motor, notify the Owner before increasing settings.

4. Set the taps on reduced-voltage autotransformer controllers at 50 **OR** 65 **OR** 80, **as directed**, percent.

5. Set field-adjustable switches and program microprocessors for required start and stop sequences in reduced-voltage, solid-state controllers.

6. Program microprocessors in VFCs for required operational sequences, status indications, alarms, event recording, and display features. Clear events memory after final acceptance testing and prior to Final Completion.

7. Set field-adjustable circuit-breaker trip ranges as specified in Division 26 Section "Overcurrent Protective Device Coordination Study".

J. Protection

1. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions until enclosed controllers are ready to be energized and placed into service.

2. Replace controllers whose interiors have been exposed to water or other liquids prior to Final Completion.

K. Demonstration

1. Train the Owner's maintenance personnel to adjust, operate, and maintain enclosed controllers, and to use and reprogram microprocessor-based, reduced-voltage, solid-state controllers, **as directed**.

END OF SECTION 26 09 23 00c

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SECTION 26 09 23 00d - CENTRAL DIMMING CONTROLS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for central dimming controls. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes microprocessor-based central dimming controls with the following components:
   a. Control network.
   b. Master-control stations.
   c. Partitioned-space master-control stations.
   d. Wall stations.
   e. Dimmer cabinets.
   f. Manual switches and plates for controlling dimmers.

C. Definitions
1. Fade Override: The ability to temporarily set fade times to zero for all lighting scenes.
2. Fade Rate: The time it takes each zone to arrive at the next scene, dependent on the degree of change in lighting level.
3. Fade Time: The time it takes all zones to fade from one lighting scene to another, with all zones arriving at the next scene at the same time.
4. Low Voltage: As defined in NFPA 70, term for circuits and equipment operating at less than 50 V or for remote-control, signaling, and power-limited circuits.
5. Scene: The lighting effect created by adjusting several zones of lighting to the desired intensity.
6. SCR: Silicon-controlled rectifier.
7. Zone: A fixture or group of fixtures controlled simultaneously as a single entity. Also known as a "channel."

D. Submittals
1. Product Data: For each type of product indicated.
   a. For central dimming controls; include elevation, features, characteristics, and labels.
   b. For dimmer panels; include dimensions, features, dimmer characteristics, ratings, and directories.
   c. Device plates, plate color, and material.
   d. Ballasts and lamp combinations compatible with dimmer controls.
   e. Sound data including results of operational tests of central dimming controls.
   f. Operational documentation for software and firmware.
2. Shop Drawings: Detail assemblies of standard components, custom assembled for specific application on Project. Indicate dimensions, weights, arrangement of components, and clearance and access requirements.
   a. Include elevation views of front panels of control and indicating devices and control stations.
   b. Wiring Diagrams: Power, signal, and control wiring.
3. Samples: For master-control stations, partitioned-space master-control stations, wall stations, dimmer cabinets, and faceplates with factory-applied color finishes and technical features.
   a. Operation and Maintenance Data: For central dimming controls with remote-mounting dimmers to include in emergency, operation, and maintenance manuals.
4. Warranty: Special warranty specified in this Section.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Comply with 47 CFR 15, Subparts A and B, for Class A digital devices.
3. Comply with NFPA 70.

F. Warranty
1. Manufacturer's standard form in which manufacturer agrees to repair or replace components of central dimming controls that fail in materials or workmanship within specified warranty period.
   a. Failures include, but are not limited to, the following:
      1) Damage from transient voltage surges.
   b. Warranty Period: Cost to repair or replace any parts for two years from date of Final Completion.
   c. Extended Warranty Period: Cost of replacement parts (materials only, f.o.b. the nearest shipping point to Project site), for eight years, that failed in service due to transient voltage surges.

G. Software Service Agreement
1. Services in this Article may not be allowed for publicly funded projects.
2. Technical Support: Beginning with Final Completion, provide software support for two years.
3. Upgrade Service: Update software to latest version at Project completion. Install and program software upgrades that become available within two years from date of Final Completion. Upgrading software shall include operating system. Upgrade shall include new or revised licenses for use of software.
   a. Provide 30 days' notice to the Owner to allow scheduling and access to system and to allow the Owner to upgrade computer equipment if necessary.

1.2 PRODUCTS

A. General System Requirements
1. Compatibility: Dimming control components shall be compatible with other elements of lighting fixtures, ballasts, transformers, and lighting controls.
2. Line-Voltage Surge Suppression: Factory installed as an integral part of 120- and 277-V ac, solid-state dimmers and control panels.
   a. Alternative Line-Voltage Surge Suppression: Comply with requirements in Division 26 Section "Transient-voltage Suppression For Low-voltage Electrical Power Circuits" for Category A **OR** B, **as directed**, locations.
3. Dimmers and Dimmer Modules: Comply with UL 508.
   a. Audible Noise and Radio-Frequency Interference Suppression: Solid-state dimmers shall operate smoothly over their operating ranges without audible lamp or dimmer noise or radio-frequency interference. Modules shall include integral or external filters to suppress audible noise and radio-frequency interference.
   b. Dimmer or Dimmer-Module Rating: Not less than 125 percent of connected load unless otherwise indicated.

B. System Description
1. Description: Microprocessor-based, solid-state controls consisting of control stations and a separately mounted dimmer cabinet.
   a. Operation: Change variable dimmer settings of indicated number of zones simultaneously from one preset scene to another when a rocker switch **OR** pushbutton **OR** slider, **as directed**, is operated.
   b. System control shall include master station(s), wall stations, and dimmer panels.
   c. Each zone shall be configurable to control the following light sources:

1) Fluorescent lamps with electronic **OR** magnetic, **as directed**, ballasts.
2) Line-voltage incandescent lamps.
3) Low-voltage incandescent lamps.
4) Cold cathode lamps.
5) Non-dimmed loads.
6) LED lamps.

d. Control of each zone shall interface with controls for the following accessory functions:
1) Curtains and drapes.
2) Blackout curtains.
3) Projector screens.
4) Motorized partitions.
5) Manually positioned partitions.

e. Memory: Retain preset scenes and fade settings through power failures for at least 90 days by retaining physical settings of controls or by an on-board, automatically recharged battery.

C. Control Network
1. Dimmers shall receive signals from control stations that are linked to dimmer cabinet with a common network data cable.
2. Functions of network control stations shall be set up at master station that include the number and arrangement of scene presets, zones, and fade times at wall stations.
a. Control Voltage: 24- or 10-V dc.
b. Comply with USITT AMX 192 **OR** USITT DMX 512, **as directed**, for data transmission.

D. Master-Control Stations
1. Functions and Features:
a. Control adjustment of the lighting level for each scene of each zone, and adjustment of fade-time setting for each scene change from one preset scene to another. Controls shall use analog manual sliders **OR** digital rocker switches with LCD graphic display of light level, **as directed**.
b. Master channel shall raise and lower lighting level of all zones.
c. Fade rate for each scene shall be adjustable from zero to 60 seconds.
d. Fade override control for each scene.
e. Recall each preset scene and allow adjustment of zone controls associated with that scene.
f. Lockout switch to prevent changes when set.
g. On and off scene controls for non-dim channel contactors.
h. Emergency-control pushbutton to bypass all controls, turning all dimmers to full bright and turning on non-dim channel contactors.
i. Master on and off switch; off position enables housekeeping controls.
j. Housekeeping controls to turn on selected lighting fixtures for housekeeping functions.
k. Pushbuttons for accessory functions.
l. Enable and disable wall stations.
m. Communications link to other master stations.
n. Provide for connecting a portable computer to program the master station.
o. Rear-illuminate all scene-select buttons.
p. Show lighting-level setting and fade-rate setting graphically using LEDs or backlighted bar-graph indicator.
2. Mounting: Single, flush wall box with manufacturer's standard faceplate with hinged transparent locking cover, **as directed**.

E. Partitioned-Space Master-Control Station
1. Functions and Features:
a. Automatically combine and separate lighting and accessory function controls as spaces are configured with movable partitions; with controls for adjustment of the lighting level for

each scene of each dimmer, and adjustment of fade-rate setting for each scene change from one preset scene to another.

b. Master controls shall accommodate partitioning the space into six adjacent rooms.
c. Manual controls to set up six scenes for each room. Include wall stations in each room to control scenes.
d. Master channel to raise and lower the lighting level of all zones.
e. Adjustable fade rate for each scene from zero to 60 seconds.
f. Fade override control for each scene.
g. On and off scene controls for non-dim channel contactors.
h. Emergency-control pushbutton to bypass all controls, turning all dimmers to full bright and turning on non-dim channel contactors.
i. Master on and off switch; off position enables housekeeping controls.
j. Housekeeping controls to turn on selected lighting fixtures for housekeeping functions.
k. Pushbuttons for accessory functions.
l. Provide for connecting a portable computer to program the master station.
m. Rear-illuminate all scene-select buttons.
n. Show lighting-level setting and fade-rate setting graphically using LEDs or backlighted bar-graph indicator.

2. Custom Graphics. Include a graphical display of room configurations and the names for each. Indicate the current spaces configuration with LCD graphic or LED-illuminated indicators, and show which wall stations are active. Inactive wall stations shall be automatically deactivated.
3. Mounting: Single, flush wall box with manufacturer's standard faceplate with hinged transparent locking cover, **as directed**.

F. Wall Stations

1. Functions and Features:
   a. Wall stations shall function as a submaster to a master station, containing limited control of selected scenes of the master station.
   b. Controls to adjust the lighting level of each dimmer for each scene, and the fade time setting for each scene change from one preset scene to another.
   c. Numbered pushbuttons to select scenes.
   d. Off switch to turn master station off. Operating the off switch at any remote station shall automatically turn on selected housekeeping lighting, **as directed**.
   e. On switch turns all scenes of master station to full bright.
   f. Pushbutton controls for accessory functions.
2. Mounting: Flush, wall box with manufacturer's standard faceplate.
3. Hand-held Cordless Control: Scene-select and accessory function pushbuttons using infrared **OR** radio-frequency, **as directed**, transmission.

G. Dimmer Cabinets

1. Factory wired, convection cooled without fans, with barriers to accommodate 120- and 277-V feeders and suitable to control designated lighting equipment or accessory functions.
2. Ambient Conditions:
   a. Temperature: 60 to 95 deg F (15 to 35 deg C).
   b. Relative Humidity: 10 to 90 percent, noncondensing.
   c. Filtered air supply.
3. Dimmer Cabinet Assembly: NRTL listed and labeled.
4. Cabinet Type: Plug in, modular, and accepting dimmers of each specified type in any plug-in position.
   a. Integrated Fault-Current Rating: 10,000-A RMS symmetrical.
5. Lighting Dimmers: Solid-state SCR dimmers.
   a. Primary Protection: Magnetic or thermal-magnetic circuit breaker, also serving as the disconnecting means.
   b. Dimmer response to control signal shall follow the "Square Law Dimming Curve" specified in IESNA's "IESNA Lighting Handbook."

c. Dimming Range: 0 to 100 percent, full output voltage not less than 98 percent of line voltage.
d. Dimmed circuits shall be filtered to provide a minimum 350-mic.sec. current-rise time at a 90-degree conduction angle and 50 percent of rated dimmer capacity. Rate of current rise shall not exceed 30 mA/mic.sec., measured from 10 to 90 percent of load-current waveform.
e. Protect controls of each dimmer with a fuse and transient voltage surge suppression, **as directed**.

6. Non-dim modules shall include relays with contacts rated to switch 20-A tungsten-filament load at 120-V ac and 20-A electronic ballast load at 277-V ac.
7. Accessory function control modules shall be compatible with requirement of the accessory being controlled.
8. Digital Control Network:
   a. Dimmers shall receive digital signals from digital network control stations that are linked to the dimmer cabinet with a common network data cable.
   b. Functions of digital network control stations shall be set up at the dimmer cabinet's electronic controls that include indicated number and arrangement of scene presets, channels, and fade times.
9. Emergency Power Transfer Switch: Comply with UL 1008; factory prewired and pretested to automatically transfer load circuits from normal to emergency power supply when normal supply fails.
   a. Transfer from normal to emergency supply when normal-supply voltage drops to 55 percent or less.
   b. Retransfer immediately to normal on failure of emergency supply and after an adjustable time-delay of 10 to 90 seconds on restoration of normal supply while emergency supply is available.
   c. Integrated Fault-Current Rating: Same value as listed for the panel.
   d. Test Switch: Simulate failure of normal supply to test controls associated with transfer scheme.
   e. Fabricate and test dimmer boards to withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".

H. Portable Computer
1. Description: As recommended by master-control station manufacturer, to program master station and associated wall stations, and all interconnected master stations, **as directed**. Portable computer shall be laptop style with a battery runtime of at least two hours. Display shall be an 11-inch (280-mm) interactive-matrix LCD and shall have required hardware, firmware, and software to program specified control functions of master-control stations.
2. Software shall be configured and customized by master-station manufacturer.

I. Manual Switches And Plates
1. Switches: Modular, momentary pushbutton, low-voltage type.
   a. Color: White unless otherwise indicated.
   b. Integral Pilot Light: Indicate when circuit is on. Use where indicated.
   c. Locator Light: Internal illumination.
   d. Wall Plates: Comply with requirements in Division 26 Section "Wiring Devices" for materials, finish, and color. Use multigang plates if more than one switch is indicated at a location.
   e. Legend: Engraved or permanently silk-screened on wall plate where indicated. Use designations indicated on Drawings.

J. Conductors And Cables
1. Wiring to Supply Side of Remote-Control Power Sources: Not smaller than No. 12 AWG. Comply with requirements in Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

2. Classes 2 and 3 Control Cable: Multiconductor cable with stranded-copper conductors not smaller than No. 18 **OR** 22 **OR** 24, **as directed**, AWG. Comply with requirements in Division 26 Section "Low-voltage Electrical Power Conductors And Cables".
3. Class 1 Control Cable: Multiconductor cable with stranded-copper conductors not smaller than No. 14 **OR** 16 **OR** 18, **as directed**, AWG. Comply with requirements in Division 26 Section "Low-voltage Electrical Power Conductors And Cables".
4. Unshielded, Twisted-Pair Data Cable: Category 5e **OR** 6, **as directed**. Comply with requirements in Division 27 Section "Communications Horizontal Cabling".

1.3 EXECUTION

A. Wiring Installation
1. Comply with NECA 1.
2. Wiring Method:
   a. Comply with requirements in Division 26 Section "Low-voltage Electrical Power Conductors And Cables"
   b. Install unshielded, twisted-pair cable for control and signal transmission conductors, complying with Division 27 Section "Communications Horizontal Cabling".
   c. Minimum conduit size shall be 1/2 inch (13 mm).
3. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points. Separate power-limited and nonpower-limited conductors according to conductor manufacturer's written instructions.
4. Size conductors according to lighting control device manufacturer's written instructions unless otherwise indicated.
5. Splices, Taps, and Terminations: Make connections only on numbered terminal strips in junction, pull, and outlet boxes; terminal cabinets; and equipment enclosures.
6. Install dimmer cabinets for each zone.

B. Identification
1. Comply with requirements in Division 26 Section "Identification For Electrical Systems" for identifying components and power and control wiring.
2. Label each dimmer module with a unique designation.
3. Label each scene control button with approved scene description.

C. Field Quality Control
1. Perform tests and inspections and prepare test reports.
   a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
2. Tests and Inspections:
   a. Continuity tests of circuits.
   b. Operational Test: Set and operate controls to demonstrate their functions and capabilities in a methodical sequence that cues and reproduces actual operating functions.
      1) Include testing of dimming control equipment under conditions that simulate actual operational conditions. Record control settings, operations, cues, and functional observations.
   c. Emergency Power Transfer: Test listed functions.
3. Remove and replace malfunctioning dimming control components and retest as specified above.
4. Test Labeling: After satisfactory completion of tests and inspections, apply a label to tested components indicating test results, date, and responsible agency and representative.
5. Reports: Written reports of tests and observations. Record defective materials and workmanship and unsatisfactory test results. Record repairs and adjustments.

D. Demonstration

1. Engage a factory-authorized service representative to train **OR** Train, **as directed**, the Owner's maintenance personnel to adjust, operate, and maintain central dimming controls. Laptop portable computer shall be used in training, **as directed**.
2. Coordinate demonstration of products specified in this Section with demonstration requirements for low-voltage, programmable lighting control system specified in Division 26 Section "Network Lighting Controls".

END OF SECTION 26 09 23 00d

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SECTION 26 09 23 00e - MODULAR DIMMING CONTROLS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for modular dimming controls. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following:
a. Manual modular dimming controls.
b. Integrated, multipreset modular dimming controls.

C. Definitions
1. Fade Rate: The time it takes each zone to arrive at the next scene, dependent on the degree of change in lighting level.
2. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling and power-limited circuits.
3. Scene: The lighting effect created by adjusting several zones of lighting to the desired intensity.
4. SCR: Silicon-controlled rectifier.
5. Zone: A fixture or group of fixtures controlled simultaneously as a single entity. Also known as a "channel."

D. Submittals
1. Product Data: For each type of product indicated.
a. For modular dimming controls; include elevation, dimensions, features, characteristics, ratings, and labels.
b. Device plates and plate color and material.
c. Ballasts and lamp combinations compatible with dimmers.
d. Wiring Diagrams: Power, signal, and control wiring.
2. Samples: For master and remote-control stations, and faceplates with factory-applied color finishes and technical features.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Comply with NFPA 70.

1.2 PRODUCTS

A. General Dimming Device Requirements
1. Compatibility: Dimming control components shall be compatible with other elements of lighting fixtures, ballasts, transformers, and lighting controls.
2. Dimmers and Dimmer Modules: Comply with UL 508.
a. Audible Noise and Radio-Frequency Interference Suppression: Solid-state dimmers shall operate smoothly over their operating ranges without audible lamp or dimmer noise or radio-frequency interference. Modules shall include integral or external filters to suppress audible noise and radio-frequency interference.
b. Dimmer or Dimmer-Module Rating: Not less than 125 percent of connected load unless otherwise indicated.

B. Manual Modular Multiscene Dimming Controls
1. Description: Factory-fabricated equipment providing manual modular dimming control consisting of a wall-box-mounted, master-scene controller and indicated number of wall-box zone stations. Controls and dimmers shall be integrated for mounting in one-, two-, or three-gang wall box under a single wall plate. Each zone station shall be adjustable to indicated number of scenes, which shall be recorded on the zone controller.
2. Operation: Automatically change variable dimmer settings of indicated number of zones simultaneously from one preset scene to another when a push button is operated.
3. Each manual modular multiscene dimming controller shall include a master control and remote controls.
4. Each zone shall be configurable to control the following:
   a. Fluorescent lamps with electronic **OR** magnetic, **as directed**, ballasts.
   b. Incandescent lamps.
   c. Low-voltage incandescent lamps.
5. Memory: Retain preset scenes through power failures for at least seven days.
6. Device Plates: Style, material, and color shall comply with Division 26 Section "Wiring Devices".
7. Master-Scene Controller: Suitable for mounting in a single flush wall box.
   a. Switches: Master off, group dim, group bright, and selectors for each scene.
   b. LED indicator lights, one associated with each scene switch, and one for the master off switch.
8. Fluorescent Zone Dimmer: Suitable for operating lighting fixtures and ballasts specified in Division 26 Section "Interior Lighting", and arranged to dim number of scenes indicated for the master-scene controller. Scene selection is at the master-scene controller for setting light levels of each zone associated with scene.
   a. Switch: Rocker **OR** Slider, **as directed**, style for setting the light level for each scene.
   b. LED indicator lights, one associated with each scene.
   c. Electrical Rating: 1000 **OR** 2000, **as directed**, VA, 120 V.
9. Incandescent Zone Dimmer: Suitable for operating incandescent lamps at line-voltage or low-voltage lamps connected to a transformer and arranged to dim number of scenes indicated for the master-scene controller. Scene selection shall be at the master-scene controller for setting light levels of each zone associated with scene.
   a. Switch: Rocker **OR** Slider, **as directed**, style for setting the light level for each scene.
   b. LED indicator lights, one associated with each scene.
   c. Voltage Regulation: Dimmer shall maintain a constant light level, with no visible flicker, when the source voltage varies plus or minus 2 percent in RMS voltage.

C. Integrated, Multipreset Modular Dimming Controls
1. Indicate number of wall-box, remote-control stations.
2. Description: Factory-fabricated, microprocessor-based, solid-state controls providing manual dimming control consisting of a master station and multiple wall-box, remote-control stations.
3. Operation: Automatically changes variable dimmer settings of indicated number of zones simultaneously from one preset scene to another when a push button is operated.
4. Each zone shall be configurable to control the following:
   a. Fluorescent lamps with electronic **OR** magnetic, **as directed**, ballasts.
   b. Incandescent lamps.
   c. Low-voltage incandescent lamps.
5. Memory: Retain preset scenes and fade settings through power failures by retaining physical settings of controls.
6. Master Station:
   a. Contains control panel and multiple control and dimmer modules.
   b. Controls and commands adjustment of each dimmer-zone setting for each scene change from one preset scene to another.
      1) Master zone raises and lowers lighting level.
      2) Adjustable fade rate for each scene from 1 to 60 seconds.
   c. Rear-illuminated, scene-select buttons.

d. Lighting-level setting and fade-rate setting shall be graphically shown using LEDs or backlighted bar-graph indicator.
e. Mounting: Flush wall box with manufacturer's standard faceplate.

7. Remote-Control Stations:
a. Numbered push buttons to select scenes.
b. Off switch to turn master station off. Operating the off switch at any remote station shall automatically turn on selected housekeeping lighting, **as directed**.
c. On switch turns all scenes of master station to full bright.
d. Control Wiring: NFPA 70, Class 2.
e. Mounting: Single flush wall box with manufacturer's standard faceplate.

8. Infrared Remote-Control Station: Same functions as for standard remote-control station, except that functions are input by a hand-held infrared transmitter.

9. Dimmers: Modular, plug-in type, with circuit breaker to protect the dimmer and branch circuit.
a. Dimming Circuit: Two SCR dimmers, in inverse parallel configuration.
b. Dimming Curve: Modified "square law" as specified in IESNA's "IESNA Lighting Handbook"; control voltage is 0- to 10-V dc.
c. Dimming Range: 0 to 100 percent, full output voltage not less than 98 percent of line voltage.
d. Voltage Regulation: Dimmer shall maintain a constant light level, with no visible flicker, when the source voltage varies plus or minus 2 percent in RMS voltage.
e. Short-Circuit Rating: 10 kA for 120 V, 14 kA for 277 V.

D. Conductors And Cables
1. Wiring to Supply Side of Remote-Control Power Sources: Not smaller than No. 12 AWG. Comply with requirements in Division 26 Section "Low-voltage Electrical Power Conductors And Cables".
2. Class 2 Control Cable: Multiconductor cable with stranded-copper conductors not smaller than No. 18 **OR** 22 **OR** 24, **as directed**, AWG. Comply with requirements in Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

1.3 EXECUTION

A. Wiring Installation
1. Comply with NECA 1.
2. Wiring Method: Comply with requirements in Division 26 Section "Low-voltage Electrical Power Conductors And Cables". Minimum conduit size shall be 1/2 inch (13 mm).
3. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points. Separate power-limited and nonpower-limited conductors according to conductor manufacturer's written instructions.
4. Size conductors according to lighting control device manufacturer's written instructions unless otherwise indicated.
5. Splices, Taps, and Terminations: Make connections only on numbered terminal strips in junction, pull, and outlet boxes; terminal cabinets; and equipment enclosures.

B. Identification
1. Comply with requirements in Division 26 Section "Identification For Electrical Systems" for identifying components and power and control wiring.
2. Label each dimmer module with a unique designation.
3. Label each scene control button with approved scene description.

C. Field Quality Control
1. Perform tests and inspections and prepare test reports.
a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

2. Tests and Inspections:
   a. Continuity tests of circuits.
   b. Operational Test: Set and operate controls to demonstrate their functions and capabilities in a methodical sequence that cues and reproduces actual operating functions.
      1) Include testing of modular dimming control equipment under conditions that simulate actual operational conditions. Record control settings, operations, cues, and functional observations.
3. Remove and replace malfunctioning modular dimming control components and retest as specified above.
4. Test Labeling: After satisfactory completion of tests and inspections, apply a label to tested components indicating test results, date, and responsible agency and representative.
5. Reports: Written reports of tests and observations. Record defective materials and workmanship and unsatisfactory test results. Record repairs and adjustments.

D. Demonstration
1. Engage a factory-authorized service representative to train **OR** Train, **as directed**, Owner's maintenance personnel to adjust, operate, and maintain modular dimming controls. Laptop portable computer shall be used in training, **as directed**.
2. Coordinate demonstration of products specified in this Section with demonstration requirements for low-voltage, programmable lighting control system specified in Division 26 Section "Network Lighting Controls".

END OF SECTION 26 09 23 00e

Task	Specification	Specification Description
26 21 13 00	26 05 13 00	Conductors And Cables
26 21 13 00	26 05 13 00a	Undercarpet Cables
26 21 13 00	26 05 13 00b	Medium-Voltage Cables

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SECTION 26 22 13 00 - MEDIUM-VOLTAGE TRANSFORMERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for medium-voltage transformers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following types of transformers with medium-voltage primaries:
   a. Liquid-filled distribution and power transformers.
   b. Dry-type distribution and power transformers.
   c. Pad-mounted, liquid-filled transformers.

C. Definitions
1. NETA ATS: Acceptance Testing Specification.

D. Submittals
1. Product Data: Include rated nameplate data, capacities, weights, dimensions, minimum clearances, installed devices and features, location of each field connection, and performance for each type and size of transformer indicated.
2. Shop Drawings: Diagram power signal and control wiring.
3. Manufacturer Seismic Qualification Certification: Submit certification that transformer assembly and components will withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".
4. Field quality-control test reports.
5. Follow-up service reports.
6. Operation and Maintenance Data: For transformer and accessories to include in emergency, operation, and maintenance manuals.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Comply with IEEE C2.
3. Comply with ANSI C57.12.10, ANSI C57.12.28, IEEE C57.12.70, and IEEE C57.12.80.
4. Comply with NFPA 70.

F. Delivery, Storage, And Handling
1. Store transformers protected from weather and so condensation will not form on or in units. Provide temporary heating according to manufacturer's written instructions.

G. Project Conditions
1. Service Conditions: IEEE C37.121, usual service conditions except for the following:
   a. Exposure to significant solar radiation.
   b. Altitudes above 3300 feet (1000 m).
   c. Exposure to fumes, vapors, or dust.
   d. Exposure to explosive environments.
   e. Exposure to hot and humid climate or to excessive moisture, including steam, salt spray, and dripping water.
   f. Exposure to seismic shock or to abnormal vibration, shock, or tilting.
   g. Exposure to excessively high or low temperatures.

h. Unusual transportation or storage conditions.
i. Unusual grounding-resistance conditions.
j. Unusual space limitations.

1.2 PRODUCTS

A. Liquid-Filled Distribution And Power Transformers
1. Description: IEEE C57.12.00 and UL 1062, liquid-filled, 2-winding transformers.
2. Insulating Liquid: Mineral oil, complying with ASTM D 3487, Type II, and tested according to ASTM D 117.
OR
Insulating Liquid: Less flammable, edible-seed-oil based, and UL listed as complying with NFPA 70 requirements for fire point of not less than 300 deg C when tested according to ASTM D 92. Liquid shall be biodegradable and nontoxic.
OR
Insulating Liquid: Less flammable, dielectric, and UL listed as complying with NFPA 70 requirements for fire point of not less than 300 deg C when tested according to ASTM D 92. Liquid shall be biodegradable and nontoxic.
OR
Insulating Liquid: Less flammable, silicone-based dielectric, and UL listed as complying with NFPA 70 requirements for fire point of not less than 300 deg C when tested according to ASTM D 92. Liquid shall have low toxicity and be nonhazardous.
3. Insulation Temperature Rise: 65/55 deg C, based on an average ambient temperature of 30 deg C over 24 hours with a maximum ambient temperature of 40 deg C. Insulation system shall be rated to continuously allow an additional 12 percent kilovolt-ampere output, at 65 deg C temperature rise, without decreasing rated transformer life.
OR
Insulation Temperature Rise: 65 deg C, based on an average ambient temperature of 30 deg C over 24 hours with a maximum ambient temperature of 40 deg C.
4. Basic Impulse Level: Comply with UL 1062.
OR
Basic Impulse Level: 60 **OR** 75 **OR** 95 **OR** 110, **as directed** kV.
5. Full-Capacity Voltage Taps: Four nominal 2.5 percent taps, 2 above and 2 below rated primary voltage; with externally operable tap changer for de-energized use and with position indicator and padlock hasp.
OR
Full-Capacity Voltage Taps: Four nominal 2.5 percent taps below rated primary voltage, with externally operable tap changer for de-energized use and with position indicator and padlock hasp.
6. Cooling System: Class OA, self-cooled **OR** OA/FA, self-cooled, and with forced-air-cooled rating **OR** OA/FFA, self-cooled, and with provisions for future forced-air-cooled rating, **as directed**. Cooling systems shall include auxiliary cooling equipment, automatic controls, and status indicating lights.
7. Sound level may not exceed sound levels listed in NEMA TR 1, without fans operating.
8. Accessories: Grounding pads, lifting lugs, and provisions for jacking under base. Transformers shall have a steel base and frame allowing use of pipe rollers in any direction, and an insulated, low-voltage, neutral bushing with removable ground strap. Include the following additional accessories:
a. Liquid-level gage.
b. Pressure-vacuum gage.
c. Liquid temperature indicator.
d. Drain and filter valves.
e. Pressure relief device.

B. Dry-Type Distribution And Power Transformers

1. Description: NEMA ST 20, IEEE C57.12.01, ANSI C57.12.50 for dry-type transformers rated up to 500 kVA, ANSI C57.12.51 for dry-type transformers rated 501 kVA and larger, or ANSI C57.12.52 for sealed dry-type transformers rated 501 kVA and larger, UL 1562 listed and labeled, dry-type, 2-winding transformers.
   a. Indoor, ventilated **OR** Outdoor, ventilated **OR** Totally enclosed, nonventilated, **as directed**, cast coil/encapsulated coil, with primary and secondary windings individually cast in epoxy; with insulation system rated at 185 deg C with an 80 deg C average winding temperature rise above a maximum ambient temperature of 40 deg C.
   b. Indoor, ventilated **OR** Outdoor, ventilated **OR** Totally enclosed, nonventilated, **as directed**, vacuum-pressure impregnated and with insulation system rated at 220 deg C with an 80 deg C average winding temperature rise above a maximum ambient temperature of 40 deg C.
2. Primary Connection: Air terminal compartment with removable **OR** hinged, **as directed,** door. Tin-plated copper bar for incoming line termination, predrilled to accept terminals for indicated conductors.
   OR
   Primary Connection: Transition terminal compartment with connection pattern to match switchgear.
3. Secondary Connection: Air terminal compartment with removable **OR** hinged, **as directed,** door. Tin-plated copper bar for incoming line termination, predrilled to accept terminals for indicated conductors.
   OR
   Secondary Connection: Transition terminal compartment with connection pattern to match switchgear **OR** bus duct, **as directed**.
4. Insulation Materials: IEEE C57.12.01, rated at 220 deg C.
5. Insulation Temperature Rise: 80 **OR** 115 **OR** 150, **as directed,** deg C, maximum rise above 40 deg C.
6. Basic Impulse Level: 60 **OR** 75 **OR** 95 **OR** 110, **as directed,** kV.
7. Full-Capacity Voltage Taps: Four nominal 2.5 percent taps, 2 above and 2 below rated primary voltage.
   OR
   Full-Capacity Voltage Taps: Four nominal 2.5 percent taps below rated primary voltage.
8. Cooling System: Class AA, self-cooled **OR** AA/FA, self-cooled, and with forced-air-cooled rating **OR** AA/FFA, self-cooled, and with provisions for future forced-air-cooled rating, **as directed**, complying with IEEE C57.12.01.
   a. Automatic forced-air cooling system controls, including thermal sensors, fans, control wiring, temperature controller with test switch, power panel with current-limiting fuses, indicating lights, alarm, and alarm silencing relay.
   b. Include mounting provision for fans.
9. Sound level may not exceed sound levels listed in NEMA TR 1, without fans operating.
10. High-Temperature Alarm: Sensor at transformer with local audible and visual alarm and contacts for remote alarm.

C. Pad-Mounted, Liquid-Filled Transformers

1. Description: ANSI C57.12.13, ANSI C57.12.26 for pad-mounted transformers with dead-front, separable, insulated, high-voltage, load-break cable connectors, IEEE C57.12.00 IEEE C57.12.22 for pad-mounted transformers with live-front high-voltage bushings pad-mounted, 2-winding transformers. Stainless-steel tank base and cabinet, **OR** cabinet, and sills, **as directed**.
2. Insulating Liquid: Mineral oil, complying with ASTM D 3487, Type II, and tested according to ASTM D 117.
   OR
   Insulating Liquid: Less flammable, edible-seed-oil based, and UL listed as complying with NFPA 70 requirements for fire point of not less than 300 deg C when tested according to ASTM D 92. Liquid shall be biodegradable and nontoxic.

OR

Insulating Liquid: Less flammable, dielectric, and UL listed as complying with NFPA 70 requirements for fire point of not less than 300 deg C when tested according to ASTM D 92. Liquid shall be biodegradable and nontoxic.

OR

Insulating Liquid: Less flammable, silicone-based dielectric, and UL listed as complying with NFPA 70 requirements for fire point of not less than 300 deg C when tested according to ASTM D 92. Liquid shall have low toxicity and be nonhazardous.

3. Insulation Temperature Rise: 55 **OR** 65, **as directed,** deg C when operated at rated kVA output in a 40 deg C ambient temperature. Transformer shall be rated to operate at rated kilovolt ampere in an average ambient temperature of 30 deg C over 24 hours with a maximum ambient temperature of 40 deg C without loss of service life expectancy.
4. Basic Impulse Level: 30 **OR** 60 **OR** 95, **as directed,** kV.
5. Full-Capacity Voltage Taps: Four 2.5 percent taps, 2 above and 2 below rated high voltage; with externally operable tap changer for de-energized use and with position indicator and padlock hasp.
6. High-Voltage Switch: 200 **OR** 300 **OR** 400, **as directed,** A, make-and-latch rating of 10-kA RMS, symmetrical, arranged for radial feed with 3-phase, 2-position, gang-operated, load-break switch that is oil immersed in transformer tank with hook-stick operating handle in primary compartment.

   OR

   High-Voltage Switch: 200 **OR** 300 **OR** 400, **as directed,** A, make-and-latch rating of 10-kA RMS, symmetrical, arranged for loop feed with 3-phase, 4-position, gang-operated, load-break switch that is oil immersed in transformer tank with hook-stick operating handle in primary compartment.
7. Primary Fuses: 150-kV fuse assembly with fuses complying with IEEE C37.47. Rating of current-limiting fuses shall be 50-kA RMS at specified system voltage.
   a. Current-limiting type in dry-fuse holder wells, mechanically interlocked with liquid-immersed switch in transformer tank to prevent disconnect under load.
   b. Internal liquid-immersed cartridge fuses.
   c. Bay-O-Net liquid-immersed fuses that are externally replaceable without opening transformer tank.
   d. Bay-O-Net liquid-immersed fuses in series with liquid-immersed current-limiting fuses. Bay-O-Net fuses shall be externally replaceable without opening transformer tank.
   e. Bay-O-Net liquid-immersed current-limiting fuses that are externally replaceable without opening transformer tank.
8. Surge Arresters: Distribution class, one for each primary phase; complying with IEEE C62.11 and NEMA LA 1; support from tank wall within high-voltage compartment. Transformers shall have three arresters for radial-feed **OR** three arresters for loop-feed **OR** six arresters for loop-feed, **as directed,** circuits.
9. High-Voltage Terminations and Equipment: Live front with externally clamped porcelain bushings and cable connectors suitable for terminating primary cable.

   OR

   High-Voltage Terminations and Equipment: Dead front with universal-type bushing wells for dead-front bushing-well inserts, complying with IEEE 386 and including the following:
   a. Bushing-Well Inserts: One for each high-voltage bushing well.
   b. Surge Arresters: Dead-front, elbow-type, metal-oxide-varistor units.
   c. Parking Stands: One for each high-voltage bushing well.
   d. Portable Insulated Bushings: Arranged for parking insulated, high-voltage, load-break cable terminators; one for each primary feeder conductor terminating at transformer.
10. Accessories:
   a. Drain Valve: 1 inch (25 mm), with sampling device.
   b. Dial-type thermometer.
   c. Liquid-level gage.
   d. Pressure-vacuum gage.
   e. Pressure Relief Device: Self-sealing with an indicator.
   f. Mounting provisions for low-voltage current transformers.

g. Mounting provisions for low-voltage potential transformers.
h. Busway terminal connection at low-voltage compartment.
i. Alarm contacts for gages and thermometer listed above.

D. Identification Devices
1. Nameplates: Engraved, laminated-plastic or metal nameplate for each transformer, mounted with corrosion-resistant screws. Nameplates and label products are specified in Division 26 Section "Identification For Electrical Systems".

E. Source Quality Control
1. Factory Tests: Perform design and routine tests according to standards specified for components. Conduct transformer tests according to ANSI C57.12.50 for ventilated dry-type distribution transformers 1 to 500 kVA, single phase, and 15 to 500 kVA, 3 phase, with high voltage 601 to 34,500 V and low voltage 208Y/120 to 4160 V; ANSI C57.12.51 for ventilated dry-type power transformers 501 kVA and larger, 3 phase, with high voltage 601 to 34,500 V and low voltage 208Y/120 to 4160 V; IEEE C57.12.90 for liquid-filled transformers; and IEEE C57.12.91 for dry-type distribution and power transformers.
2. Factory Tests: Perform the following factory-certified tests on each transformer:
a. Resistance measurements of all windings on rated-voltage connection and on tap extreme connections.
b. Ratios on rated-voltage connection and on tap extreme connections.
c. Polarity and phase relation on rated-voltage connection.
d. No-load loss at rated voltage on rated-voltage connection.
e. Excitation current at rated voltage on rated-voltage connection.
f. Impedance and load loss at rated current on rated-voltage connection and on tap extreme connections.
g. Applied potential.
h. Induced potential.
i. Temperature Test: If transformer is supplied with auxiliary cooling equipment to provide more than one rating, test at lowest kilovolt-ampere Class OA or Class AA rating and highest kilovolt-ampere Class OA/FA or Class AA/FA rating.
1) Temperature test is not required if record of temperature test on an essentially duplicate unit is available.

1.3 EXECUTION

A. Installation
1. Install transformers on concrete bases.
a. Anchor transformers to concrete bases according to manufacturer's written instructions, seismic codes at Project, and requirements in Division 26 Section "Hangers And Supports For Electrical Systems".
b. Construct concrete bases of dimensions indicated, but not less than 4 inches (100 mm) larger in both directions than supported unit and 4 inches (100 mm) high.
c. Use 3000-psi (20.7-MPa), 28-day compressive-strength concrete and reinforcement as specified in Division 03 Section "Cast-in-place Concrete".
d. Install dowel rods to connect concrete bases to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around full perimeter of base.
e. Install epoxy-coated anchor bolts, for supported equipment, that extend through concrete base and anchor into structural concrete floor.
f. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
g. Tack-weld or bolt transformers to channel-iron sills embedded in concrete bases. Install sills level and grout flush with floor or base.

2. Maintain minimum clearances and workspace at equipment according to manufacturer's written instructions and NFPA 70.

B. Identification
1. Identify field-installed wiring and components and provide warning signs as specified in Division 26 Section "Identification For Electrical Systems", **as directed.**

C. Connections
1. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
2. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

D. Field Quality Control
1. Perform the following field tests and inspections and prepare test reports:
   a. After installing transformers but before primary is energized, verify that grounding system at substation is tested at specified value or less.
   b. After installing transformers and after electrical circuitry has been energized, test for compliance with requirements.
   c. Perform visual and mechanical inspection and electrical test stated in NETA ATS. Certify compliance with test parameters.
   d. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
2. Remove and replace malfunctioning units and retest as specified above.
3. Test Reports: Prepare written reports to record the following:
   a. Test procedures used.
   b. Test results that comply with requirements.
   c. Test results that do not comply with requirements and corrective actions taken to achieve compliance with requirements.

E. Follow-Up Service
1. Voltage Monitoring and Adjusting: If requested by the Owner, perform the following voltage monitoring after Final Completion but not more than six months after Final Acceptance:
   a. During a period of normal load cycles as evaluated by the Owner, perform seven days of three-phase voltage recording at secondary terminals of each transformer. Use voltmeters with calibration traceable to National Institute of Science and Technology standards and with a chart speed of not less than 1 inch (25 mm) per hour. Voltage unbalance greater than 1 percent between phases, or deviation of any phase voltage from nominal value by more than plus or minus 5 percent during test period, is unacceptable.
   b. Corrective Actions: If test results are unacceptable, perform the following corrective actions, as appropriate:
      1) Adjust transformer taps.
      2) Prepare written request for voltage adjustment by electric utility.
   c. Retests: After corrective actions have been performed, repeat monitoring until satisfactory results are obtained.
   d. Report: Prepare written report covering monitoring and corrective actions performed.
2. Infrared Scanning: Perform as specified in Division 26 Section "Medium-voltage Switchgear".

END OF SECTION 26 22 13 00

SECTION 26 22 13 00a - LOW-VOLTAGE TRANSFORMERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for low-voltage transformers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following types of dry-type transformers rated 600 V and less, with capacities up to 1000 kVA:
   a. Distribution transformers.
   b. Buck-boost transformers.

C. Submittals
1. Product Data: For each product indicated.
2. Shop Drawings: Indicate dimensions and weights.
   a. Wiring Diagrams: Power, signal, and control wiring.
3. Manufacturer Seismic Qualification Certification: Submit certification that transformers, accessories, and components will withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".
4. Field quality-control test reports.
5. Operation and maintenance data.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Comply with IEEE C57.12.91, "Test Code for Dry-Type Distribution and Power Transformers."

E. Delivery, Storage, And Handling
1. Temporary Heating: Apply temporary heat according to manufacturer's written instructions within the enclosure of each ventilated-type unit, throughout periods during which equipment is not energized and when transformer is not in a space that is continuously under normal control of temperature and humidity.

1.2 PRODUCTS

A. General Transformer Requirements
1. Description: Factory-assembled and -tested, air-cooled units for 60-Hz service.
2. Cores: Grain-oriented, non-aging silicon steel.
3. Coils: Continuous windings without splices except for taps.
   a. Internal Coil Connections: Brazed or pressure type.
   b. Coil Material: Aluminum **OR** Copper, **as directed**.

B. Distribution Transformers
1. Comply with NEMA ST 20, and list and label as complying with UL 1561.
2. Provide transformers that are constructed to withstand seismic forces specified in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".
3. Cores: One leg per phase.
4. Enclosure: Ventilated **OR** Totally enclosed, nonventilated, **as directed**, NEMA 250, Type 2.

a. Core and coil shall be encapsulated within resin compound, sealing out moisture and air.

5. Enclosure: Ventilated **OR** Totally enclosed, nonventilated, **as directed**, NEMA 250, Type 3R **OR** Type 4X, stainless steel, **as directed**.
   a. Core and coil shall be encapsulated within resin compound, sealing out moisture and air.
6. Transformer Enclosure Finish: Comply with NEMA 250.
   a. Finish Color: Gray **OR** ANSI 49 gray **OR** ANSI 61 gray, **as directed**.
7. Taps for Transformers Smaller Than 3 kVA: None **OR** One 5 percent tap above normal full capacity, **as directed**.
8. Taps for Transformers 7.5 to 24 kVA: One 5 percent tap above and one 5 percent tap below normal full capacity **OR** Two 5 percent taps below rated voltage, **as directed**.
9. Taps for Transformers 25 kVA and Larger: Two 2.5 percent taps above and two 2.5 percent taps below normal full capacity **OR** Two 2.5 percent taps above and four 2.5 percent taps below normal full capacity, **as directed**.
10. Insulation Class: 220 deg C, UL-component-recognized insulation system with a maximum of 150 **OR** 115 **OR** 80, **as directed**, deg C rise above 40 deg C ambient temperature.
11. Energy Efficiency for Transformers Rated 15 kVA and Larger:
    a. Complying with NEMA TP 1, Class 1 efficiency levels.
    b. Tested according to NEMA TP 2.
12. K-Factor Rating: Transformers indicated to be K-factor rated shall comply with UL 1561 requirements for nonsinusoidal load current-handling capability to the degree defined by designated K-factor.
    a. Unit shall not overheat when carrying full-load current with harmonic distortion corresponding to designated K-factor.
    b. Indicate value of K-factor on transformer nameplate.
13. Electrostatic Shielding: Each winding shall have an independent, single, full-width copper electrostatic shield arranged to minimize interwinding capacitance.
14. Wall Brackets: Manufacturer's standard brackets.
15. Fungus Proofing: Permanent fungicidal treatment for coil and core.
16. Low-Sound-Level Requirements: Minimum of 3 dBA less than NEMA ST 20 standard sound levels when factory tested according to IEEE C57.12.91.

C. Buck-Boost Transformers
1. Description: Self-cooled, two-winding dry type, rated for continuous duty and with wiring terminals suitable for connection as autotransformer. Transformers shall comply with NEMA ST 1 and shall be listed and labeled as complying with UL 506 or UL 1561.
2. Enclosure: Ventilated, NEMA 250, Type 2.
   a. Finish Color: Gray **OR** ANSI 49 gray **OR** ANSI 61 gray, **as directed**.

D. Identification Devices
1. Nameplates: Engraved, laminated-plastic or metal nameplate. Nameplates are specified in Division 26 Section "Identification For Electrical Systems".

1.3 EXECUTION

A. Installation
1. Install wall-mounting transformers level and plumb with wall brackets fabricated by transformer manufacturer.
   a. Brace wall-mounting transformers as specified in Division 26 Section "Hangers And Supports For Electrical Systems".
2. Construct concrete bases and anchor floor-mounting transformers according to manufacturer's written instructions, seismic codes applicable to Project, **as directed**, and requirements in Division 26 Section "Hangers And Supports For Electrical Systems".

B. Field Quality Control

1. Perform tests and inspections.
2. Tests and Inspections:
   a. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
   b. Infrared Scanning: Two months after Final Completion, perform an infrared scan of transformer connections.
      1) Use an infrared-scanning device designed to measure temperature or detect significant deviations from normal values. Provide documentation of device calibration.
      2) Perform 2 follow-up infrared scans of transformers, one at 4 months and the other at 11 months after Final Completion.
      3) Prepare a certified report identifying transformer checked and describing results of scanning. Include notation of deficiencies detected, remedial action taken, and scanning observations after remedial action.

C. Adjusting
1. Adjust transformer taps to provide optimum voltage conditions at secondary terminals. Optimum is defined as not exceeding nameplate voltage plus 10 percent and not being lower than nameplate voltage minus 3 percent at maximum load conditions. Submit recording and tap settings as test results.
2. Connect buck-boost transformers to provide nameplate voltage of equipment being served, plus or minus 5 percent, at secondary terminals.
3. Output Settings Report: Prepare a written report recording output voltages and tap settings.

D. Cleaning
1. Vacuum dirt and debris; do not use compressed air to assist in cleaning.

END OF SECTION 26 22 13 00a

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SECTION 26 24 13 00 - ELECTRICITY METERING

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for electricity metering. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section includes equipment for electricity metering by utility company and electricity metering by the Owner.

C. Definitions
1. KY Pulse: Term used by the metering industry to describe a method of measuring consumption of electricity that is based on a relay opening and closing in response to the rotation of the disk in the meter.
2. PC: Personal computer.

D. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings: For electricity-metering equipment.
   a. Wiring Diagrams: For power, signal, and control wiring. Identify terminals and wiring designations and color-codes to facilitate installation, operation, and maintenance. Indicate recommended types, wire sizes, and circuiting arrangements for field-installed wiring, and show circuit protection features.
3. Field quality-control reports.
4. Operation and Maintenance Data. Include the following:
   a. Application and operating software documentation.
   b. Software licenses.
   c. Software service agreement.
   d. Hard copies of manufacturer's operating specifications, design user's guides for software and hardware, and PDF files on CD-ROM of the hard-copy Submittal.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

F. Delivery, Storage, And Handling
1. Receive, store, and handle modular meter center according to NECA 400.

G. Project Conditions
1. Interruption of Existing Electrical Service: Do not interrupt electrical service to facilities occupied by the Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:
   a. Notify the Owner no fewer than two days in advance of proposed interruption of electrical service.
   b. Do not proceed with interruption of electrical service without the Owner's written permission.

H. Coordination
1. Electrical Service Connections: Coordinate with utility companies and components they furnish as follows:

a. Comply with requirements of utilities providing electrical power services.
b. Coordinate installation and connection of utilities and services, including provision for electricity-metering components.

I. Software Service Agreement (May Not Be Allowed For Publicly Funded Projects)
1. Technical Support: Beginning with Final Completion, provide software support for two years.
2. Upgrade Service: Update software to latest version at Project completion. Install and program software upgrades that become available within two years from date of Final Completion. Upgrading software shall include operating system. Upgrade shall include new or revised licenses for use of software.
a. Provide 30 days' notice to the Owner to allow scheduling and access to system and to allow the Owner to upgrade its computer equipment if necessary.

1.2 PRODUCTS

A. Equipment For Electricity Metering By Utility Company
1. Meters will be furnished by utility company.
2. Current-Transformer Cabinets: Comply with requirements of electrical-power utility company.
3. Meter Sockets: Comply with requirements of electrical-power utility company.
OR
Meter Sockets: Steady-state and short-circuit current ratings shall meet indicated circuit ratings.
4. Modular Meter Center: Factory-coordinated assembly of a main service terminal box with lugs only **OR** disconnect device, **as directed**, wireways, tenant meter socket modules, and tenant feeder circuit breakers arranged in adjacent vertical sections. Assembly shall be complete with interconnecting buses and other features as specified below.
a. Comply with requirements of utility company for meter center.
b. Housing: NEMA 250, Type 1 **OR** Type 3R, **as directed**, enclosure.
c. Minimum Short-Circuit Rating: 22,000 **OR** 42,000 **OR** 65,000 **OR** 100,000, **as directed**, A symmetrical at rated voltage.
d. Main Disconnect Device: Circuit breaker, series-combination rated for use with downstream feeder and branch circuit breakers.
OR
Main Disconnect Device: Fusible switch, series-combination rated by circuit-breaker manufacturer to protect downstream feeder and branch circuit breakers.
e. Tenant Feeder Circuit Breakers: Series-combination-rated molded-case units, rated to protect circuit breakers in downstream tenant and to house loadcenters and panelboards that have 10,000-A interrupting capacity.
1) Identification: Complying with requirements in Division 26 Section "Identification For Electrical Systems" with legend identifying tenant's address.
2) Physical Protection: Tamper resistant, with hasp for padlock.
f. Meter Socket: Rating coordinated with indicated tenant feeder circuit rating.
g. Surge Protection: For main disconnect device, comply with requirements in Division 26 Section "Transient-voltage Suppression For Low-voltage Electrical Power Circuits".

B. Equipment For Electricity Metering By the Owner
1. General Requirements for the Owner's Meters:
a. Comply with UL 1244.
b. Meters used for billing shall have an accuracy of 0.2 **OR** 0.5 **OR** 1.0, **as directed**, percent of reading, complying with requirements in ANSI C12.20.
c. Meters shall be certified by California Type Evaluation Program, **as directed**, as complying with Title 4, California Code of Regulations, Article 2.2, **as directed**.
d. Enclosure: NEMA 250, Type 1 **OR** Type 3R, **as directed**, minimum, with hasp for padlocking or sealing.

e. Identification: Comply with requirements in Division 26 Section "Identification For Electrical Systems".
f. Memory Backup: Self-contained to maintain memory throughout power outages of 72 hours, minimum.
g. Sensors: Current-sensing type, with current or voltage output, selected for optimum range and accuracy for meters indicated for this application.
1) Type: Split **OR** Split and solid, **as directed**, core.
h. Current-Transformer Cabinet: Listed or recommended by metering equipment manufacturer for use with sensors indicated.
i. Building Automation System (BAS) Interface: One digital KY pulse to a user-definable increment of energy measurement. Match signal to BAS input and arrange to convey the instantaneous, integrated, demand level measured by meter to provide data for processing and possible programmed demand control action by destination system.

2. Kilowatt-hour Meter: Electronic single **OR** three **OR** single- and three, **as directed**,-phase meters, measuring electricity used.
a. Voltage and Phase Configuration: Meter shall be designed for use on circuits with voltage rating and phase configuration indicated for its application.
b. Display: LCD with characters not less than 0.25 inch (6 mm) high, indicating accumulative kilowatt-hours and current kilowatt load. Retain accumulated kilowatt-hour in a nonvolatile memory, until reset.
OR
Display: Digital electromechanical counter, indicating accumulative kilowatt-hours.

3. Kilowatt-hour/Demand Meter: Electronic single **OR** three **OR** single- and three, **as directed**,-phase meters, measuring electricity use and demand. Demand shall be integrated over a 15-minute interval.
a. Voltage and Phase Configuration: Meter shall be designed for use on circuits with voltage rating and phase configuration indicated for its application.
b. Display: LCD with characters not less than 0.25 inch (6 mm) high, indicating accumulative kilowatt-hours, current time and date, current demand, and historic peak demand, and time and date of historic peak demand. Retain accumulated kilowatt-hour and historic peak demand in a nonvolatile memory, until reset.

4. Data Transmission Cable: Transmit KY pulse data over Class 1 control-circuit conductors in raceway. Comply with Division 26 Section "Control-voltage Electrical Power Cables".

5. Software: PC based, a product of meter manufacturer, suitable for calculation of utility cost allocation and billing, **as directed**.
a. Utility Cost Allocation: Automatically import energy-usage records to allocate energy costs for the following:
1) At least 15 departments.
2) At least 30 tenants.
3) At least five processes.
4) At least five buildings.
b. Tenant or Activity Billing Software: Automatically import energy-usage records to automatically compute and prepare tenant bills **OR** activity demand and energy-use statements, **as directed**, based on metering of energy use and peak demand, **as directed**. Maintain separate directory for each tenant's historical billing information. Prepare summary reports in user-defined formats and time intervals.

1.3 EXECUTION

A. Installation
1. Comply with equipment installation requirements in NECA 1.
2. Install meters furnished by utility company. Install raceways and equipment according to utility company's written requirements. Provide empty conduits for metering leads and extend grounding connections as required by utility company.
3. Install modular meter center according to NECA 400 switchboard installation requirements.

B. Identification
   1. Comply with requirements for identification specified in Division 26 Section "Identification For Electrical Systems".
      a. Series Combination Warning Label: Self-adhesive type, with text as required by NFPA 70.
      b. Equipment Identification Labels: Adhesive film labels with clear protective overlay. For residential meters, provide an additional card holder suitable for printed, weather-resistant card **OR** typewritten card, **as directed**, with occupant's name.

C. Field Quality Control
   1. Perform tests and inspections.
      a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
   2. Tests and Inspections:
      a. Connect a load of known kilowatt rating, 1.5 kW minimum, to a circuit supplied by metered feeder.
      b. Turn off circuits supplied by metered feeder and secure them in off condition.
      c. Run test load continuously for eight hours minimum, or longer, to obtain a measurable meter indication. Use test-load placement and setting that ensures continuous, safe operation.
      d. Check and record meter reading at end of test period and compare with actual electricity used, based on test-load rating, duration of test, and sample measurements of supply voltage at test-load connection. Record test results.
   3. Electricity metering will be considered defective if it does not pass tests and inspections.
   4. Prepare test and inspection reports.

END OF SECTION 26 24 13 00

SECTION 26 24 13 00a - ENCLOSED SWITCHES AND CIRCUIT BREAKERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for enclosed switches and circuit breakers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Fusible switches.
b. Nonfusible switches.
c. Receptacle switches.
d. Shunt trip switches.
e. Molded-case circuit breakers (MCCBs).
f. Molded-case switches.
g. Enclosures.

C. Definitions
1. NC: Normally closed.
2. NO: Normally open.
3. SPDT: Single pole, double throw.

D. Performance Requirements
1. Seismic Performance: Enclosed switches and circuit breakers shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event," **as directed**.

E. Submittals
1. Product Data: For each type of enclosed switch, circuit breaker, accessory, and component indicated.
2. Shop Drawings: For enclosed switches and circuit breakers. Include plans, elevations, sections, details, and attachments to other work.
a. Wiring Diagrams: For power, signal, and control wiring.
3. Seismic Qualification Certificates: For enclosed switches and circuit breakers, accessories, and components, from manufacturer.
4. Field quality-control reports.
5. Operation and maintenance data.

F. Quality Assurance
1. Testing Agency Qualifications: Member company of NETA or an NRTL.
a. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.
2. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
3. Comply with NFPA 70.

G. Project Conditions
1. Environmental Limitations: Rate equipment for continuous operation under the following conditions unless otherwise indicated:

a. Ambient Temperature: Not less than minus 22 deg F (minus 30 deg C) and not exceeding 104 deg F (40 deg C).
b. Altitude: Not exceeding 6600 feet (2010 m).

2. Interruption of Existing Electric Service: Do not interrupt electric service to facilities occupied by the Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electric service according to requirements indicated:
   a. Notify the Owner no fewer than seven days in advance of proposed interruption of electric service.
   b. Indicate method of providing temporary electric service.
   c. Do not proceed with interruption of electric service without the Owner's written permission.
   d. Comply with NFPA 70E.

1.2 PRODUCTS

A. Fusible Switches
1. Type GD, General Duty, Single Throw, 240-V ac, 800 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, with cartridge **OR** plug, **as directed**, fuse interiors to accommodate specified **OR** indicated, **as directed**, fuses, lockable handle with capability to accept two padlocks, and interlocked with cover in closed position.
2. Type HD, Heavy Duty, Single Throw, 240 **OR** 600, **as directed**,-V ac, 1200 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, with clips or bolt pads to accommodate specified **OR** indicated, **as directed**, fuses, lockable handle with capability to accept three padlocks, and interlocked with cover in closed position.
3. Type HD, Heavy Duty, Six Pole, Single Throw, 240 **OR** 600, **as directed**,-V ac, 200 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, with clips or bolt pads to accommodate specified **OR** indicated, **as directed**, fuses, lockable handle with capability to accept three padlocks, and interlocked with cover in closed position.
4. Type HD, Heavy Duty, Double Throw, 240 **OR** 600, **as directed**,-V ac, 1200 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, with clips or bolt pads to accommodate specified **OR** indicated, **as directed**, fuses, lockable handle with capability to accept three padlocks, and interlocked with cover in closed position.
5. Accessories:
   a. Equipment Ground Kit: Internally mounted and labeled for copper and aluminum ground conductors.
   b. Neutral Kit: Internally mounted; insulated, capable of being grounded and bonded; labeled for copper and aluminum neutral conductors.
   c. Isolated Ground Kit: Internally mounted; insulated, capable of being grounded and bonded; labeled for copper and aluminum neutral conductors.
   d. Class R Fuse Kit: Provides rejection of other fuse types when Class R fuses are specified.
   e. Auxiliary Contact Kit: One **OR** Two, **as directed**, NO/NC (Form "C") auxiliary contact(s), arranged to activate before switch blades open.
   f. Hookstick Handle: Allows use of a hookstick to operate the handle.
   g. Lugs: Mechanical **OR** Compression, **as directed**, type, suitable for number, size, and conductor material.
   h. Service-Rated Switches: Labeled for use as service equipment.
   i. Accessory Control Power Voltage: Remote mounted and powered; 24-V ac **OR** 120-V ac **OR** 208-V ac **OR** 240-V ac **OR** 6-V dc **OR** 12-V dc **OR** 24-V dc, **as directed**.

B. Nonfusible Switches
1. Type GD, General Duty, Single Throw, 600 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, lockable handle with capability to accept two padlocks, and interlocked with cover in closed position.

2. Type HD, Heavy Duty, Single Throw, 240 **OR** 600, **as directed**,-V ac, 1200 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, lockable handle with capability to accept three padlocks, and interlocked with cover in closed position.
3. Type HD, Heavy Duty, Six Pole, Single Throw, 240 **OR** 600, **as directed**,-V ac, 200 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, lockable handle with capability to accept three padlocks, and interlocked with cover in closed position.
4. Type HD, Heavy Duty, Double Throw, 240 **OR** 600, **as directed**,-V ac, 1200 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, lockable handle with capability to accept three padlocks, and interlocked with cover in closed position.
5. Accessories:
   a. Equipment Ground Kit: Internally mounted and labeled for copper and aluminum ground conductors.
   b. Neutral Kit: Internally mounted; insulated, capable of being grounded and bonded; labeled for copper and aluminum neutral conductors.
   c. Isolated Ground Kit: Internally mounted; insulated, capable of being grounded and bonded; labeled for copper and aluminum neutral conductors.
   d. Auxiliary Contact Kit: One **OR** Two, **as directed**, NO/NC (Form "C") auxiliary contact(s), arranged to activate before switch blades open.
   e. Hookstick Handle: Allows use of a hookstick to operate the handle.
   f. Lugs: Mechanical **OR** Compression, **as directed**, type, suitable for number, size, and conductor material.
   g. Accessory Control Power Voltage: Remote mounted and powered; 24-V ac **OR** 120-V ac **OR** 208-V ac **OR** 240-V ac **OR** 6-V dc **OR** 12-V dc **OR** 24-V dc, **as directed**.

C. Receptacle Switches
1. Type HD, Heavy-Duty, Single-Throw Fusible Switch: 240 **OR** 600, **as directed**,-V ac, 30 **OR** 60 **OR** 100, **as directed**, A; UL 98 and NEMA KS 1; horsepower rated, with clips or bolt pads to accommodate specified **OR** indicated, **as directed**, fuses; lockable handle with capability to accept three padlocks; interlocked with cover in closed position.
2. Type HD, Heavy-Duty, Single-Throw Nonfusible Switch: 240 **OR** 600, **as directed**,-V ac, 30 **OR** 60 **OR** 100, **as directed**, A; UL 98 and NEMA KS 1; horsepower rated, lockable handle with capability to accept three padlocks; interlocked with cover in closed position.
3. Interlocking Linkage: Provided between the receptacle and switch mechanism to prevent inserting or removing plug while switch is in the on position, inserting any plug other than specified, and turning switch on if an incorrect plug is inserted or correct plug has not been fully inserted into the receptacle.
4. Receptacle: Polarized, three-phase, four-wire receptacle (fourth wire connected to enclosure ground lug).

D. Shunt Trip Switches
1. General Requirements: Comply with ASME A17.1, **as directed**, UL 50, and UL 98, with 200-kA interrupting and short-circuit current rating when fitted with Class J fuses.
2. Switches: Three-pole, horsepower rated, with integral shunt trip mechanism and Class J fuse block; lockable handle with capability to accept three padlocks; interlocked with cover in closed position.
3. Control Circuit: 120-V ac; obtained from integral control power transformer, with primary and secondary fuses, with a control power transformer **OR** source, **as directed**, of enough capacity to operate shunt trip, connected pilot, and indicating and control devices.
4. Accessories:
   a. Oiltight key switch for key-to-test function.
   b. Oiltight red **OR** green **OR** white **OR** yellow, **as directed**, ON pilot light.
   c. Isolated neutral lug; 100 **OR** 200, **as directed**, percent rating.
   d. Mechanically interlocked auxiliary contacts that change state when switch is opened and closed.
   e. Form C alarm contacts that change state when switch is tripped.

f. Three-pole, double-throw, fire-safety and alarm relay; 120-V ac **OR** 24-V dc, **as directed**, coil voltage.
g. Three-pole, double-throw, fire-alarm voltage monitoring relay complying with NFPA 72.

E. Molded-Case Circuit Breakers
1. General Requirements: Comply with UL 489, NEMA AB 1, and NEMA AB 3, with interrupting capacity to comply with available fault currents.
2. Thermal-Magnetic Circuit Breakers: Inverse time-current element for low-level overloads and instantaneous magnetic trip element for short circuits. Adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
3. Adjustable, Instantaneous-Trip Circuit Breakers: Magnetic trip element with front-mounted, field-adjustable trip setting.
4. Electronic Trip Circuit Breakers: Field-replaceable rating plug, rms sensing, with the following field-adjustable settings:
   a. Instantaneous trip.
   b. Long- and short-time pickup levels.
   c. Long- and short-time time adjustments.
   d. Ground-fault pickup level, time delay, and I^2t response.
5. Current-Limiting Circuit Breakers: Frame sizes 400 A and smaller, and let-through ratings less than NEMA FU 1, RK-5.
6. Integrally Fused Circuit Breakers: Thermal-magnetic trip element with integral limiter-style fuse listed for use with circuit breaker and trip activation on fuse opening or on opening of fuse compartment door.
7. Ground-Fault, Circuit-Interrupter (GFCI) Circuit Breakers: Single- and two-pole configurations with Class A ground-fault protection (6-mA trip).
8. Ground-Fault, Equipment-Protection (GFEP) Circuit Breakers: With Class B ground-fault protection (30-mA trip).
9. Features and Accessories:
   a. Standard frame sizes, trip ratings, and number of poles.
   b. Lugs: Mechanical **OR** Compression, **as directed**, type, suitable for number, size, trip ratings, and conductor material.
   c. Application Listing: Appropriate for application; Type SWD for switching fluorescent lighting loads; Type HID for feeding fluorescent and high-intensity discharge lighting circuits.
   d. Ground-Fault Protection: Comply with UL 1053; integrally mounted, self-powered **OR** remote-mounted and powered, **as directed**, type with mechanical ground-fault indicator; relay with adjustable pickup and time-delay settings, push-to-test feature, internal memory, and shunt trip unit; and three-phase, zero-sequence current transformer/sensor.
   e. Communication Capability: Circuit-breaker-mounted **OR** Universal-mounted **OR** Integral **OR** Din-rail-mounted, **as directed**, communication module with functions and features compatible with power monitoring and control system, specified in Division 26 Section "Electrical Power Monitoring And Control".
   f. Shunt Trip: Trip coil energized from separate circuit, with coil-clearing contact.
   g. Undervoltage Trip: Set to operate at 35 to 75 percent of rated voltage without intentional time delay.
   h. Auxiliary Contacts: One SPDT switch **OR** Two SPDT switches, **as directed**, with "a" and "b" contacts; "a" contacts mimic circuit-breaker contacts, "b" contacts operate in reverse of circuit-breaker contacts.
   i. Alarm Switch: One NO **OR** NC, **as directed**, contact that operates only when circuit breaker has tripped.
   j. Key Interlock Kit: Externally mounted to prohibit circuit-breaker operation; key shall be removable only when circuit breaker is in off position.
   k. Zone-Selective Interlocking: Integral with electronic **OR** ground-fault, **as directed**, trip unit; for interlocking ground-fault protection function.
   l. Electrical Operator: Provide remote control for on, off, and reset operations.

m. Accessory Control Power Voltage: Integrally mounted, self-powered **OR** Remote mounted and powered, **as directed**; 24-V ac **OR** 120-V ac **OR** 208-V ac **OR** 240-V ac **OR** 6-V dc **OR** 12-V dc **OR** 24-V dc, **as directed**.

F. Molded-Case Switches
1. General Requirements: MCCB with fixed, high-set instantaneous trip only, and short-circuit withstand rating equal to equivalent breaker frame size interrupting rating.
2. Features and Accessories:
a. Standard frame sizes and number of poles.
b. Lugs: Mechanical **OR** Compression, **as directed**, type, suitable for number, size, trip ratings, and conductor material.
c. Ground-Fault Protection: Comply with UL 1053; remote-mounted and powered type with mechanical ground-fault indicator; relay with adjustable pickup and time-delay settings, push-to-test feature, internal memory, and shunt trip unit; and three-phase, zero-sequence current transformer/sensor.
d. Shunt Trip: Trip coil energized from separate circuit, with coil-clearing contact.
e. Undervoltage Trip: Set to operate at 35 to 75 percent of rated voltage without intentional time delay.
f. Auxiliary Contacts: One SPDT switch **OR** Two SPDT switches, **as directed**, with "a" and "b" contacts; "a" contacts mimic switch contacts, "b" contacts operate in reverse of switch contacts.
g. Alarm Switch: One NO **OR** NC, **as directed**, contact that operates only when switch has tripped.
h. Key Interlock Kit: Externally mounted to prohibit switch operation; key shall be removable only when switch is in off position.
i. Zone-Selective Interlocking: Integral with ground-fault shunt trip unit; for interlocking ground-fault protection function.
j. Electrical Operator: Provide remote control for on, off, and reset operations.
k. Accessory Control Power Voltage: Integrally mounted, self-powered **OR** Remote mounted and powered, **as directed**; 24-V ac **OR** 120-V ac **OR** 208-V ac **OR** 240-V ac **OR** 6-V dc **OR** 12-V dc **OR** 24-V dc, **as directed**.

G. Enclosures
1. Enclosed Switches and Circuit Breakers: NEMA AB 1, NEMA KS 1, NEMA 250, and UL 50, to comply with environmental conditions at installed location.
a. Indoor, Dry and Clean Locations: NEMA 250, Type 1.
b. Outdoor Locations: NEMA 250, Type 3R.
c. Kitchen **OR** Wash-Down, **as directed**, Areas: NEMA 250, Type 4X, stainless steel.
d. Other Wet or Damp, Indoor Locations: NEMA 250, Type 4.
e. Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: NEMA 250, Type 12.
f. Hazardous Areas Indicated on Drawings: NEMA 250, Type 7 **OR** Type 9, **as directed**.

1.3 EXECUTION

A. Installation
1. Install individual wall-mounted switches and circuit breakers with tops at uniform height unless otherwise indicated.
2. Comply with mounting and anchoring requirements specified in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".
3. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.
4. Install fuses in fusible devices.
5. Comply with NECA 1.

B. Identification
   1. Comply with requirements in Division 26 Section "Identification For Electrical Systems".
      a. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
      b. Label each enclosure with engraved metal or laminated-plastic nameplate.

C. Field Quality Control
   1. Perform tests and inspections.
   2. Acceptance Testing Preparation:
      a. Test insulation resistance for each enclosed switch and circuit breaker, component, connecting supply, feeder, and control circuit.
      b. Test continuity of each circuit.
   3. Tests and Inspections:
      a. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
      b. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
      c. Perform the following infrared scan tests and inspections and prepare reports:
         1) Initial Infrared Scanning: After Final Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each enclosed switch and circuit breaker. Remove front panels so joints and connections are accessible to portable scanner.
         2) Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each enclosed switch and circuit breaker 11 months after date of Final Completion.
         3) Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
      d. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.
   4. Enclosed switches and circuit breakers will be considered defective if they do not pass tests and inspections.
   5. Prepare test and inspection reports, including a certified report that identifies enclosed switches and circuit breakers and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

D. Adjusting
   1. Adjust moving parts and operable components to function smoothly, and lubricate as recommended by manufacturer.
   2. Set field-adjustable circuit-breaker trip ranges as specified in Division 26 Section "Overcurrent Protective Device Coordination Study".

END OF SECTION 26 24 13 00a

SECTION 26 24 13 00b - SWITCHBOARDS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for switchboards. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Service and distribution switchboards rated 600 V and less.
b. Transient voltage suppression devices.
c. Disconnecting and overcurrent protective devices.
d. Instrumentation.
e. Control power.
f. Accessory components and features.
g. Identification.
h. Mimic bus.

C. Performance Requirements
1. Seismic Performance: Switchboards shall withstand the effects of earthquake motions determined according to SEI/ASCE 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

D. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings: For each switchboard and related equipment.
a. Include dimensioned plans, elevations, sections, and details, including required clearances and service space around equipment. Show tabulations of installed devices, equipment features, and ratings.
b. Detail enclosure types for types other than NEMA 250, Type 1.
c. Detail bus configuration, current, and voltage ratings.
d. Detail short-circuit current rating of switchboards and overcurrent protective devices.
e. Include descriptive documentation of optional barriers specified for electrical insulation and isolation.
f. Detail utility company's metering provisions with indication of approval by utility company.
g. Include evidence of NRTL listing for series rating of installed devices.
h. Detail features, characteristics, ratings, and factory settings of individual overcurrent protective devices and auxiliary components.
i. Include time-current coordination curves for each type and rating of overcurrent protective device included in switchboards. Submit on translucent log-log graft paper; include selectable ranges for each type of overcurrent protective device.
j. Include diagram and details of proposed mimic bus.
k. Include schematic and wiring diagrams for power, signal, and control wiring.
3. Samples: Representative portion of mimic bus with specified material and finish, for color selection.
4. Seismic Qualification Certificates: Submit certification that switchboards, overcurrent protective devices, accessories, and components will withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".
5. Field Quality-Control Reports.

6. Operation and maintenance data.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. Comply with NEMA PB 2.
3. Comply with NFPA 70.
4. Comply with UL 891.

F. Delivery, Storage, And Handling
1. Deliver switchboards in sections or lengths that can be moved past obstructions in delivery path.
2. Remove loose packing and flammable materials from inside switchboards and install temporary electric heating (250 W per section) **OR** connect factory-installed space heaters to temporary electrical service, **as directed**, to prevent condensation.
3. Handle and prepare switchboards for installation according to NECA 400 **OR** NEMA PB 2.1, **as directed**.

G. Project Conditions
1. Interruption of Existing Electric Service: Do not interrupt electric service to facilities occupied by the Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electric service according to requirements indicated:
   a. Notify the Owner no fewer than seven days in advance of proposed interruption of electric service.
   b. Indicate method of providing temporary electric service.
   c. Do not proceed with interruption of electric service without the Owner's written permission.
   d. Comply with NFPA 70E.

H. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace transient voltage suppression devices that fail in materials or workmanship within five years from date of Final Completion.

1.2 PRODUCTS

A. Manufactured Units
1. Front-Connected, Front-Accessible Switchboards:
   a. Main Devices: Panel **OR** Fixed, individually, **as directed**, mounted.
   b. Branch Devices: Panel mounted.
   c. Sections front and rear aligned.
2. Front- and Side-Accessible Switchboards:
   a. Main Devices: Fixed, individually mounted.
   b. Branch Devices: Panel mounted.
   c. Sections front and rear aligned.
3. Front- and Rear-Accessible Switchboards:
   a. Main Devices: Fixed, individually **OR** Drawout, **as directed**, mounted.
   b. Branch Devices: Panel **OR** Fixed, individually **OR** Panel and fixed, individually **OR** Fixed and individually compartmented **OR** Individually compartmented and drawout, **as directed**, mounted.
   c. Sections front and rear **OR** rear, **as directed**, aligned.
4. Nominal System Voltage: 480Y/277 V **OR** 208Y/120 V, **as directed**.
5. Main-Bus Continuous: 5000 **OR** 4000 **OR** 3000 **OR** 2500 **OR** 2000 **OR** 1600 **OR** 1200, **as directed**, A.

6. Seismic Requirements: Fabricate and test switchboards according to IEEE 344 to withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".
7. Indoor Enclosures: Steel, NEMA 250, Type 1 **OR** Type 5, **as directed**.
8. Enclosure Finish for Indoor Units: Factory-applied finish in manufacturer's standard gray **OR** custom color, **as directed**, finish over a rust-inhibiting primer on treated metal surface.
9. Outdoor Enclosures: Type 3R **OR** Type 3R, with interior-lighted walk-in aisle, **as directed**.
   a. Finish: Factory-applied finish in manufacturer's standard **OR** custom, **as directed**, color; undersurfaces treated with corrosion-resistant undercoating.
   b. Enclosure: Flat **OR** Downward, rearward sloping, **as directed**, roof; bolt-on rear covers **OR** rear hinged doors, **as directed**, for each section, with provisions for padlocking.
   c. Doors: Personnel door at each end of aisle, minimum width of 30 inches (762 mm); opening outwards; with panic hardware and provisions for padlocking **OR** cylinder lock, **as directed**.
   d. Accessories: Fluorescent lighting fixtures, ceiling mounted; wired to a three-way light switch at each end of aisle; ground-fault circuit interrupter (GFCI) duplex receptacle; emergency battery pack lighting fixture installed on wall of aisle midway between personnel doors.
   e. Walk-in Aisle Heating and Ventilating:
      1) Factory-installed electric unit heater(s), wall or ceiling mounted, with integral thermostat and disconnect and with capacities to maintain switchboard interior temperature of 40 deg F (5 deg C) with outside design temperature of 104 deg F (40 deg C).
      2) Factory-installed exhaust fan with capacities to maintain switchboard interior temperature of 100 deg F (38 deg C) with outside design temperature of 23 deg F (minus 5 deg C).
      3) Ventilating openings complete with replaceable fiberglass air filters.
      4) Thermostat: Single stage; wired to control heat and exhaust fan.
   f. Power for Space Heaters, Ventilation, Lighting, and Receptacle: Include a control-power transformer within the switchboard. Supply voltage shall be 120 **OR** 120/240 **OR** 120/208, **as directed**,-V ac.
   g. Power for space heaters, ventilation, lighting, and receptacle provided by a remote source.
10. Barriers: Between adjacent switchboard sections.
11. Insulation and isolation for main bus of main section, **as directed**, and main and vertical buses of feeder sections.
12. Cubical Space Heaters: Factory-installed electric space heaters of sufficient wattage in each vertical section to maintain enclosure temperature above expected dew point.
    a. Space-Heater Control: Thermostats to maintain temperature of each section above expected dew point **OR** Manual switching of branch-circuit protective device, **as directed**.
    b. Space-Heater Power Source: Transformer, factory installed in switchboard **OR** 120-V external branch circuit, **as directed**.
13. Utility Metering Compartment: Fabricated, barrier compartment and section complying with utility company's requirements; hinged sealed door; buses provisioned for mounting utility company's current transformers and potential transformers or potential taps as required by utility company. If separate vertical section is required for utility metering, match and align with basic switchboard. Provide service entrance label and necessary applicable service entrance features.
14. Customer Metering Compartment: A separate customer metering compartment and section with front hinged door, for indicated metering, and current transformers for each meter. Current transformer secondary wiring shall be terminated on shorting-type terminal blocks. Include potential transformers having primary and secondary fuses with disconnecting means and secondary wiring terminated on terminal blocks, **as directed**.
15. Bus Transition and Incoming Pull Sections: Matched and aligned with basic switchboard.
16. Removable, Hinged Rear Doors and Compartment Covers: Secured by captive thumb screws **OR** standard bolts, **as directed**, for access to rear interior of switchboard.
17. Hinged Front Panels: Allow access to circuit breaker, metering, accessory, and blank compartments.

18. Pull Box on Top of Switchboard:
    a. Adequate ventilation to maintain temperature in pull box within same limits as switchboard.
    b. Set back from front to clear circuit-breaker removal mechanism.
    c. Removable covers shall form top, front, and sides. Top covers at rear shall be easily removable for drilling and cutting.
    d. Bottom shall be insulating, fire-resistive material with separate holes for cable drops into switchboard.
    e. Cable supports shall be arranged to facilitate cabling and adequate to support cables indicated, including those for future installation.
19. Buses and Connections: Three phase, four wire unless otherwise indicated.
    a. Phase- and Neutral-Bus Material: One of the following:
        1) Hard-drawn copper of 98 percent conductivity, silver-plated, **as directed**, with tin-plated aluminum or copper feeder circuit-breaker line connections.
        2) Tin-plated, high-strength, electrical-grade aluminum alloy with tin-plated aluminum circuit-breaker line connections.
        3) Hard-drawn copper of 98 percent conductivity, silver-plated, **as directed**, or tin-plated, high-strength, electrical-grade aluminum alloy.
    b. Load Terminals: Insulated, rigidly braced, runback bus extensions, of same material as through buses, equipped with mechanical **OR** compression, **as directed**, connectors for outgoing circuit conductors. Provide load terminals for future circuit-breaker positions at full-ampere rating of circuit-breaker position.
    c. Ground Bus: 1/4-by-2-inch- (6-by-50-mm-) **OR** 1/4-by-1-inch- (6-by-25-mm-) **OR** Minimum-size required by UL 891, **as directed**, hard-drawn copper of 98 percent conductivity, equipped with mechanical **OR** compression, **as directed**, connectors for feeder and branch-circuit ground conductors. For busway feeders, extend insulated equipment grounding cable to busway ground connection and support cable at intervals in vertical run.
    d. Main Phase Buses and Equipment Ground Buses: Uniform capacity for entire length of switchboard's main and distribution sections. Provide for future extensions from both ends.
    e. Neutral Buses: 50 percent of the ampacity of phase buses unless otherwise indicated, equipped with mechanical **OR** compression, **as directed**, connectors for outgoing circuit neutral cables. Brace bus extensions for busway feeder neutral bus.
    f. Neutral Buses: 100 percent of the ampacity of phase buses unless otherwise indicated, equipped with mechanical **OR** compression, **as directed**, connectors for outgoing circuit neutral cables. Brace bus extensions for busway feeder neutral bus.
    g. Isolation Barrier Access Provisions: Permit checking of bus-bolt tightness.
20. Future Devices: Equip compartments with mounting brackets, supports, bus connections, and appurtenances at full rating of circuit-breaker compartment.
21. Bus-Bar Insulation: Factory-applied, flame-retardant, tape wrapping of individual bus bars or flame-retardant, spray-applied insulation. Minimum insulation temperature rating of 105 deg C.
22. Fungus Proofing: Permanent fungicidal treatment for overcurrent protective devices and other components including instruments and instrument transformers.

B. Transient Voltage Suppression Devices
1. Surge Protection Device Description: IEEE C62.41-compliant, integrally mounted, wired-in **OR** plug-in **OR** bolt-on, **as directed**, solid-state, parallel-connected, modular (with field-replaceable modules) **OR** non-modular, **as directed**, type, with sine-wave tracking suppression and filtering modules, UL 1449, second edition, short-circuit current rating matching or exceeding the switchboard short-circuit rating, and with the following features and accessories:
    a. Fuses, rated at 200-kA interrupting capacity.
    b. Fabrication using bolted compression lugs for internal wiring.
    c. Integral disconnect switch.
    d. Redundant suppression circuits.
    e. Redundant replaceable modules.
    f. Arrangement with wire connections to phase buses, neutral bus, and ground bus.

g. LED indicator lights for power and protection status.
h. Audible alarm, with silencing switch, to indicate when protection has failed.
i. Form-C contacts rated at 5 A and 250-V ac, one normally open and one normally closed, for remote monitoring of system operation. Contacts shall reverse position on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.
j. Four **OR** Six, **as directed**,-digit, transient-event counter set to totalize transient surges.

2. Peak Single-Impulse Surge Current Rating: 160 kA per mode/320 kA per phase **OR** 120 kA per mode/240 kA per phase **OR** 80 kA per mode/160 kA per phase, **as directed**.
3. Withstand Capabilities: 12,000 IEEE C62.41, Category C3 (10 kA), 8-by-20-mic.sec. surges with less than 5 percent change in clamping voltage.
4. Protection modes and UL 1449 SVR for grounded wye circuits with 480Y/277 **OR** 208Y/120 **OR** 600Y/347, **as directed**,-V, three-phase, four-wire circuits shall be as follows:
   a. Line to Neutral: 800 V for 480Y/277 **OR** 400 V for 208Y/120 **OR** 1200 V for 600Y/347, **as directed**.
   b. Line to Ground: 800 V for 480Y/277 **OR** 400 V for 208Y/120 **OR** 1200 V for 600Y/347, **as directed**.
   c. Neutral to Ground: 800 V for 480Y/277 **OR** 400 V for 208Y/120 **OR** 1200 V for 600Y/347, **as directed**.
5. Protection modes and UL 1449 SVR for 240/120-V, three-phase, four-wire circuits with high leg shall be as follows:
   a. Line to Neutral: 400 V, 800 V from high leg.
   b. Line to Ground: 400 V.
   c. Neutral to Ground: 400 V.
6. Protection modes and UL 1449 SVR for 240-, 480-, or 600-V, three-phase, three-wire, delta circuits shall be as follows:
   a. Line to Line: 2000 V for 480 V **OR** 1000 V for 240 V **OR** 2500 V for 600 V, **as directed**.
   b. Line to Ground: 1500 V for 480 V **OR** 800 V for 240 V **OR** 2500 V for 600 V, **as directed**.

C. Disconnecting And Overcurrent Protective Devices
1. Molded-Case Circuit Breaker (MCCB): Comply with UL 489, with series-connected rating **OR** interrupting capacity, **as directed**, to meet available fault currents.
   a. Thermal-Magnetic Circuit Breakers: Inverse time-current element for low-level overloads, and instantaneous magnetic trip element for short circuits. Adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
   b. Adjustable Instantaneous-Trip Circuit Breakers: Magnetic trip element with front-mounted, field-adjustable trip setting.
   c. Electronic trip circuit breakers with rms sensing; field-replaceable rating plug or field-replicable electronic trip; and the following field-adjustable settings:
      1) Instantaneous trip.
      2) Long- and short-time pickup levels.
      3) Long- and short-time time adjustments.
      4) Ground-fault pickup level, time delay, and I^2t response.
   d. Current-Limiting Circuit Breakers: Frame sizes 400 A and smaller; let-through ratings less than NEMA FU 1, RK-5.
   e. Integrally Fused Circuit Breakers: Thermal-magnetic trip element with integral limiter-style fuse listed for use with circuit breaker; trip activation on fuse opening or on opening of fuse compartment door.
   f. GFCI Circuit Breakers: Single- and two-pole configurations with Class A ground-fault protection (6-mA trip).
   g. Ground-Fault Equipment Protection (GFEP) Circuit Breakers: Class B ground-fault protection (30-mA trip).
   h. Molded-Case Circuit-Breaker (MCCB) Features and Accessories:
      1) Standard frame sizes, trip ratings, and number of poles.
      2) Lugs: Mechanical **OR** Compression, **as directed**, style, suitable for number, size, trip ratings, and conductor material.

3) Application Listing: Appropriate for application; Type SWD for switching fluorescent lighting loads; Type HID for feeding fluorescent and high-intensity discharge (HID) lighting circuits.
4) Ground-Fault Protection: Integrally mounted **OR** Remote-mounted, **as directed**, relay and trip unit with adjustable pickup and time-delay settings, push-to-test feature, and ground-fault indicator.
5) Zone-Selective Interlocking: Integral with electronic trip unit; for interlocking ground-fault protection function.
6) Communication Capability: Circuit-breaker-mounted **OR** Universal-mounted **OR** Integral **OR** Din-rail-mounted, **as directed**, communication module with functions and features compatible with power monitoring and control system specified in Division 26 Section "Electrical Power Monitoring And Control".
7) Shunt Trip: 120-V trip coil energized from separate circuit, set to trip at 55 **OR** 75, **as directed**, percent of rated voltage.
8) Undervoltage Trip: Set to operate at 35 to 75 percent of rated voltage without intentional time delay.
9) Auxiliary Contacts: One SPDT switch **OR** Two SPDT switches, **as directed**, with "a" and "b" contacts; "a" contacts mimic circuit-breaker contacts, "b" contacts operate in reverse of circuit-breaker contacts.
10) Key Interlock Kit: Externally mounted to prohibit circuit-breaker operation; key shall be removable only when circuit breaker is in off position.

2. Insulated-Case Circuit Breaker (ICCB): 80 **OR** 100, **as directed**, percent rated, sealed, insulated-case power circuit breaker with interrupting capacity rating to meet available fault current.
   a. Fixed **OR** Drawout, **as directed**, circuit-breaker mounting.
   b. Two-step, stored-energy closing.
   c. Standard **OR** Full, **as directed**,-function, microprocessor-based trip units with interchangeable rating plug, trip indicators, and the following field-adjustable settings:
      1) Instantaneous trip.
      2) Long- and short-time time adjustments.
      3) Ground-fault pickup level, time delay, and I^2t response.
   d. Zone-Selective Interlocking: Integral with electronic trip unit; for interlocking ground-fault protection function.
   e. Remote trip indication and control.
   f. Communication Capability: Integral communication module with functions and features compatible with power monitoring and control system specified in Division 26 Section "Electrical Power Monitoring And Control".
   g. Key Interlock Kit: Externally mounted to prohibit circuit-breaker operation; key shall be removable only when circuit breaker is in off position.
   h. Control Voltage: 40-V dc **OR** 125-V dc **OR** 250-V dc **OR** 120-V ac, **as directed**.
3. Bolted-Pressure Contact Switch: Operating mechanism uses rotary-mechanical-bolting action to produce and maintain high clamping pressure on the switch blade after it engages the stationary contacts.
   a. Main-Contact Interrupting Capability: Minimum of 12 times the switch current rating.
   b. Operating Mechanism: Manual handle operation to close switch; stores energy in mechanism for opening and closing.
      1) Electrical Trip: Operation of lever or push-button trip switch, or trip signal from ground-fault relay or remote-control device, causes switch to open.
      2) Mechanical Trip: Operation of mechanical lever, push button, or other device causes switch to open.
   c. Auxiliary Switches: Factory installed, single pole, double throw, with leads connected to terminal block, and including one set more than quantity required for functional performance indicated.
   d. Service-Rated Switches: Labeled for use as service equipment.

e. Ground-Fault Relay: Comply with UL 1053; self-powered type with mechanical ground-fault indicator, test function, tripping relay with internal memory, and three-phase current transformer/sensor.
   1) Configuration: Integrally mounted **OR** Remote-mounted, **as directed**, relay and trip unit with adjustable pickup and time-delay settings, push-to-test feature, and ground-fault indicator.
   2) Internal Memory: Integrates the cumulative value of intermittent arcing ground-fault currents and uses the effect to initiate tripping.
   3) No-Trip Relay Test: Permits ground-fault simulation test without tripping switch.
   4) Test Control: Simulates ground fault to test relay and switch (or relay only if "no-trip" mode is selected).
f. Open-Fuse Trip Device: Arranged to trip switch open if a phase fuse opens.

4. High-Pressure, Butt-Type Contact Switch: Operating mechanism uses butt-type contacts and a spring-charged mechanism to produce and maintain high-pressure contact when switch is closed.
   a. Main-Contact Interrupting Capability: Minimum of 12 times the switch current rating.
   b. Operating Mechanism: Manual handle operation to close switch; stores energy in mechanism for opening and closing.
      1) Electrical Trip: Operation of lever or push-button trip switch, or trip signal from ground-fault relay or remote-control device, causes switch to open.
      2) Mechanical Trip: Operation of mechanical lever, push button, or other device causes switch to open.
   c. Auxiliary Switches: Factory installed, single pole, double throw, with leads connected to terminal block, and including one set more than quantity required for functional performance indicated.
   d. Service-Rated Switches: Labeled for use as service equipment.
   e. Ground-Fault Relay: Comply with UL 1053; self-powered type with mechanical ground-fault indicator, test function, tripping relay with internal memory, and three-phase current transformer/sensor.
      1) Configuration: Integrally mounted **OR** Remote-mounted, **as directed**, relay and trip unit with adjustable pickup and time-delay settings, push-to-test feature, and ground-fault indicator.
      2) Internal Memory: Integrates the cumulative value of intermittent arcing ground-fault currents and uses the effect to initiate tripping.
      3) No-Trip Relay Test: Permits ground-fault simulation test without tripping switch.
      4) Test Control: Simulates ground fault to test relay and switch (or relay only if "no-trip" mode is selected).
   f. Open-Fuse Trip Device: Arranged to trip switch open if a phase fuse opens.
5. Fused Switch: NEMA KS 1, Type HD; clips to accommodate specified fuses; lockable handle.
6. Fuses are specified in Division 26 Section "Fuses".

D. Instrumentation
   1. Instrument Transformers: IEEE C57.13, NEMA EI 21.1, and the following:
      a. Potential Transformers: IEEE C57.13; 120 V, 60 Hz, single **OR** tapped **OR** double, **as directed**, secondary; disconnecting type with integral fuse mountings. Burden and accuracy shall be consistent with connected metering and relay devices.
      b. Current Transformers: IEEE C57.13; 5 A, 60 Hz, secondary; wound **OR** bushing **OR** bar or window, **as directed**, type; single **OR** double, **as directed**, secondary winding and secondary shorting device. Burden and accuracy shall be consistent with connected metering and relay devices.
      c. Control-Power Transformers: Dry type, mounted in separate compartments for units larger than 3 kVA.
      d. Current Transformers for Neutral and Ground-Fault Current Sensing: Connect secondary wiring to ground overcurrent relays, via shorting terminals, to provide selective tripping of main and tie circuit breaker. Coordinate with feeder circuit-breaker, ground-fault protection.

2. Multifunction Digital-Metering Monitor: Microprocessor-based unit suitable for three- or four-wire systems and with the following features:
   a. Switch-selectable digital display of the following values with maximum accuracy tolerances as indicated:
      1) Phase Currents, Each Phase: Plus or minus 1 percent.
      2) Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent.
      3) Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 percent.
      4) Megawatts: Plus or minus 2 percent.
      5) Megavars: Plus or minus 2 percent.
      6) Power Factor: Plus or minus 2 percent.
      7) Frequency: Plus or minus 0.5 percent.
      8) Accumulated Energy, Megawatt Hours: Plus or minus 2 percent; accumulated values unaffected by power outages up to 72 hours.
      9) Megawatt Demand: Plus or minus 2 percent; demand interval programmable from five to 60 minutes.
      10) Contact devices to operate remote impulse-totalizing demand meter.
   b. Mounting: Display and control unit flush or semiflush mounted in instrument compartment door.
3. Ammeters, Voltmeters, and Power-Factor Meters: ANSI C39.1.
   a. Meters: 4-inch (100-mm) diameter or 6 inches (150 mm) square, flush or semiflush, with antiparallax 250-degree scales and external zero adjustment.
   b. Voltmeters: Cover an expanded-scale range of nominal voltage plus 10 percent.
4. Instrument Switches: Rotary type with off position.
   a. Voltmeter Switches: Permit reading of all phase-to-phase voltages and, where a neutral is indicated, phase-to-neutral voltages.
   b. Ammeter Switches: Permit reading of current in each phase and maintain current-transformer secondaries in a closed-circuit condition at all times.
5. Feeder Ammeters: 2-1/2-inch (64-mm) minimum size with 90- or 120-degree scale. Meter and transfer device with off position, located on overcurrent device door for indicated feeder circuits only.
6. Watt-Hour Meters and Wattmeters:
   a. Comply with ANSI C12.1.
   b. Three-phase induction type with two stators, each with current and potential coil, rated 5 A, 120 V, 60 Hz.
   c. Suitable for connection to three- and four-wire circuits.
   d. Potential indicating lamps.
   e. Adjustments for light and full load, phase balance, and power factor.
   f. Four-dial clock register.
   g. Integral demand indicator.
   h. Contact devices to operate remote impulse-totalizing demand meter.
   i. Ratchets to prevent reverse rotation.
   j. Removable meter with drawout test plug.
   k. Semiflush mounted case with matching cover.
   l. Appropriate multiplier tag.
7. Impulse-Totalizing Demand Meter:
   a. Comply with ANSI C12.1.
   b. Suitable for use with switchboard watt-hour meter, including two-circuit totalizing relay.
   c. Cyclometer.
   d. Four-dial, totalizing kilowatt-hour register.
   e. Positive chart drive mechanism.
   f. Capillary pen holding a minimum of one month's ink supply.
   g. Roll chart with minimum 31-day capacity; appropriate multiplier tag.
   h. Capable of indicating and recording five **OR** 15 **OR** 30, **as directed**,-minute integrated demand of totalized system.

E. Control Power
1. Control Circuits: 120-V ac, supplied through secondary disconnecting devices from control-power transformer **OR** 120-V ac, supplied from remote branch circuit, **as directed**.
2. Electrically Interlocked Main and Tie Circuit Breakers: Two control-power transformers in separate compartments, with interlocking relays, connected to the primary side of each control-power transformer at the line side of the associated main circuit breaker. 120-V secondaries connected through automatic transfer relays to ensure a fail-safe automatic transfer scheme.
3. Control-Power Fuses: Primary and secondary fuses for current-limiting and overload protection of transformer and fuses for protection of control circuits.
4. Control Wiring: Factory installed, with bundling, lacing, and protection included. Provide flexible conductors for No. 8 AWG and smaller, for conductors across hinges, and for conductors for interconnections between shipping units.

F. Accessory Components And Features
1. Accessory Set: Include tools and miscellaneous items required for overcurrent protective device test, inspection, maintenance, and operation.
2. Portable Test Set: For testing functions of solid-state trip devices without removing from switchboard. Include relay and meter test plugs suitable for testing switchboard meters and switchboard class relays.
3. Portable Circuit-Breaker Lifting Device: Floor-supported, roller-based, elevating carriage arranged for movement of circuit breakers in and out of compartments for present and future circuit breakers.
4. Overhead Circuit-Breaker Lifting Device: Mounted at top front of switchboard, with hoist and lifting yokes matching each drawout circuit breaker.
5. Spare-Fuse Cabinet: Suitably identified, wall-mounted, lockable, compartmented steel box or cabinet. Arrange for wall mounting.

G. Identification
1. Mimic Bus: Entire single-line switchboard bus work, as depicted on factory record drawing, on a photoengraved nameplate.
   a. Nameplate: At least 0.032-inch- (0.813-mm-) thick anodized aluminum, located at eye level on front cover of the switchboard incoming service section.
2. Mimic Bus: Entire single-line switchboard bus work, as depicted on factory record drawing, on an engraved laminated-plastic (Gravoply) nameplate.
   a. Nameplate: At least 0.0625-inch- (1.588 mm-) thick laminated plastic (Gravoply), located at eye level on front cover of the switchboard incoming service section.
3. Mimic Bus: Continuously integrated mimic bus factory applied to front of switchboard. Arrange in single-line diagram format, using symbols and letter designations consistent with final mimic-bus diagram.
4. Coordinate mimic-bus segments with devices in switchboard sections to which they are applied. Produce a concise visual presentation of principal switchboard components and connections.
5. Presentation Media: Painted graphics in color contrasting with background color to represent bus and components, complete with lettered designations.
6. Service Equipment Label: NRTL labeled for use as service equipment for switchboards with one or more service disconnecting and overcurrent protective devices.

1.3 EXECUTION

A. Installation
1. Install switchboards and accessories according to NECA 400 **OR** NEMA PB 2.1, **as directed**.
2. Equipment Mounting: Install switchboards on concrete base, 4-inch (100-mm) nominal thickness. Comply with requirements for concrete base specified in Division 03 Section "Cast-in-place Concrete".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.

b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
d. Install anchor bolts to elevations required for proper attachment to switchboards.

3. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from switchboard units and components.
4. Comply with mounting and anchoring requirements specified in Division 26 Section "Hangers And Supports For Electrical Systems".
5. Operating Instructions: Frame and mount the printed basic operating instructions for switchboards, including control and key interlocking sequences and emergency procedures. Fabricate frame of finished wood or metal and cover instructions with clear acrylic plastic. Mount on front of switchboards.
6. Install filler plates in unused spaces of panel-mounted sections.
7. Install overcurrent protective devices, transient voltage suppression devices, and instrumentation.
   a. Set field-adjustable switches and circuit-breaker trip ranges.
8. Install spare-fuse cabinet.
9. Comply with NECA 1.

B. Connections
1. Comply with requirements for terminating feeder bus specified in Division 26 Section "Enclosed Bus Assemblies". Drawings indicate general arrangement of bus, fittings, and specialties.
2. Comply with requirements for terminating cable trays specified in Division 26 Section "Cable Trays For Electrical Systems". Drawings indicate general arrangement of cable trays, fittings, and specialties.

C. Identification
1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs complying with requirements for identification specified in Division 26 Section "Identification For Electrical Systems".
2. Switchboard Nameplates: Label each switchboard compartment with a nameplate complying with requirements for identification specified in Division 26 Section "Identification For Electrical Systems".
3. Device Nameplates: Label each disconnecting and overcurrent protective device and each meter and control device mounted in compartment doors with a nameplate complying with requirements for identification specified in Division 26 Section "Identification For Electrical Systems".

D. Field Quality Control
1. Acceptance Testing Preparation:
   a. Test insulation resistance for each switchboard bus, component, connecting supply, feeder, and control circuit.
   b. Test continuity of each circuit.
2. Tests and Inspections:
   a. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
   b. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
   c. Perform the following infrared scan tests and inspections and prepare reports:
      1) Initial Infrared Scanning: After Final Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each switchboard. Remove front **OR** front and rear, **as directed**, panels so joints and connections are accessible to portable scanner.
      2) Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each switchboard 11 months after date of Final Completion.
      3) Instruments and Equipment:

a) Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

d. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

3. Switchboard will be considered defective if it does not pass tests and inspections.
4. Prepare test and inspection reports, including a certified report that identifies switchboards included and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

E. Adjusting
1. Adjust moving parts and operable components to function smoothly, and lubricate as recommended by manufacturer.
2. Set field-adjustable circuit-breaker trip ranges as indicated **OR** as specified in Division 26 Section "Overcurrent Protective Device Coordination Study", **as directed**.

F. Protection
1. Temporary Heating: Apply temporary heat, to maintain temperature according to manufacturer's written instructions, until switchboard is ready to be energized and placed into service.

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SECTION 26 24 16 00 - PANELBOARDS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for panelboards. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Distribution panelboards.
b. Lighting and appliance branch-circuit panelboards.
c. Load centers.
d. Electronic-grade panelboards.

C. Definitions
1. SVR: Suppressed voltage rating.
2. TVSS: Transient voltage surge suppressor.

D. Performance Requirements
1. Seismic Performance: Panelboards shall withstand the effects of earthquake motions determined according to SEI/ASCE 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

E. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings: For each panelboard and related equipment.
a. Include dimensioned plans, elevations, sections, and details. Show tabulations of installed devices, equipment features, and ratings.
b. Detail enclosure types and details for types other than NEMA 250, Type 1.
c. Detail bus configuration, current, and voltage ratings.
d. Short-circuit current rating of panelboards and overcurrent protective devices.
e. Include evidence of NRTL listing for series rating of installed devices.
f. Detail features, characteristics, ratings, and factory settings of individual overcurrent protective devices and auxiliary components.
g. Include wiring diagrams for power, signal, and control wiring.
h. Include time-current coordination curves for each type and rating of overcurrent protective device included in panelboards. Submit on translucent log-log graft paper; include selectable ranges for each type of overcurrent protective device.
3. Seismic Qualification Certificates: Submit certification that panelboards, overcurrent protective devices, accessories, and components will withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".
4. Panelboard Schedules: For installation in panelboards.
5. Operation and maintenance data

F. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. Comply with NEMA PB 1.
3. Comply with NFPA 70.

G. Delivery, Storage, And Handling
1. Remove loose packing and flammable materials from inside panelboards; install temporary electric heating (250 W per panelboard) to prevent condensation.
2. Handle and prepare panelboards for installation according to NECA 407 **OR** NEMA PB 1.

H. Project Conditions
1. Interruption of Existing Electric Service: Do not interrupt electric service to facilities occupied by the Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electric service according to requirements indicated:
   a. Notify the Owner no fewer than two days in advance of proposed interruption of electric service.
   b. Do not proceed with interruption of electric service without the Owner's written permission.
   c. Comply with NFPA 70E.

I. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace transient voltage suppression devices that fail in materials or workmanship within five years from date of Final Completion.

1.2 PRODUCTS

A. General Requirements For Panelboards
1. Fabricate and test panelboards according to IEEE 344 to withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".
2. Enclosures: Flush **OR** Surface **OR** Flush- and surface, **as directed**,-mounted cabinets.
   a. Rated for environmental conditions at installed location.
      1) Indoor Dry and Clean Locations: NEMA 250, Type 1.
      2) Outdoor Locations: NEMA 250, Type 3R.
      3) Kitchen or Wash-Down Areas: NEMA 250, Type 4X, stainless steel.
      4) Other Wet or Damp Indoor Locations: NEMA 250, Type 4.
      5) Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: NEMA 250, Type 5 **OR** Type 12, **as directed**.
   b. Front: Secured to box with concealed trim clamps. For surface-mounted fronts, match box dimensions; for flush-mounted fronts, overlap box.
   c. Hinged Front Cover: Entire front trim hinged to box and with standard door within hinged trim cover.
   d. Skirt for Surface-Mounted Panelboards: Same gage and finish as panelboard front with flanges for attachment to panelboard, wall, and ceiling or floor.
   e. Gutter Extension and Barrier: Same gage and finish as panelboard enclosure; integral with enclosure body. Arrange to isolate individual panel sections.
   f. Finishes:
      1) Panels and Trim: Steel and galvanized steel, factory finished immediately after cleaning and pretreating with manufacturer's standard two-coat, baked-on finish consisting of prime coat and thermosetting topcoat.
      2) Back Boxes: Galvanized steel **OR** Same finish as panels and trim, **as directed**.
      3) Fungus Proofing: Permanent fungicidal treatment for overcurrent protective devices and other components.
   g. Directory Card: Inside panelboard door, mounted in transparent card holder **OR** metal frame with transparent protective cover, **as directed**.
3. Incoming Mains Location: Top **OR** Bottom **OR** Top and bottom, **as directed**.
4. Phase, Neutral, and Ground Buses:
   a. Material: Tin-plated aluminum **OR** Hard-drawn copper, 98 percent conductivity, **as directed**.

b. Equipment Ground Bus: Adequate for feeder and branch-circuit equipment grounding conductors; bonded to box.
c. Isolated Ground Bus: Adequate for branch-circuit isolated ground conductors; insulated from box.
d. Extra-Capacity Neutral Bus: Neutral bus rated 200 percent of phase bus and UL listed as suitable for nonlinear loads.
e. Split Bus: Vertical buses divided into individual vertical sections.

5. Conductor Connectors: Suitable for use with conductor material and sizes.
   a. Material: Tin-plated aluminum **OR** Hard-drawn copper, 98 percent conductivity, **as directed**.
   b. Main and Neutral Lugs: Compression **OR** Mechanical, **as directed**, type.
   c. Ground Lugs and Bus-Configured Terminators: Compression **OR** Mechanical, **as directed**, type.
   d. Feed-Through Lugs: Compression **OR** Mechanical, **as directed**, type, suitable for use with conductor material. Locate at opposite end of bus from incoming lugs or main device.
   e. Subfeed (Double) Lugs: Compression **OR** Mechanical, **as directed**, type suitable for use with conductor material. Locate at same end of bus as incoming lugs or main device.
   f. Gutter-Tap Lugs: Compression **OR** Mechanical, **as directed**, type suitable for use with conductor material. Locate at same end of bus as incoming lugs or main device.
   g. Extra-Capacity Neutral Lugs: Rated 200 percent of phase lugs mounted on extra-capacity neutral bus.
6. Service Equipment Label: NRTL labeled for use as service equipment for panelboards or load centers with one or more main service disconnecting and overcurrent protective devices.
7. Future Devices: Mounting brackets, bus connections, filler plates, and necessary appurtenances required for future installation of devices.
8. Panelboard Short-Circuit Current Rating: Rated for series-connected system with integral or remote upstream overcurrent protective devices and labeled by an NRTL. Include size and type of allowable upstream and branch devices, listed and labeled for series-connected short-circuit rating by an NRTL.
9. Panelboard Short-Circuit Current Rating: Fully rated to interrupt symmetrical short-circuit current available at terminals.

B. Distribution Panelboards
1. Panelboards: NEMA PB 1, power and feeder distribution type.
2. Doors: Secured with vault-type latch with tumbler lock; keyed alike.
   a. For doors more than 36 inches (914 mm) high, provide two latches, keyed alike.
3. Mains: Circuit breaker **OR** Fused switch **OR** Lugs only, **as directed**.
4. Branch Overcurrent Protective Devices for Circuit-Breaker Frame Sizes 125 A and Smaller: Plug-in **OR** Bolt-on, **as directed**, circuit breakers.
5. Branch Overcurrent Protective Devices for Circuit-Breaker Frame Sizes Larger Than 125 A: Bolt-on circuit breakers; plug-in circuit breakers where individual positive-locking device requires mechanical release for removal.
6. Branch Overcurrent Protective Devices: Fused switches.
7. Contactors in Main Bus: NEMA ICS 2, Class A, electrically **OR** mechanically, **as directed**, held, general-purpose controller, with same short-circuit interrupting rating as panelboard.
   a. Internal Control-Power Source: Control-power transformer, with fused primary and secondary terminals, connected to main bus ahead of contactor connection.
   b. External Control-Power Source: 120-V branch circuit **OR** 24-V control circuit, **as directed**.

C. Lighting And Appliance Branch-Circuit Panelboards
1. Panelboards: NEMA PB 1, lighting and appliance branch-circuit type.
2. Mains: Circuit breaker **OR** Lugs only, **as directed**.
3. Branch Overcurrent Protective Devices: Plug-in **OR** Bolt-on, **as directed**, circuit breakers, replaceable without disturbing adjacent units.
4. Contactors in Main Bus: NEMA ICS 2, Class A, electrically **OR** mechanically, **as directed**, held, general-purpose controller, with same short-circuit interrupting rating as panelboard.

a. Internal Control-Power Source: Control-power transformer, with fused primary and secondary terminals, connected to main bus ahead of contactor connection.
b. External Control-Power Source: 120-V branch circuit **OR** 24-V control circuit, **as directed**.

5. Doors: Concealed hinges; secured with flush latch with tumbler lock; keyed alike.
6. Column-Type Panelboards: Narrow gutter extension, with cover, to overhead junction box equipped with ground and neutral terminal buses.

D. Load Centers
1. Load Centers: Comply with UL 67.
2. Mains: Circuit breaker **OR** Lugs only, **as directed**.
3. Branch Overcurrent Protective Devices: Plug-in circuit breakers, replaceable without disturbing adjacent units.
4. Conductor Connectors: Mechanical type for main, neutral, and ground lugs and buses.

E. Electronic-Grade Panelboards
1. Panelboards: NEMA PB 1; with factory-installed, integral TVSS; labeled by an NRTL for compliance with UL 67 after installing TVSS.
2. Doors: Secured with vault-type latch with tumbler lock; keyed alike.
3. Main Overcurrent Protective Devices: Bolt-on thermal-magnetic circuit breakers.
4. Branch Overcurrent Protective Devices: Bolt-on thermal-magnetic circuit breakers.
5. Buses:
   a. Copper phase and neutral buses; 200 percent capacity neutral bus and lugs.
   b. Copper equipment and isolated ground buses.
6. Surge Protection Device: IEEE C62.41-compliant, integrally mounted, plug-in **OR** wired-in **OR** bolt-on, **as directed**, solid-state, parallel-connected, modular (with field-replaceable modules) **OR** non-modular, **as directed**, type, with sine-wave tracking suppression and filtering modules, short-circuit current rating complying with UL 1449, second edition, and matching or exceeding the panelboard short-circuit rating, redundant suppression circuits, with individually fused metal-oxide varistors.
   a. Accessories:
      1) Fuses rated at 200-kA interrupting capacity.
      2) Fabrication using bolted compression lugs for internal wiring.
      3) Integral disconnect switch.
      4) Redundant suppression circuits.
      5) Redundant replaceable modules.
      6) Arrangement with wire connections to phase buses, neutral bus, and ground bus.
      7) LED indicator lights for power and protection status.
      8) Audible alarm, with silencing switch, to indicate when protection has failed.
      9) Form-C contacts rated at 5 A and 250-V ac, one normally open and one normally closed, for remote monitoring of system operation. Contacts shall reverse position on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.
      10) Four **OR** Six, **as directed**,-digit, transient-event counter set to totalize transient surges.
   b. Peak Single-Impulse Surge Current Rating: 160 kA per mode/320 kA per phase **OR** 120 kA per mode/240 kA per phase **OR** 80 kA per mode/160 kA per phase, **as directed**.
   c. Minimum single-impulse current ratings, using 8-by-20-mic.sec. waveform described in IEEE C62.41.2.
      1) Line to Neutral: 70,000 A.
      2) Line to Ground: 70,000 A.
      3) Neutral to Ground: 50,000 A.
   d. Withstand Capabilities: 12,000 IEEE C62.41, Category C3 (10 kA), 8-by-20-mic.sec. surges with less than 5 percent change in clamping voltage.
   e. Protection modes and UL 1449 SVR for grounded wye circuits with 480Y/277 **OR** 208Y/120 **OR** 600Y/347, **as directed**,-V, three-phase, four-wire circuits shall be as follows:

1) Line to Neutral: 800 V for 480Y/277 **OR** 400 V for 208Y/120 **OR** 1200 V for 600Y/347, **as directed**.
2) Line to Ground: 800 V for 480Y/277 **OR** 400 V for 208Y/120 **OR** 1200 V for 600Y/347, **as directed**.
3) Neutral to Ground: 800 V for 480Y/277 **OR** 400 V for 208Y/120 **OR** 1200 V for 600Y/347, **as directed**.

f. Protection modes and UL 1449 SVR for 240/120-V, single-phase, three-wire circuits shall be as follows:
1) Line to Neutral: 400 V.
2) Line to Ground: 400 V.
3) Neutral to Ground: 400 V.

g. Protection modes and UL 1449 SVR for 240/120-V, three-phase, four-wire circuits with high leg shall be as follows:
1) Line to Neutral: 400 V, 800 V from high leg.
2) Line to Ground: 400 V.
3) Neutral to Ground: 400 V.

h. Protection modes and UL 1449 SVR for 240-, 480-, or 600-V, three-phase, three-wire, delta circuits shall be as follows:
1) Line to Line: 2000 V for 480 V **OR** 1000 V for 240 V **OR** 2500 V for 600 V, **as directed**.
2) Line to Ground: 1500 V for 480 V **OR** 800 V for 240 V **OR** 2500 V for 600 V, **as directed**.

F. Disconnecting And Overcurrent Protective Devices

1. Molded-Case Circuit Breaker (MCCB): Comply with UL 489, with series-connected rating **OR** interrupting capacity, **as directed**, to meet available fault currents.

a. Thermal-Magnetic Circuit Breakers: Inverse time-current element for low-level overloads, and instantaneous magnetic trip element for short circuits. Adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.

b. Adjustable Instantaneous-Trip Circuit Breakers: Magnetic trip element with front-mounted, field-adjustable trip setting.

c. Electronic trip circuit breakers with rms sensing; field-replaceable rating plug or field-replicable electronic trip; and the following field-adjustable settings:
1) Instantaneous trip.
2) Long- and short-time pickup levels.
3) Long- and short-time time adjustments.
4) Ground-fault pickup level, time delay, and I^2t response.

d. Current-Limiting Circuit Breakers: Frame sizes 400 A and smaller; let-through ratings less than NEMA FU 1, RK-5.

e. GFCI Circuit Breakers: Single- and two-pole configurations with Class A ground-fault protection (6-mA trip).

f. Ground-Fault Equipment Protection (GFEP) Circuit Breakers: Class B ground-fault protection (30-mA trip).

g. Arc-Fault Circuit Interrupter (AFCI) Circuit Breakers: Comply with UL 1699; 120/240-V, single-pole configuration.

h. Molded-Case Circuit-Breaker (MCCB) Features and Accessories:
1) Standard frame sizes, trip ratings, and number of poles.
2) Lugs: Compression **OR** Mechanical, **as directed**, style, suitable for number, size, trip ratings, and conductor materials.
3) Application Listing: Appropriate for application; Type SWD for switching fluorescent lighting loads; Type HID for feeding fluorescent and high-intensity discharge (HID) lighting circuits.
4) Ground-Fault Protection: Integrally mounted **OR** Remote-mounted, **as directed**, relay and trip unit with adjustable pickup and time-delay settings, push-to-test feature, and ground-fault indicator.

5) Communication Capability: Circuit-breaker-mounted **OR** Universal-mounted **OR** Integral **OR** Din-rail-mounted, **as directed**, communication module with functions and features compatible with power monitoring and control system specified in Division 26 Section "Electrical Power Monitoring And Control".
6) Shunt Trip: 120 **OR** 24, **as directed**,-V trip coil energized from separate circuit, set to trip at 55 **OR** 75, **as directed**, percent of rated voltage.
7) Undervoltage Trip: Set to operate at 35 to 75 percent of rated voltage without intentional **OR** with field-adjustable 0.1- to 0.6-second, **as directed**, time delay.
8) Auxiliary Contacts: One SPDT switch **OR** Two SPDT switches, **as directed**, with "a" and "b" contacts; "a" contacts mimic circuit-breaker contacts and "b" contacts operate in reverse of circuit-breaker contacts.
9) Alarm Switch: Single-pole, normally open contact that actuates only when circuit breaker trips.
10) Key Interlock Kit: Externally mounted to prohibit circuit-breaker operation; key shall be removable only when circuit breaker is in off position.
11) Zone-Selective Interlocking: Integral with electronic trip unit; for interlocking ground-fault protection function with other upstream or downstream devices.
12) Multipole units enclosed in a single housing or factory assembled to operate as a single unit.
13) Handle Padlocking Device: Fixed attachment, for locking circuit-breaker handle in on **OR** off, **as directed**, position.
14) Handle Clamp: Loose attachment, for holding circuit-breaker handle in on position.

2. Fused Switch: NEMA KS 1, Type HD; clips to accommodate specified fuses; lockable handle.
   a. Fuses, and Spare-Fuse Cabinet: Comply with requirements specified in Division 26 Section "Fuses".
   b. Fused Switch Features and Accessories: Standard ampere ratings and number of poles.
   c. Auxiliary Contacts: One **OR** Two, **as directed**, normally open and normally closed contact(s) that operate with switch handle operation.

G. Panelboard Suppressors
1. Surge Protection Device: IEEE C62.41-compliant, integrally mounted, solid-state, parallel-connected, non-modular type, with sine-wave tracking suppression and filtering modules, UL 1449, second edition, short-circuit current rating matching or exceeding the panelboard short-circuit rating, and with the following features and accessories:
   a. Accessories:
      1) LED indicator lights for power and protection status.
      2) Audible alarm, with silencing switch, to indicate when protection has failed.
      3) One set of dry contacts rated at 5 A and 250-V ac, for remote monitoring of protection status.
2. Surge Protection Device: IEEE C62.41-compliant, integrally mounted, plug-in **OR** wired-in **OR** bolt-on, **as directed**, solid-state, parallel-connected, modular (with field-replaceable modules) **OR** non-modular, **as directed**, type, with sine-wave tracking suppression and filtering modules, UL 1449, second edition, short-circuit current rating matching or exceeding the panelboard short-circuit rating, and with the following features and accessories:
   a. Accessories:
      1) Fuses rated at 200-kA interrupting capacity.
      2) Fabrication using bolted compression lugs for internal wiring.
      3) Integral disconnect switch.
      4) Redundant suppression circuits.
      5) Redundant replaceable modules.
      6) Arrangement with wire connections to phase buses, neutral bus, and ground bus.
      7) LED indicator lights for power and protection status.
      8) Audible alarm, with silencing switch, to indicate when protection has failed.
      9) Form-C contacts rated at 5 A and 250-V ac, one normally open and one normally closed, for remote monitoring of system operation. Contacts shall reverse position

on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.

10) Four **OR** Six, **as directed**,-digit, transient-event counter set to totalize transient surges.

b. Peak Single-Impulse Surge Current Rating: 160 kA per mode/320 kA per phase **OR** 120 kA per mode/240 kA per phase **OR** 80 kA per mode/160 kA per phase, **as directed**.

c. Minimum single-impulse current ratings, using 8-by-20-mic.sec. waveform described in IEEE C62.41.2.

1) Line to Neutral: 70,000 A.
2) Line to Ground: 70,000 A.
3) Neutral to Ground: 50,000 A.

d. Withstand Capabilities: 12,000 IEEE C62.41, Category C3 (10 kA), 8-by-20-mic.sec. surges with less than 5 percent change in clamping voltage.

e. Protection modes and UL 1449 SVR for grounded wye circuits with 480Y/277 **OR** 208Y/120 **OR** 600Y/347, **as directed**,-V, three-phase, four-wire circuits shall be as follows:

1) Line to Neutral: 800 V for 480Y/277 **OR** 400 V for 208Y/120 **OR** 1200 V for 600Y/347, **as directed**.
2) Line to Ground: 800 V for 480Y/277 **OR** 400 V for 208Y/120 **OR** 1200 V for 600Y/347, **as directed**.
3) Neutral to Ground: 800 V for 480Y/277 **OR** 400 V for 208Y/120 **OR** 1200 V for 600Y/347, **as directed**.

f. Protection modes and UL 1449 SVR for 240/120-V, single-phase, three-wire circuits shall be as follows:

1) Line to Neutral: 400 V.
2) Line to Ground: 400 V.
3) Neutral to Ground: 400 V.

g. Protection modes and UL 1449 SVR for 240/120-V, three-phase, four-wire circuits with high leg shall be as follows:

1) Line to Neutral: 400 V, 800 V from high leg.
2) Line to Ground: 400 V.
3) Neutral to Ground: 400 V.

h. Protection modes and UL 1449 SVR for 240-, 480-, or 600-V, three-phase, three-wire, delta circuits shall be as follows:

1) Line to Line: 2000 V for 480 V **OR** 1000 V for 240 V **OR** 2500 V for 600 V, **as directed**.
2) Line to Ground: 1500 V for 480 V **OR** 800 V for 240 V **OR** 2500 V for 600 V, **as directed**.

H. Accessory Components And Features

1. Accessory Set: Include tools and miscellaneous items required for overcurrent protective device test, inspection, maintenance, and operation.
2. Portable Test Set: For testing functions of solid-state trip devices without removing from panelboard. Include relay and meter test plugs suitable for testing panelboard meters and switchboard class relays.

1.3 EXECUTION

A. Installation

1. Install panelboards and accessories according to NECA 407 **OR** NEMA PB 1.1, **as directed**.
2. Equipment Mounting: Install panelboards on concrete bases, 4-inch (100-mm) nominal thickness. Comply with requirements for concrete base specified in Division 03 Section "Cast-in-place Concrete".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around full perimeter of base.

b. For panelboards, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
d. Install anchor bolts to elevations required for proper attachment to panelboards.
e. Attach panelboard to the vertical finished or structural surface behind the panelboard.

3. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from panelboards.
4. Comply with mounting and anchoring requirements specified in Division 26 Section "Hangers And Supports For Electrical Systems".
5. Mount top of trim 90 inches (2286 mm) above finished floor unless otherwise indicated.
6. Mount panelboard cabinet plumb and rigid without distortion of box. Mount recessed panelboards with fronts uniformly flush with wall finish and mating with back box.
7. Install overcurrent protective devices and controllers not already factory installed.
   a. Set field-adjustable, circuit-breaker trip ranges.
8. Install filler plates in unused spaces.
9. Stub four 1-inch (27-GRC) empty conduits from panelboard into accessible ceiling space or space designated to be ceiling space in the future. Stub four 1-inch (27-GRC) empty conduits into raised floor space or below slab not on grade.
10. Arrange conductors in gutters into groups and bundle and wrap with wire ties after completing load balancing, **as directed**.
11. Comply with NECA 1.

B. Identification
1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs complying with Division 26 Section "Identification For Electrical Systems".
2. Create a directory to indicate installed circuit loads after balancing panelboard loads, **as directed**; incorporate the Owner's final room designations. Obtain approval before installing. Use a computer or typewriter to create directory; handwritten directories are not acceptable.
3. Panelboard Nameplates: Label each panelboard with a nameplate complying with requirements for identification specified in Division 26 Section "Identification For Electrical Systems".
4. Device Nameplates: Label each branch circuit device in distribution panelboards with a nameplate complying with requirements for identification specified in Division 26 Section "Identification For Electrical Systems".

C. Field Quality Control
1. Perform tests and inspections.
2. Acceptance Testing Preparation:
   a. Test insulation resistance for each panelboard bus, component, connecting supply, feeder, and control circuit.
   b. Test continuity of each circuit.
3. Tests and Inspections:
   a. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
   b. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.
   c. Perform the following infrared scan tests and inspections and prepare reports:
      1) Initial Infrared Scanning: After Final Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each panelboard. Remove front panels so joints and connections are accessible to portable scanner.
      2) Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each panelboard 11 months after date of Final Completion.
      3) Instruments and Equipment:

a) Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

4. Panelboards will be considered defective if they do not pass tests and inspections.
5. Prepare test and inspection reports, including a certified report that identifies panelboards included and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

D. Adjusting
1. Adjust moving parts and operable component to function smoothly, and lubricate as recommended by manufacturer.
2. Set field-adjustable circuit-breaker trip ranges as indicated **OR** as specified in Division 26 Section "Overcurrent Protective Device Coordination Study", **as directed**.
3. Load Balancing: After Final Completion, but not more than 60 days after Final Acceptance, measure load balancing and make circuit changes.
   a. Measure as directed during period of normal system loading.
   b. Perform load-balancing circuit changes outside normal occupancy/working schedule of the facility and at time directed. Avoid disrupting critical 24-hour services such as fax machines and on-line data processing, computing, transmitting, and receiving equipment.
   c. After circuit changes, recheck loads during normal load period. Record all load readings before and after changes and submit test records.
   d. Tolerance: Difference exceeding 20 percent between phase loads, within a panelboard, is not acceptable. Rebalance and recheck as necessary to meet this minimum requirement.

E. Protection
1. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions.

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SECTION 26 24 19 00 - SWITCHGEAR

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for switchgear. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes metal-enclosed, low-voltage power circuit-breaker switchgear rated 1000 V and less for use in ac systems.

C. Definitions
1. ATS: Acceptance Testing Service.
2. GFCI: Ground-fault circuit interrupter.

D. Submittals
1. Product Data: For each type of switchgear, circuit breaker, accessory, and component indicated. Include dimensions and manufacturers' technical data on features, performance, electrical characteristics, ratings, and finishes.
2. Shop Drawings: For each type of switchgear and related equipment.
   a. Dimensioned plans, elevations, sections, and details, including required clearances and service space around equipment. Include the following:
   b. Wiring Diagrams: Power, signal, and control wiring.
3. Coordination Drawings: Floor plans showing dimensioned layout, required working clearances, and required area above and around switchgear where pipe and ducts are prohibited. Show switchgear layout and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate field measurements.
4. Samples: Representative portion of mimic bus with specified finish. Manufacturer's color charts showing colors available for mimic bus.
5. Manufacturer Seismic Qualification Certification: Submit certification that switchgear, overcurrent protective devices, accessories, and components will withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".
6. Field quality-control test reports.
7. Updated mimic-bus diagram reflecting field changes after final switchgear load connections have been made, for record.
8. Operation and Maintenance Data: For switchgear and components to include in emergency, operation, and maintenance manuals. Include the following:
   a. Manufacturer's written instructions for testing and adjusting overcurrent protective devices.
   b. Time-current curves, including selectable ranges for each type of overcurrent protective device.

E. Quality Assurance
1. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a member company of the InterNational Electrical Testing Association or is a nationally recognized testing laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7, and that is acceptable to authorities having jurisdiction.
   a. Testing Agency's Field Supervisor: Person currently certified by the InterNational Electrical Testing Association or the National Institute for Certification in Engineering Technologies to supervise on-site testing specified in Part 3.

2. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
3. Comply with NFPA 70.

F. Delivery, Storage, And Handling
1. Deliver switchgear in sections of lengths that can be moved past obstructions in delivery path.
2. Store switchgear indoors in clean dry space with uniform temperature to prevent condensation. Protect switchgear from exposure to dirt, fumes, water, corrosive substances, and physical damage.
3. If stored in areas subjected to weather, cover switchgear to provide protection from weather, dirt, dust, corrosive substances, and physical damage. Remove loose packing and flammable materials from inside switchgear; install electric heating (250 W per section) to prevent condensation.

G. Project Conditions
1. Installation Pathway: Remove and replace building components and structures to provide pathway for moving switchgear into place.
2. Interruption of Existing Electric Service: Do not interrupt electric service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electric service.
3. Product Selection for Restricted Space: Drawings indicate maximum dimensions for switchgear, including clearances between switchgear, and adjacent surfaces and other items. Comply with indicated maximum dimensions.
4. Environmental Limitations: Rate equipment for continuous operation under the following conditions, unless otherwise indicated:
   a. Ambient Temperature: Not exceeding 40 deg C.
   b. Altitude: Not exceeding 6600 feet (2010 m).

1.2 PRODUCTS

A. Ratings
1. Nominal System Voltage: 480 V, 3 wire **OR** 480/277 V, 4 wire **OR** 240 V, 3 wire **OR** 208/120 V, 4 wire, **as directed,** 60 Hz.
2. Main-Bus Continuous: 4000 **OR** 3200 **OR** 2000 **OR** 1600, **as directed,** A.
3. Short-Time and Short-Circuit Current: Match rating of highest-rated circuit breaker in switchgear assembly.

B. Fabrication
1. Factory assembled and tested and complying with IEEE C37.20.1.
2. Indoor Enclosure Material: Steel.
3. Outdoor Enclosure Material: Galvanized steel.
4. Outdoor Enclosure Fabrication Requirements: Weatherproof; integral structural-steel base frame with factory-applied asphaltic undercoating; and each compartment equipped with the following features:
   a. Structural design and anchorage adequate to resist loads imposed by 125-mph (200-km/h), **as directed**, wind.
   b. Space heater operating at one-half or less of rated voltage, sized to prevent condensation.
   c. Louvers equipped with insect and rodent screen and filter; arranged to permit air circulation while excluding insects, rodents, and exterior dust.
   d. Hinged front door with padlocking provisions.
   e. Interior light with switch.
   f. Weatherproof duplex receptacle.

g. Common internal aisle of sufficient width to permit protective-device withdrawal, disassembly, and servicing in aisle.
h. Aisle access doors with outside padlocking provisions and interior panic latches.
i. Aisle space heaters operating at one-half or less of rated voltage, thermostatically controlled.
j. Vaporproof fluorescent aisle lights with low-temperature ballasts, controlled by wall switch at each entrance.
k. GFCI duplex receptacles, a minimum of two, located in aisle.
l. Aisle ventilation louvers equipped with insect and rodent screen and filter and arranged to permit air circulation while excluding insects, rodents, and exterior dust.

5. Finish: IEEE C37.20.1, manufacturer's standard gray finish over a rust-inhibiting primer on phosphatizing-treated metal surfaces.
6. Section barriers between main and tie circuit-breaker compartments shall be extended to rear of section.
7. Bus isolation barriers shall be arranged to isolate line bus from load bus at each main and tie circuit breaker.
8. Circuit-breaker compartments shall be equipped to house drawout-type circuit breakers and shall be fitted with hinged outer doors.
9. Fabricate enclosure with removable, hinged, rear cover panels to allow access to rear interior of switchgear.
10. Auxiliary Compartments: Match and align with basic switchgear assembly. Include the following:
    a. Utility metering compartment that complies with utility company requirements.
    b. Bus transition sections.
    c. Incoming-line pull sections.
    d. Hinged front panels for access to metering, accessory, and blank compartments.
    e. Pull box on top of switchgear for extra room for pulling cable, with removable top, front, and side covers and ventilation provisions adequate to maintain air temperature in pull box within same limits as switchgear.
        1) Set pull box back from front to clear circuit-breaker lifting mechanism.
        2) Bottom: Insulating, fire-resistant material with separate holes for cable drops into switchgear.
        3) Cable Supports: Arranged to ease cabling and adequate to support cables indicated, including those for future installation.
11. Bus bars connect between vertical sections and between compartments. Cable connections are not permitted.
    a. Main Phase Bus: Uniform capacity the entire length of assembly.
    b. Neutral Bus: 50 **OR** 100, **as directed,** percent of phase-bus ampacity, except as indicated. Equip bus with pressure-connector terminations for outgoing circuit neutral conductors. Include braces for neutral-bus extensions for busway feeders.
    c. Vertical Section Bus Size: Comply with IEEE C37.20.1, including allowance for spare circuit breakers and spaces for future circuit breakers.
    d. Phase- and Neutral-Bus Material: Hard-drawn copper of 98 percent minimum conductivity, with copper feeder circuit-breaker line connections.
       OR
       Phase- and Neutral-Bus Material: Silver- or tin-plated, high-strength, with copper circuit-breaker line connections.
       OR
       Phase- and Neutral-Bus Material: Hard-drawn copper of 98 percent minimum conductivity or tin-plated, high-strength.
    e. Use silver-plated copper for connecting circuit-breaker line to bus.
    f. Use copper for connecting circuit-breaker line to copper bus.
    g. Contact Surfaces of Buses: Silver plated.
    h. Feeder Circuit-Breaker Load Terminals: Silver-plated copper bus extensions equipped with pressure connectors for outgoing circuit conductors.

i. Ground Bus: Hard-drawn copper of 98 percent minimum conductivity, with pressure connector for feeder and branch-circuit ground conductors, minimum size 1/4 by 2 inches (6 by 50 mm).
j. Supports and Bracing for Buses: Adequate strength for indicated short-circuit currents.
k. Neutral bus equipped with pressure-connector terminations for outgoing circuit neutral conductors. Neutral-bus extensions for busway feeders are braced.
l. Neutral Disconnect Link: Bolted, uninsulated, 1/4-by-2-inch (6-by-50-mm) copper bus, arranged to connect neutral bus to ground bus.
m. Provide for future extensions from either end of main phase, neutral, and ground bus by means of predrilled bolt-holes and connecting links.
n. Bus-Bar Insulation: Individual bus bars wrapped with factory-applied, flame-retardant tape or spray-applied, flame-retardant insulation.
1) Sprayed Insulation Thickness: 3 mils (0.08 mm), minimum.
2) Bolted Bus Joints: Insulate with secure joint covers that can easily be removed and reinstalled.

C. Components
1. Instrument Transformers: Comply with IEEE C57.13.
a. Potential Transformers: Secondary-voltage rating of 120 V and NEMA accuracy class of 0.3 with burdens of W, X, and Y.
b. Current Transformers: Ratios as indicated; burden and accuracy class suitable for connected relays, meters, and instruments.
2. Multifunction Digital-Metering Monitor: UL-listed or -recognized, microprocessor-based unit suitable for three- or four-wire systems and with the following features:
a. Inputs from sensors or 5-A current-transformer secondaries, and potential terminals rated to 600 V.
b. Switch-selectable digital display of the following:
1) Phase Currents, Each Phase: Plus or minus 1 percent.
2) Phase-to-Phase Voltages, Three Phase: Plus or minus 1 percent.
3) Phase-to-Neutral Voltages, Three Phase: Plus or minus 1 percent.
4) Three-Phase Real Power: Plus or minus 2 percent.
5) Three-Phase Reactive Power: Plus or minus 2 percent.
6) Power Factor: Plus or minus 2 percent.
7) Frequency: Plus or minus 0.5 percent.
8) Integrated Demand, with Demand Interval Selectable from 5 to 60 Minutes: Plus or minus 2 percent.
9) Accumulated energy, in megawatt hours (joules), plus or minus 2 percent; stored values unaffected by power outages for up to 72 hours.
c. Mounting: Display and control unit flush or semiflush mounted in instrument compartment door.
3. Analog Instruments: Rectangular, 4-1/2-inch (115-mm) square, accurate within 1 percent, semiflush mounting, with antiparallax 250-degree scale and external zero adjustment, complying with ANSI C39.1.
a. Voltmeters: Cover an expanded scale range of normal voltage plus 10 percent.
b. Voltmeter Selector Switch: Rotary type with off position to provide readings of phase-to-phase and phase-to-neutral voltages.
c. Ammeters: Cover an expanded scale range of bus rating plus 10 percent.
d. Ammeter Selector Switch: Permits current reading in each phase and keeps current-transformer secondary circuits closed in off position.
e. Locate meter and selector switch on circuit-breaker compartment door for indicated feeder circuits only.
f. Watt-Hour Meters: Flush- or semiflush-mounting type, 5 A, 120 V, 3 phase, 3 wire; with 3 elements, 15-minute indicating demand register, and provision for testing and adding pulse initiation.

g. Recording Demand Meter: Usable as totalizing relay or indicating and recording maximum demand meter with 15-minute interval.
   1) Operation: Meter counts and records a succession of pulses entering two channels.
   2) Housing: Drawout, back-connected case arranged for semiflush mounting.

4. Relays: Comply with IEEE C37.90, types and settings as indicated; with test blocks and plugs.
5. Surge Arresters: Distribution class, metal-oxide-varistor type. Comply with IEEE C62.11 and NEMA LA 1.
   a. Install in cable termination compartments and connect in each phase of circuit.
   b. Coordinate rating with circuit voltage.
6. Provision for Future Devices: Equip compartments with rails, mounting brackets, supports, necessary appurtenances, and bus connections.
7. Fungus Proofing: Permanent fungicidal treatment for switchgear interior, including instruments and instrument transformers.
8. Control Power Supply: Control power transformer supplying 120-V control circuits through secondary disconnect devices. Include the following features:
   a. Dry-type transformers, in separate compartments for units larger than 3 kVA, including primary and secondary fuses.
   b. Two control power transformers in separate compartments with necessary interlocking relays; each transformer connected to line side of associated main circuit breaker.
      1) Secondary windings connected through a relay or relays to control bus to effect an automatic transfer scheme.
      2) Secondary windings connected through an internal automatic transfer switch to switchgear control power bus.
   c. Control Power Fuses: Primary and secondary fuses with current-limiting and overload protection.
   d. Fuses are specified in Division 26 Section "Fuses".
9. Control Wiring: Factory installed, complete with bundling, lacing, and protection; and complying with the following:
   a. Flexible conductors for No. 8 AWG and smaller, for conductors across hinges and for conductors for interconnections between shipping units.
   b. Conductors sized according to NFPA 70 for duty required.

D. Circuit Breakers
1. Description: Comply with IEEE C37.13.
2. Ratings: As indicated for continuous, interrupting, and short-time current ratings for each circuit breaker; voltage and frequency ratings same as switchgear.
3. Operating Mechanism: Mechanically and electrically trip-free, stored-energy operating mechanism with the following features:
   a. Normal Closing Speed: Independent of both control and operator.
   b. Slow Closing Speed: Optional with operator for inspection and adjustment.
   c. Stored-Energy Mechanism: Manually charged **OR** Electrically charged, with optional manual charging, **as directed**.
   d. Operation counter.
4. Trip Devices: Solid-state, overcurrent trip-device system consisting of one or two current transformers or sensors per phase, a release mechanism, and the following features:
   a. Functions: Long-time-delay, short-time-delay, and instantaneous-trip functions, independent of each other in both action and adjustment.
   b. Temperature Compensation: Ensures accuracy and calibration stability from minus 5 to plus 40 deg C.
   c. Field-adjustable, time-current characteristics.
   d. Current Adjustability: Dial settings and rating plugs on trip units or sensors on circuit breakers, or a combination of these methods.
   e. Three bands, minimum, for long-time- and short-time-delay functions; marked "minimum," "intermediate," and "maximum."
   f. Pickup Points: Five minimum, for long-time- and short-time-trip functions. Equip short-time-trip function for switchable I^2t operation.

g. Pickup Points: Five minimum, for instantaneous-trip functions.
h. Ground-fault protection with at least three short-time-delay settings and three trip-time-delay bands; adjustable current pickup. Arrange to provide protection for the following:
   1) Three-wire circuit or system.
   2) Four-wire circuit or system.
   3) Four-wire, double-ended substation.
i. Trip Indication: Labeled, battery-powered lights or mechanical targets on trip device to indicate type of fault.

5. Auxiliary Contacts: For interlocking or remote indication of circuit-breaker position, with spare auxiliary switches and other auxiliary switches required for normal circuit-breaker operation, quantity as indicated. Each consists of two Type "a" and two Type "b" stages (contacts) wired through secondary disconnect devices to a terminal block in stationary housing.
6. Drawout Features: Circuit-breaker mounting assembly equipped with a racking mechanism to position circuit breaker and hold it rigidly in connected, test, and disconnected positions. Include the following features:
   a. Interlocks: Prevent movement of circuit breaker to or from connected position when it is closed, and prevent closure of circuit breaker unless it is in connected, test, or disconnected position.
   b. Circuit-Breaker Positioning: An open circuit breaker may be racked to or from connected, test, and disconnected positions only with the associated compartment door closed unless live parts are covered by a full dead-front shield. An open circuit breaker may be manually withdrawn to a position for removal from the structure with the door open. Status for connection devices for different positions includes the following:
      1) Test Position: Primary disconnect devices disengaged, and secondary disconnect devices and ground contact engaged.
      2) Disconnected Position: Primary and secondary devices and ground contact disengaged.
7. Arc Chutes: Readily removable from associated circuit breaker when it is in disconnected position, and arranged to permit inspection of contacts without removing circuit breaker from switchgear.
8. Padlocking Provisions: For installing at least three padlocks on each circuit breaker to secure its enclosure and prevent movement of drawout mechanism.
9. Operating Handle: One for each circuit breaker capable of manual operation.
10. Electric Close Button: One for each electrically operated circuit breaker.
11. Mechanical Interlocking of Circuit Breakers: Uses a mechanical tripping lever or equivalent design and electrical interlocks.
12. Key Interlocks: Arranged so keys are attached at devices indicated. Mountings and hardware are included where future installation of key-interlock devices is indicated.
13. Undervoltage Trip Devices: Instantaneous, with adjustable pickup voltage **OR** Adjustable time-delay and pickup voltage, **as directed**.
14. Shunt-Trip Devices: Where indicated.
15. Fused Circuit Breakers: Circuit breaker and fuse combinations complying with requirements for circuit breakers and trip devices and with the following:
   a. Fuses: NEMA FU 1, Class L current limiting, sized to coordinate with and protect associated circuit breaker.
   b. Circuit Breakers with Frame Size 1600 A and Smaller: Fuses on line side of associated circuit breaker, on a common drawout mounting, arranged so fuses are accessible only when circuit breaker is in disconnected position.
   c. Circuit Breakers with Frame Sizes More Than 1600 A: Fuses and circuit breakers may be installed in separate compartments on separate drawout mountings. Fuse drawout element is interlocked with associated power circuit breaker to prevent drawing out fuse element unless circuit breaker is in open position.
   d. Open-Fuse Trip Device: Positive means of tripping and holding circuit breaker in open position when a fuse opens. Open-fuse status is indicated at front of circuit breaker or fuse drawout element.

16. Indicating Lights: To indicate circuit breaker is open or closed, for main and bus tie circuit breakers interlocked either with each other or with external devices.

E. Accessories
1. Accessory Set: Furnish tools and miscellaneous items required for circuit-breaker and switchgear test, inspection, maintenance, and operation.
   a. Racking handle to manually move circuit breaker between connected and disconnected positions.
   b. Portable test set for testing all functions of circuit-breaker, solid-state trip devices without removal from switchgear.
   c. Relay and meter test plugs suitable for testing switchgear meters and switchgear class relays.
2. Circuit-Breaker Removal Apparatus: Portable, floor-supported, roller-base, elevating carriage arranged for moving circuit breakers in and out of compartments.
3. Circuit-Breaker Removal Apparatus: Overhead-circuit-breaker lifting device, track mounted at top front of switchgear and complete with hoist and lifting yokes matching each size of drawout circuit breaker installed.
4. Spare-Fuse Cabinet: Identified and compartmented steel box or cabinet with lockable door.
5. Storage for Manual: Include a rack or holder, near the operating instructions, for a copy of maintenance manual.

F. Identification
1. Mimic Bus: Continuous mimic bus, arranged in single-line diagram format, using symbols and lettered designations consistent with approved mimic-bus diagram.
   a. Mimic-bus segments coordinated with devices in switchgear sections to which applied, to produce a concise visual presentation of principal switchgear components and connections.
   b. Medium: Painted graphics, as selected by Architect.
   c. Color: Contrasting with factory-finish background; as selected by Architect from manufacturer's full range.
2. System Power Riser Diagrams: Depict power sources, feeders, distribution components, and major loads. Include as-built data for low-voltage power switchgear and connections as follows:
   a. Frame size of each circuit breaker.
   b. Trip rating for each circuit breaker.
   c. Conduit and wire size for each feeder.

1.3 EXECUTION

A. Installation
1. Comply with applicable portions of NECA 400.
2. Anchor switchgear assembly to 4-inch (100-mm), channel-iron floor sill embedded in floor **OR** concrete base, **as directed,** and attach by bolting.
   a. Sills: Select to suit switchgear; level and grout flush into floor **OR** concrete base, **as directed**.
   b. Design each fastener and support to carry load indicated by seismic requirements and according to seismic-restraint details. See Division 26 Section "Hangers And Supports For Electrical Systems" for seismic-restraint requirements.
   c. Concrete Bases: 4 inches (100 mm) high, reinforced, with chamfered edges. Extend base no more than 3 inches (75 mm) in all directions beyond the maximum dimensions of switchgear unless otherwise indicated or unless required for seismic anchor support. Construct concrete bases according to Division 26 Section "Hangers And Supports For Electrical Systems".
3. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, brackets, and temporary blocking of moving parts from switchgear units and components.

B. Identification
1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs as specified in Division 26 Section "Identification For Electrical Systems".
2. Diagram and Instructions:
   a. Frame and mount under clear acrylic plastic on the front of switchgear.
      1) Operating Instructions: Printed basic instructions for switchgear, including control and key-interlock sequences and emergency procedures.
      2) System Power Riser Diagrams: Depict power sources, feeders, distribution components, and major loads.
   b. Storage for Maintenance: Include a rack or holder, near the operating instructions, for a copy of maintenance manual.

C. Connections
1. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
2. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

D. Field Quality Control
1. Prepare for acceptance tests as follows:
   a. Test insulation resistance for each switchgear bus, component, connecting supply, feeder, and control circuit.
   b. Test continuity of each circuit.
2. Manufacturer's Field Service: Engage a factory-authorized service representative to perform the following:
   a. Inspect switchgear installation, including wiring, components, connections, and equipment. Test and adjust components and equipment.
   b. Verify that electrical control wiring installation complies with manufacturer's submittal by means of point-to-point continuity testing. Verify that wiring installation complies with requirements in Division 22.
   c. Complete installation and startup checks according to manufacturer's written instructions.
   d. Assist in field testing of equipment including pretesting and adjusting of equipment and components.
   e. Report results in writing.
3. Testing Agency: Engage a qualified independent testing and inspecting agency to perform field tests and inspections and prepare test reports.
   a. Perform each visual and mechanical inspection and electrical test stated in NETA ATS. Certify compliance with test parameters. Perform NETA tests and inspections for each of the following NETA categories:
      1) Switchgear.
      2) Circuit breakers.
      3) Protective relays.
      4) Instrument transformers.
      5) Metering and instrumentation.
      6) Ground-fault systems.
      7) Battery systems.
      8) Surge arresters.
      9) Capacitors.
   b. Remove and replace malfunctioning units and retest as specified above.
4. Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each switchgear. Remove front and rear panels so joints and connections are accessible to portable scanner.
   a. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each switchgear 11 months after date of Substantial Completion.

b. Instrument: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

c. Record of Infrared Scanning: Prepare a certified report that identifies switchgear checked and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

E. Adjusting

1. Set field-adjustable, protective-relay trip characteristics according to results in Division 26 Section "Overcurrent Protective Device Coordination Study".
2. Set field-adjustable, protective-relay trip characteristics.

F. Cleaning

1. On completion of installation, inspect interior and exterior of switchgear. Remove paint splatters and other spots. Vacuum dirt and debris; do not use compressed air to assist in cleaning. Repair exposed surfaces to match original finish.

G. Protection

1. Temporary Heating: Apply temporary heat to switchgear, according to manufacturer's written instructions, throughout periods when switchgear environment is not controlled for temperature and humidity within manufacturer's stipulated service conditions.

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SECTION 26 24 19 00a - POWER DISTRIBUTION UNITS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for power distribution units. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes freestanding, prepackaged, power distribution units for transforming, conditioning, and distributing electrical power.

C. Definitions
1. TVSS: Transient voltage surge suppression.
2. UPS: Uninterrupted power supply.

D. Submittals
1. Product Data: For power distribution units.
2. Shop Drawings: Include dimensioned plans, sections, and elevations. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   a. Wiring Diagrams: Power, signal, and control wiring.
3. Manufacturer Seismic Qualification Certification: Submit certification that power distribution units, accessories, and components will withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems". Include the following:
4. Field quality-control test reports.
5. Operation and Maintenance Data: For power distribution units to include in emergency, operation, and maintenance manuals.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Comply with NFPA 70.

F. Delivery, Storage, And Handling
1. Deliver equipment in fully enclosed vehicles after specified environmental conditions have been permanently established in spaces where equipment is to be placed.
2. Store equipment in spaces with environments controlled within manufacturer's ambient temperature and humidity tolerances for non-operating equipment.

1.2 PRODUCTS

A. Manufactured Units
1. Description: Integrated and coordinated assembly of power-line-conditioning and distribution components packaged in a single cabinet or modular assembly of cabinets each with full-swivel casters mounted to bottom frame, **as directed**. Include the following components:
   a. Input-power, circuit-breaker section.
   b. Isolation transformer.
   c. TVSS system.
   d. Output panelboard(s).

e. Alarm, monitoring, and control system.

2. Provide units that are constructed to withstand seismic forces specified in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".

3. Unit Capacity Rating: Unit shall carry indicated rms kilovolt-ampere load continuously without exceeding rated insulation temperature for the following input voltage and load current:

a. Input Voltage: Within rated input-voltage tolerance band of unit.

b. Load Current: Minimum of 3.0 crest factor and 85 percent total harmonic distortion.

B. Input-Power, Circuit-Breaker Section

1. Description: 3-pole, shunt-tripped, thermal-magnetic-type circuit breaker, rated for indicated interrupting capacity and 125 percent of input current of unit at 100 percent rated load.

a. Dual-Input Units:

1) Two input circuit breakers arranged to provide transfer between two input-voltage sources.

2) Controls and interfaces to allow both open- and closed-transition transfer between two input-voltage sources.

3) Use a 120-V permissive signal from both upstream voltage sources to indicate acceptable conditions for closed-transition transfer.

4) Open second circuit breaker automatically after closed-transition transfer is competed.

C. Isolation Transformer Section

1. Description: Dry-type, electrostatically shielded, three-phase, common-core, convection-air-cooled isolation transformer.

a. Comply with UL 1561 including requirements for nonsinusoidal load-current-handling capability defined by designated K-factor, **as directed**.

b. Cores: Grain-oriented, non-aging silicon steel, one leg per phase.

c. Coil Material and Insulation: Copper windings with a 220 deg C insulation class.

d. Temperature Rise: Designed for 80 **OR** 115 **OR** 150, **as directed**, deg C rise above 40 deg C ambient.

e. Output Impedance: 3.5 plus or minus 0.5 percent.

f. Regulation: 2 to 4 percent maximum, at full-resistive load; 5 percent maximum, at rated nonlinear load.

g. Taps: 6 full-capacity compensation taps at 2.5 percent increments; 2 above and 4 below nominal voltage.

h. Full-Load Efficiency: Minimum 96 percent at rated nonlinear, **as directed**, load.

i. Magnetic-Field Strength External to Transformer Enclosure: Less than 0.1 gauss at 450 mm.

j. Audible Noise: Comply with NEMA ST 20.

k. Electrostatic Shielding: Independently shield each winding with a double-copper, electrostatic shield arranged to minimize interwinding capacitance.

1) Coil leads and terminal trips shall be arranged to minimize capacitive coupling between input and output connections.

2) Shield Terminal: Separate, and marked "Shield" for grounding connection.

3) Capacitance: Limit capacitance between primary and secondary windings to a maximum of 33 picofarads over a frequency range of 20 Hz to 1 MHz.

4) Common-Mode Noise Attenuation: 120 dB minimum, 0.5 to 1.5 kHz; minus 65 dB minimum, 1.5 to 100 kHz.

5) Normal-Mode Noise Attenuation: Minus 52 dB minimum, 1.5 to 10 kHz.

l. Neutral Rating: 1.732 times the system full-load ampere rating.

D. TVSS System

1. Description: Integrated TVSS system complying with Division 26 Section "Transient-voltage Suppression For Low-voltage Electrical Power Circuits", to protect unit panelboard, and having the following features:

a. Disconnect Device: Manual, three-pole, fused disconnect switch to de-energize TVSS system while permitting power distribution units to continue operation. Fuses are rated at 200-kA interrupting capacity.
b. Nonlinear Loading: System shall accommodate rated-load current with a minimum 3.0 crest factor and 85 percent total harmonic distortion.

E. Output Panelboards
1. Description: Panelboards complying with Division 26 Section "Panelboards", except for mounting provisions. Mount in front of power distribution units behind flush doors. Include the following features:
a. Construction: 42 pole, 240 V, 3 phase; capable of accepting branch circuit breakers rated to 100 A.
b. Panelboard Rating: 225 A, with main circuit breaker.
c. Panelboard Phase, Neutral and Ground Buses: Copper, with neutral bus at least 1.732 times the nominal phase bus rating.
d. Isolated Ground Bus: Copper, adequate for branch-circuit equipment ground conductors; insulated from supports.
e. Branch Circuit Breakers: Bolt **OR** Plug, **as directed**, on.
f. Cable Racks: Removable and arranged for supporting and routing cables for panelboard entrance.
g. Access Panels: Arranged so additional branch-circuit wiring can be installed and connected in the future.

F. Power Distribution Unit Controls
1. Include the following control features:
a. Emergency, power-off switch integral with power distribution unit.
b. Emergency, power-off input terminals for connection to remote power-off switch.
c. Over-under alarm shutdown with automatic unit disconnection for the following alarm conditions:
1) High temperature.
2) High and low input or output voltage.
3) Phase loss.
4) Ground fault.
5) Reverse phase rotation.
d. Ground-fault protection with automatic system shutdown.
e. Alarm Contacts: Electrically isolated, Form C (one normally open and one normally closed), summary alarm; contact set shall change state if any monitored function goes into alarm mode.
f. Remote Power-Off Control: Control circuit with connection to shunt trip of power distribution unit main power circuit breaker and terminals for connection to one or more remote power-off, push-button stations.

G. Monitoring, Status, And Alarm Annunciation
1. Description: Microprocessor-based monitoring, status, and alarm annunciation panel mounted flush in front of power distribution unit to provide status display and failure-indicating interface for the following:
a. Power Monitoring:
1) Input Voltage: Line to line, rms.
2) Output Voltage: Line to line, rms.
3) Output Voltage: Line to neutral, rms.
4) Output current.
b. Status Indication: Unit on.
c. Alarm Annunciation:
1) High temperature.
2) High and low input voltage.
3) High and low output voltage.

4) Phase loss.
5) Ground fault.
6) Frequency.
7) Phase rotation.
8) TVSS module failure.

d. Audible Alarm and Silencing Switch: Alarm sounds when alarm indication occurs. Silencing switch shall silence audible alarm but leave visual indication active until failure or other alarm conditions are corrected.

H. Sound Level
1. General: Fully assembled products comply with minimum sound-level requirements in NEMA ST 20 for transformers of corresponding ratings when factory tested according to IEEE C57.12.91.
2. General: Fully assembled products have a minimum of 3 dB less than the maximum sound levels prescribed for transformers of corresponding ratings when factory tested according to IEEE C57.12.91.

I. Finishes
1. Manufacturer's standard finish over corrosion-resistant pretreatment and primer.

J. Source Quality Control
1. Factory Tests: Design and routine tests shall comply with referenced standards.
2. Factory Sound-Level Tests: Conduct sound-level tests on equipment. Comply with IEEE C57.12.91 and NEMA ST 20.

1.3 EXECUTION

A. Installation
1. Arrange power distribution units to provide adequate access to equipment and circulation of cooling air.
2. Anchor or restrain floor-mounting power distribution units according to manufacturer's written instructions, seismic codes applicable to Project, **as directed**, and requirements in Division 26 Section "Hangers And Supports For Electrical Systems".
3. Identify equipment and install warning signs according to Division 26 Section "Identification For Electrical Systems".

B. Connections
1. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
   a. Separately Derived Systems: Make grounding connections to grounding electrodes as indicated; comply with NFPA 70.
2. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

C. Field Quality Control
1. Perform tests and inspections and prepare test reports.
2. Tests and Inspections:
   a. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification for circuit breakers, molded case; and for transformers, dry type, air cooled, low voltage, small. Certify compliance with test parameters.
   b. Perform functional tests of power distribution units throughout their operating ranges. Test each monitoring, status, and alarm function.
   c. Infrared Scanning: Two months after Final Completion, perform an infrared scan of conductor and bus connections.

1) Use an infrared-scanning device designed to measure temperature or detect significant deviations from normal values. Provide documentation of device calibration.
2) Perform 2 follow-up infrared scans of transformers, one at 4 months and the other at 11 months after Final Completion.
3) Prepare a certified report identifying connections checked and describing results of scanning. Include notation of deficiencies detected, remedial action taken, and scanning observations after remedial action.

3. Test Labeling: On completion of satisfactory testing of each unit, attach a dated and signed "Satisfactory Test" label to tested component.

D. Adjusting
1. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
2. Adjust power distribution units to provide optimum voltage to equipment served throughout normal operating cycle of loads served. Record input and output voltages and adjustment settings, and incorporate into test results.

E. Cleaning
1. Vacuum dirt and debris; do not use compressed air to assist in cleaning.

END OF SECTION 26 24 19 00a

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Task	Specification	Specification Description
26 24 19 00	01 22 16 00	No Specification Required
26 24 19 00	26 09 23 00b	Electrical Power Monitoring And Control
26 24 19 00	23 09 23 00	Enclosed Controllers
26 24 19 00	26 09 23 00c	Motor-Control Centers

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SECTION 26 25 00 00 - ENCLOSED BUS ASSEMBLIES

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for enclosed bus assemblies. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes the following:
a. Feeder-bus assemblies.
b. Plug-in bus assemblies.
c. Bus plug-in devices.

C. Definitions
1. TVSS: Transient voltage surge suppressor.

D. Submittals
1. Shop Drawings: For each type of bus assembly **OR** bus assembly and plug-in device, **as directed**.
a. Show fabrication and installation details for enclosed bus assemblies. Include plans, elevations, and sections of components. Designate components and accessories, including clamps, brackets, hanger rods, connectors, straight lengths, and fittings.
b. Show fittings, materials, fabrication, and installation methods for listed fire-stop barriers and weather barriers.
c. Indicate required clearances, method of field assembly, and location and size of each field connection.
d. Detail connections to switchgear, switchboards, transformers, and panelboards.
e. Wiring Diagrams: Power and signal **OR** and control, **OR** signal, and control, **as directed**, wiring.
f. Seismic-Restraint Details: Signed and sealed by a qualified professional engineer.
1) Design Calculations: Calculate requirements for selecting seismic restraints.
2) Detail fabrication, including anchorages and attachments to structure and to supported equipment.
2. Coordination Drawings: Floor plans and sections, drawn to scale. Include scaled bus-assembly layouts and relationships between components and adjacent structural, mechanical, and electrical elements. Show the following:
a. Vertical and horizontal enclosed bus-assembly runs, offsets, and transitions.
b. Clearances for access above and to the side of enclosed bus assemblies.
c. Vertical elevation of enclosed bus assemblies above the floor or bottom of structure.
d. Support locations, type of support, and weight on each support.
3. Location of adjacent construction elements including light fixtures, HVAC and plumbing equipment, fire sprinklers and piping, signal and control devices, and other equipment.
4. Product Certificates: For each type of enclosed bus assembly, signed by product manufacturer.
5. Manufacturer Seismic Qualification Certification: Submit certification that enclosed bus assemblies, plug-in devices, accessories, and components will withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems" Include the following:
a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
1) The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."

2) The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

6. Qualification Data: For professional engineer and testing agency.
7. Field quality-control test reports.
8. Operation and Maintenance Data: For enclosed bus assemblies to include in emergency, operation, and maintenance manuals.

E. Quality Assurance

1. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a member company of the InterNational Electrical Testing Association or is a nationally recognized testing laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7, and that is acceptable to authorities having jurisdiction.

   a. Testing Agency's Field Supervisor: Person currently certified by the InterNational Electrical Testing Association or the National Institute for Certification in Engineering Technologies to supervise on-site testing specified in Part 1.3.

2. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a nationally recognized testing laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7, and that is acceptable to authorities having jurisdiction.
3. Source Limitations: Obtain enclosed bus assemblies and plug-in devices through one source from a single manufacturer.
4. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
5. Comply with NEMA BU 1, "Busways."
6. Comply with NFPA 70.

F. Delivery, Storage, And Handling

1. Deliver, store, and handle enclosed bus assemblies according to NEMA BU 1.1, "General Instructions for Proper Handling, Installation, Operation and Maintenance of Busway Rated 600 Volts or Less."

G. Project Conditions

1. Derate enclosed bus assemblies for continuous operation at indicated ampere ratings for ambient temperature not exceeding 122 deg F (50 deg C) **OR** 140 deg F (60 deg C), **as directed**.

H. Coordination

1. Coordinate layout and installation of enclosed bus assemblies and suspension system with other construction that penetrates ceilings or floors or is supported by them, including light fixtures, HVAC equipment, fire-suppression system, and partition assemblies.
2. Coordinate size and location of concrete curbs around openings for vertical bus. Concrete, reinforcement, and formwork requirements are specified in Division 31.

1.2 PRODUCTS

A. Enclosed Bus Assemblies

1. Feeder-Bus Assemblies: NEMA BU 1, low-impedance bus assemblies in nonventilated housing; single-bolt joints; ratings as indicated.

   a. Seismic Fabrication Requirements: Fabricate mounting provisions and attachments for feeder-bus assemblies with reinforcement strong enough to withstand seismic forces

defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems" when mounting provisions and attachments are anchored to building structure

b. Voltage: 120/208 **OR** 240 **OR** 480 **OR** 277/480, **as directed**, V; 3 phase; 100 **OR** 200 **OR** percent neutral capacity, **as directed**.

c. Temperature Rise: 55 deg C above 40 deg C ambient maximum for continuous rated current.

d. Bus Materials: Current-carrying copper, **as directed**, conductors, fully insulated with Class 130C insulation except at joints; plated surface at joints.

e. Ground:

1) 50 percent capacity integral with housing.

2) 50 percent capacity internal bus bars of material matching bus material.

3) 50 percent capacity isolated, internal bus bar of material matching bus material.

f. Enclosure: Steel with manufacturer's standard finish **OR** Aluminum with manufacturer's standard finish **OR** Weatherproof, steel or aluminum with manufacturer's standard finish, sealed seams, drains, and removable closures, **as directed**.

g. Fittings and Accessories: Manufacturer's standard.

h. Mounting: Arranged flat, edgewise, or vertically without derating.

2. Plug-in Bus Assemblies: NEMA BU 1, low-impedance bus assemblies in nonventilated housing; single-bolt joints; ratings as indicated.

a. Seismic Fabrication Requirements: Fabricate mounting provisions and attachments for switchboards with reinforcement strong enough to withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems" when mounting provisions and attachments are anchored to building structure.

b. Voltage: 120/208 **OR** 240 **OR** 480 **OR** 277/480, **as directed**, V; 3 phase; 100 **OR** 200 **OR** percent neutral capacity, **as directed**.

c. Temperature Rise: 55 deg C above 40 deg C ambient maximum for continuous rated current.

d. Bus Materials: Current-carrying copper **OR** aluminum, **as directed**, conductors, fully insulated with Class 130C insulation except at stabs and joints; plated surface at stabs and joints.

e. Ground:

1) 50 percent capacity integral with housing.

2) 50 percent capacity internal bus bar of material matching bus material.

3) 50 percent capacity isolated, internal bus bar of material matching bus material.

f. Enclosure: Steel, with manufacturer's standard finish, plug-in openings 24 inches (610 mm) o.c., and hinged covers over unused openings **OR** Aluminum, with manufacturer's standard finish, plug-in openings 24 inches (610 mm) o.c., and hinged covers over unused openings, **as directed**.

g. Fittings and Accessories: Manufacturer's standard.

h. Mounting: Arranged flat, edgewise, or vertically without derating.

B. Plug-In Devices

1. Fusible Switches: NEMA KS 1, heavy duty; with R-type rejection **OR** J-type **OR** L-type, **as directed**, fuse clips to accommodate specified fuses; hookstick-operated handle, lockable with two padlocks, and interlocked with cover in closed position. See Division 16 Section "Fuses" for fuses and fuse installation requirements.

2. Molded-Case Circuit Breakers: NEMA AB 1; hookstick-operated handle, lockable with two padlocks, and interlocked with cover in closed position.

3. TVSS: NEMA 250, Type 1 enclosure with NEMA KS 1, fusible, disconnect switch and external handle to isolate TVSS from busway. TVSS product and installation requirements are specified in Division 16 Section "Transient Voltage Suppression."

4. Motor Controllers: NEMA ICS 2, Class A, full voltage, nonreversing, across the line, unless otherwise indicated.

a. Control Circuit: 120 V; obtained from integral control power transformer, **as directed**, with a control power transformer **OR** source, **as directed**, of enough capacity to operate connected pilot, indicating and control devices, plus 100 percent spare capacity.

b. Combination Controller: Factory-assembled combination controller and disconnect switch with or without overcurrent protection as indicated.
   1) Fusible Disconnecting Means: NEMA KS 1, heavy-duty, fusible switch with R-type rejection **OR** J-type, **as directed**, fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 947-4-1, as certified by a nationally recognized testing laboratory (NRTL) acceptable to authorities having jurisdiction. See Division 26 Section "Fuses" for fuses and fuse installation requirements.
      OR
      Nonfusible Disconnecting Means: NEMA KS 1, heavy-duty, nonfusible switch.
      OR
      Circuit-Breaker Disconnecting Means: NEMA AB 1, motor-circuit protector with field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
c. Overload Relay: Ambient-compensated type with inverse-time-current characteristic and NEMA ICS 2, Class 10 **OR** Class 20 **OR** Class 30, **as directed**, tripping characteristic. Overload relays shall have heaters or sensors in each phase matched to nameplate full-load current of specific motor to which they connect and with appropriate adjustment for duty cycle.
d. Adjustable Overload Relay: Dipswitch selected for motor running overload protection with NEMA ICS 2, Class 10 **OR** Class 20 **OR** Class 30, **as directed**, tripping characteristic, and selected to protect motor against voltage and current unbalance and single phasing. Adjustable overload relays shall have Class II ground-fault protection with start and run delays to prevent nuisance trip on starting.

5. Multispeed Motor Controllers: Match controller to motor type, application, and number of speeds; include the following accessories:
   a. Compelling relay ensures motor starts only at low speed.
   b. Accelerating relay ensures properly timed acceleration through speeds lower than that selected.
   c. Decelerating relay ensures automatically timed deceleration through each speed.
6. Accessories: Hookstick operator, adjustable to maximum extension of 14 feet (4.3 m), **as directed**.

1.3 EXECUTION

A. Installation
   1. Support bus assemblies independent of supports for other elements such as equipment enclosures at connections to panelboards and switchboards, pipes, conduits, ceilings, and ducts.
      a. Design each fastener and support to carry load indicated by seismic requirements and to comply with seismic-restraint details according to Division 26 Section "Vibration And Seismic Controls For Electrical Systems".
      b. Design each fastener and support to carry 200 lb (90 kg) or 4 times the weight of bus assembly, whichever is greater.
      c. Support bus assembly to prevent twisting from eccentric loading.
      d. Support bus assembly with not less than 3/8-inch (10-mm) steel rods. Install side bracing to prevent swaying or movement of bus assembly. Modify supports after completion to eliminate strains and stresses on bus bars and housings.
      e. Fasten supports securely to building structure according to Division 26 Section "Hangers And Supports For Electrical Systems".
   2. Install expansion fittings at locations where bus assemblies cross building expansion joints. Install at other locations so distance between expansion fittings does not exceed manufacturer's recommended distance between fittings.
   3. Construct rated fire-stop assemblies where bus assemblies penetrate fire-rated elements such as walls, floors, and ceilings. Seal around penetrations according to Division 07 Section "Penetration Firestopping".

4. Install weatherseal fittings and flanges where bus assemblies penetrate exterior elements such as walls or roofs. Seal around openings to make weathertight. See Division 07 Section "Joint Sealants" for materials and application.
5. Install a concrete curb at least 4 inches (100 mm) high around bus-assembly floor penetrations.
6. Coordinate bus-assembly terminations to equipment enclosures to ensure proper phasing, connection, and closure.
7. Tighten bus-assembly joints with torque wrench or similar tool recommended by bus-assembly manufacturer. Tighten joints again after bus assemblies have been energized for 30 days.
8. Install bus-assembly, plug-in units. Support connecting conduit independent of plug-in unit.

B. Connections
1. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
2. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

C. Field Quality Control
1. Perform tests and inspections and prepare test reports.
2. Tests and Inspections:
   a. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
3. Remove and replace units that do not pass tests and inspections and retest as specified above.
4. Infrared Scanning: Two months after Substantial Completion, perform an infrared scan of bus assembly including joints and plug-in units.
   a. Use an infrared-scanning device designed to measure temperature or detect significant deviations from normal values. Provide documentation of device calibration.
   b. Perform 2 follow-up infrared scans of bus assembly, one at 4 months and the other at 11 months after Substantial Completion.
   c. Prepare a certified report identifying bus assembly checked and describing results of scanning. Include notation of deficiencies detected, remedial action taken, and scanning observations after remedial action.
5. Test Labeling: On completion of satisfactory testing of each unit, attach a dated and signed "Satisfactory Test" label to tested component.

D. Adjusting
1. Set field-adjustable, circuit-breaker trip ranges and overload relay trip settings, **as directed**, as indicated.

E. Cleaning
1. Vacuum dirt and debris; do not use compressed air to assist in cleaning.

F. Protection
1. Provide final protection to ensure that moisture does not enter bus assembly.

END OF SECTION 26 25 00 00

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Task	Specification	Specification Description
26 26 00 00	26 24 19 00a	Power Distribution Units
26 27 13 00	26 05 26 00b	Overhead Electrical Distribution
26 27 16 00	26 05 33 16	Raceways And Boxes
26 27 16 00	26 09 23 00b	Electrical Power Monitoring And Control
26 27 16 00	26 09 23 00c	Motor-Control Centers
26 27 23 00	26 05 33 16a	Wiring Devices
26 27 26 00	01 22 16 00	No Specification Required
26 27 26 00	26 05 33 16	Raceways And Boxes
26 27 26 00	26 05 33 16a	Wiring Devices
26 27 26 00	26 09 23 00b	Electrical Power Monitoring And Control
26 27 73 00	26 05 33 16a	Wiring Devices

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SECTION 26 28 13 00 - FUSES

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for fuses. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Cartridge fuses rated 600-V ac and less for use in control circuits, enclosed switches, panelboards, switchboards, enclosed controllers, and motor-control centers.
b. Plug fuses rated 125-V ac and less for use in plug-fuse-type enclosed switches, fuseholders, and panelboards.
c. Plug-fuse adapters for use in Edison-base, plug-fuse sockets.
d. Spare-fuse cabinets.

C. Submittals
1. Product Data: For each type of product indicated.
2. Operation and maintenance data.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. Comply with NEMA FU 1 for cartridge fuses.
3. Comply with NFPA 70.
4. Comply with UL 248-11 for plug fuses.

E. Project Conditions
1. Where ambient temperature to which fuses are directly exposed is less than 40 deg F (5 deg C) or more than 100 deg F (38 deg C), apply manufacturer's ambient temperature adjustment factors to fuse ratings.

1.2 PRODUCTS

A. Cartridge Fuses
1. Characteristics: NEMA FU 1, nonrenewable cartridge fuses with voltage ratings consistent with circuit voltages.

B. Plug Fuses
1. Characteristics: UL 248-11, nonrenewable plug fuses; 125-V ac.

C. Plug-Fuse Adapters
1. Characteristics: Adapters for using Type S, rejection-base plug fuses in Edison-base fuseholders or sockets; ampere ratings matching fuse ratings; irremovable once installed.

D. Spare-Fuse Cabinet
1. Characteristics: Wall-mounted steel unit with full-length, recessed piano-hinged door and key-coded cam lock and pull.
a. Size: Adequate for storage of spare fuses specified with 15 percent spare capacity minimum.

b. Finish: Gray, baked enamel.
c. Identification: "SPARE FUSES" in 1-1/2-inch- (38-mm-) high letters on exterior of door.
d. Fuse Pullers: For each size of fuse, where applicable and available, from fuse manufacturer.

1.3 EXECUTION

A. Fuse Applications
1. Cartridge Fuses:
a. Service Entrance: Class L, fast acting **OR** Class L, time delay **OR** Class RK1, fast acting **OR** Class RK1, time delay **OR** Class J, fast acting **OR** Class J, time delay **OR** Class T, fast acting, **as directed**.
b. Feeders: Class L, fast acting **OR** Class L, time delay **OR** Class RK1, fast acting **OR** Class RK1, time delay **OR** Class RK5, fast acting **OR** Class RK5, time delay **OR** Class J, fast acting **OR** Class J, time delay, **as directed**.
c. Motor Branch Circuits: Class RK1 **OR** Class RK5, **as directed**, time delay.
d. Other Branch Circuits: Class RK1, time delay **OR** Class RK5, time delay **OR** Class J, fast acting **OR** Class J, time delay, **as directed**.
e. Control Circuits: Class CC, fast acting **OR** time delay, **as directed**.
2. Plug Fuses:
a. Motor Branch Circuits: Edison-base type, dual **OR** Edison-base type, single **OR** Type S, dual **OR** Type S, single, **as directed**,-element time delay.
b. Other Branch Circuits: Edison-base type, single-element fast acting **OR** Edison-base type, dual-element time delay **OR** Edison-base type, single-element time delay **OR** Type S, dual-element time delay **OR** Type S, single-element time delay, **as directed**.

B. Installation
1. Install fuses in fusible devices. Arrange fuses so rating information is readable without removing fuse.
2. Install plug-fuse adapters in Edison-base fuseholders and sockets. Ensure that adapters are irremovable once installed.
3. Install spare-fuse cabinet(s).

C. Identification
1. Install labels complying with requirements for identification specified in Division 26 Section "Identification For Electrical Systems" and indicating fuse replacement information on inside door of each fused switch and adjacent to each fuse block, socket, and holder.

END OF SECTION 26 28 13 00

Task	Specification	Specification Description
26 28 13 00	26 24 19 00	Switchgear
26 29 13 13	01 22 16 00	No Specification Required
26 29 13 13	23 09 23 00	Enclosed Controllers

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SECTION 26 29 23 00 - VARIABLE FREQUENCY CONTROLLERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for variable frequency controllers. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section includes separately enclosed, pre-assembled, combination VFCs, rated 600 V and less, for speed control of three-phase, squirrel-cage induction motors.

C. Definitions
1. BAS: Building automation system.
2. CE: Conformite Europeene (European Compliance).
3. CPT: Control power transformer.
4. EMI: Electromagnetic interference.
5. IGBT: Insulated-gate bipolar transistor.
6. LAN: Local area network.
7. LED: Light-emitting diode.
8. MCP: Motor-circuit protector.
9. NC: Normally closed.
10. NO: Normally open.
11. OCPD: Overcurrent protective device.
12. PCC: Point of common coupling.
13. PID: Control action, proportional plus integral plus derivative.
14. PWM: Pulse-width modulated.
15. RFI: Radio-frequency interference.
16. TDD: Total demand (harmonic current) distortion.
17. THD(V): Total harmonic voltage demand.
18. VFC: Variable-frequency motor controller.

D. Performance Requirements
1. Seismic Performance: VFCs shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
   a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

E. Submittals
1. Product Data: For each type and rating of VFC indicated. Include features, performance, electrical ratings, operating characteristics, shipping and operating weights, and furnished specialties and accessories.
2. LEED Submittals:
   a. Product Data for Credit EA 5: For continuous metering equipment for energy consumption.
3. Shop Drawings: For each VFC indicated. Include dimensioned plans, elevations, and sections; and conduit entry locations and sizes, mounting arrangements, and details, including required clearances and service space around equipment.
   a. Show tabulations of installed devices, equipment features, and ratings. Include the following:
      1) Each installed unit's type and details.
      2) Factory-installed devices.

3) Enclosure types and details.
4) Nameplate legends.
5) Short-circuit current (withstand) rating of enclosed unit.
6) Features, characteristics, ratings, and factory settings of each VFC and installed devices.
7) Specified modifications.

b. Schematic and Connection Wiring Diagrams: For power, signal, and control wiring.

4. Harmonic Analysis Study and Report: Comply with IEEE 399 and NETA Acceptance Testing Specification; identify the effects of nonlinear loads and their associated harmonic contributions on the voltages and currents throughout the electrical system. Analyze possible **OR** designated, **as directed**, operating scenarios, including recommendations for VFC input filtering to limit TDD and THD(V) at each VFC **OR** at the defined PCC, **as directed**, to specified levels.
5. Coordination Drawings: Floor plans, drawn to scale, showing dimensioned layout, required working clearances, and required area above and around VFCs. Show VFC layout and relationships between electrical components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate field measurements.
6. Qualification Data: For qualified testing agency.
7. Seismic Qualification Certificates: For VFCs, accessories, and components, from manufacturer.
   a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
   c. Detailed description of equipment anchorage devices on which the certification is based, and their installation requirements.
8. Product Certificates: For each VFC, from manufacturer.
9. Source quality-control reports.
10. Field quality-control reports.
11. Operation and Maintenance Data: For VFCs to include in emergency, operation, and maintenance manuals. Include the following:
    a. Manufacturer's written instructions for testing and adjusting thermal-magnetic circuit breaker and MCP trip settings.
    b. Manufacturer's written instructions for setting field-adjustable overload relays.
    c. Manufacturer's written instructions for testing, adjusting, and reprogramming microprocessor control modules.
    d. Manufacturer's written instructions for setting field-adjustable timers, controls, and status and alarm points.
12. Load-Current and Overload-Relay Heater List: Compile after motors have been installed, and arrange to demonstrate that selection of heaters suits actual motor nameplate, full-load currents.
13. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed and arrange to demonstrate that switch settings for motor-running overload protection suit actual motors to be protected.

F. Quality Assurance
1. Testing Agency Qualifications: Member company of NETA or an NRTL.
   a. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.
2. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
3. Comply with NFPA 70.
4. IEEE Compliance: Fabricate and test VFC according to IEEE 344 to withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".

G. Delivery, Storage, And Handling

1. If stored in space that is not permanently enclosed and air conditioned, remove loose packing and flammable materials from inside controllers and install temporary electric heating, with at least 250 W per controller **OR** connect factory-installed space heaters to temporary electrical service, **as directed**.

H. Project Conditions
1. Environmental Limitations: Rate equipment for continuous operation, capable of driving full load without derating, under the following conditions unless otherwise indicated:
   a. Ambient Temperature: Not less than 14 deg F (minus 10 deg C) and not exceeding 104 deg F (40 deg C).
   b. Ambient Storage Temperature: Not less than minus 4 deg F (minus 20 deg C) and not exceeding 140 deg F (60 deg C)
   c. Humidity: Less than 95 percent (noncondensing).
   d. Altitude: Not exceeding 3300 feet (1005 m).
2. Interruption of Existing Electrical Systems: Do not interrupt electrical systems in facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:
   a. Notify Owner no fewer than two days in advance of proposed interruption of electrical systems.
   b. Indicate method of providing temporary electrical service.
   c. Do not proceed with interruption of electrical systems without Owner's written permission.
   d. Comply with NFPA 70E.
3. Product Selection for Restricted Space: Drawings indicate maximum dimensions for VFCs, including clearances between VFCs, and adjacent surfaces and other items.

I. Coordination
1. Coordinate features of motors, load characteristics, installed units, and accessory devices to be compatible with the following:
   a. Torque, speed, and horsepower requirements of the load.
   b. Ratings and characteristics of supply circuit and required control sequence.
   c. Ambient and environmental conditions of installation location.
2. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases.
3. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

J. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace VFCs that fail in materials or workmanship within specified warranty period.
   a. Warranty Period: Five years from date of Final Completion.

1.2 PRODUCTS

A. Manufactured Units
1. General Requirements for VFCs: Comply with NEMA ICS 7, NEMA ICS 61800-2, and UL 508C.
2. Application: Constant torque and variable torque.
3. VFC Description: Variable-frequency power converter (rectifier, dc bus, and IGBT, PWM inverter) factory packaged in an enclosure, with integral disconnecting means and overcurrent and overload protection; listed and labeled by an NRTL as a complete unit; arranged to provide self-protection, protection, and variable-speed control of one or more three-phase induction motors by adjusting output voltage and frequency.
   a. Units suitable for operation of NEMA MG 1, Design A and Design B motors as defined by NEMA MG 1, Section IV, Part 30, "Application Considerations for Constant Speed Motors Used on a Sinusoidal Bus with Harmonic Content and General Purpose Motors Used with Adjustable-Voltage or Adjustable-Frequency Controls or Both."

b. Units suitable for operation of inverter-duty motors as defined by NEMA MG 1, Section IV, Part 31, "Definite-Purpose Inverter-Fed Polyphase Motors."
c. Listed and labeled for integrated short-circuit current (withstand) rating by an NRTL acceptable to authorities having jurisdiction.

4. Design and Rating: Match load type, such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.
5. Output Rating: Three-phase; 10 to 60 Hz, with voltage proportional to frequency throughout voltage range **OR** 66 Hz, with torque constant as speed changes, **as directed**; maximum voltage equals input voltage.
6. Unit Operating Requirements:
   a. Input AC Voltage Tolerance: Plus 10 and minus 10 **OR** 15, **as directed**, percent of VFC input voltage rating.
   b. Input AC Voltage Unbalance: Not exceeding 3 **OR** 5, **as directed**, percent.
   c. Input Frequency Tolerance: Plus or minus 3 percent of VFC frequency rating.
   d. Minimum Efficiency: 96 **OR** 97, **as directed**, percent at 60 Hz, full load.
   e. Minimum Displacement Primary-Side Power Factor: 96 **OR** 98, **as directed**, percent under any load or speed condition.
   f. Minimum Short-Circuit Current (Withstand) Rating: 10 **OR** 22 **OR** 65 **OR** 100, **as directed**, kA.
   g. Ambient Temperature Rating: Not less than 14 deg F (minus 10 deg C) and not exceeding 104 deg F (40 deg C).
   h. Ambient Storage Temperature Rating: Not less than minus 4 deg F (minus 20 deg C) and not exceeding 140 deg F (60 deg C)
   i. Humidity Rating: Less than 95 percent (noncondensing).
   j. Altitude Rating: Not exceeding 3300 feet (1005 m).
   k. Vibration Withstand: Comply with IEC 60068-2-6.
   l. Overload Capability: 1.1 **OR** 1.5, **as directed**, times the base load current for 60 seconds; minimum of 1.8 times the base load current for three seconds.
   m. Starting Torque: Minimum 100 percent of rated torque from 3 to 60 Hz.
   n. Speed Regulation: Plus or minus 5 **OR** 10, **as directed**, percent.
   o. Output Carrier Frequency: Selectable; 0.5 to 15, **as directed**, kHz.
   p. Stop Modes: Programmable; includes fast, free-wheel, and dc injection braking.
7. Inverter Logic: Microprocessor based, 16 **OR** 32, **as directed**, bit, isolated from all power circuits.
8. Isolated Control Interface: Allows VFCs to follow remote-control signal over a minimum 40:1 speed range.
   a. Signal: Electrical.
   b. Signal: Pneumatic.
9. Internal Adjustability Capabilities:
   a. Minimum Speed: 5 to 25 percent of maximum rpm.
   b. Maximum Speed: 80 to 100 percent of maximum rpm.
   c. Acceleration: 0.1 to 999.9 seconds.
   d. Deceleration: 0.1 to 999.9 seconds.
   e. Current Limit: 30 to minimum of 150 percent of maximum rating.
10. Self-Protection and Reliability Features:
   a. Input transient protection by means of surge suppressors to provide three-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.
   b. Loss of Input Signal Protection: Selectable response strategy, including speed default to a percent of the most recent speed, a preset speed, or stop; with alarm.
   c. Under- and overvoltage trips.
   d. Inverter overcurrent trips.
   e. VFC and Motor Overload/Overtemperature Protection: Microprocessor-based thermal protection system for monitoring VFCs and motor thermal characteristics, and for providing

VFC overtemperature and motor overload alarm and trip; settings selectable via the keypad; NRTL approved.

f. Critical frequency rejection, with three selectable, adjustable deadbands.
g. Instantaneous line-to-line and line-to-ground overcurrent trips.
h. Loss-of-phase protection.
i. Reverse-phase protection.
j. Short-circuit protection.
k. Motor overtemperature fault.

11. Automatic Reset/Restart: Attempt three restarts after drive fault or on return of power after an interruption and before shutting down for manual reset or fault correction; adjustable delay time between restart attempts.
12. Power-Interruption Protection: To prevent motor from re-energizing after a power interruption until motor has stopped, unless "Bidirectional Autospeed Search" feature is available and engaged.
13. Bidirectional Autospeed Search: Capable of starting VFC into rotating loads spinning in either direction and returning motor to set speed in proper direction, without causing damage to drive, motor, or load.
14. Torque Boost: Automatically varies starting and continuous torque to at least 1.5 times the minimum torque to ensure high-starting torque and increased torque at slow speeds.
15. Motor Temperature Compensation at Slow Speeds: Adjustable current fall-back based on output frequency for temperature protection of self-cooled, fan-ventilated motors at slow speeds.
16. Integral Input Disconnecting Means and OCPD: NEMA AB 1, instantaneous-trip circuit breaker **OR** NEMA AB 1, molded-case switch, with power fuse block and current-limiting fuses **OR** NEMA AB 1, thermal-magnetic circuit breaker **OR** NEMA KS 1, nonfusible switch, with power fuse block and current-limiting fuses **OR** NEMA KS 1, fusible switch, **as directed**, with pad-lockable, door-mounted handle mechanism.
    a. Disconnect Rating: Not less than 115 percent of VFC input current rating.
    b. Disconnect Rating: Not less than 115 percent of NFPA 70 motor full-load current rating or VFC input current rating, whichever is larger.
    c. Auxiliary Contacts: NO/NC, arranged to activate before switch blades open.
    d. Auxiliary contacts "a" and "b" arranged to activate with circuit-breaker handle.
    e. NC **OR** NO, **as directed**, alarm contact that operates only when circuit breaker has tripped.

B. Controls And Indication
1. Status Lights: Door-mounted LED indicators displaying the following conditions:
    a. Power on.
    b. Run.
    c. Overvoltage.
    d. Line fault.
    e. Overcurrent.
    f. External fault.
2. Panel-Mounted Operator Station: Manufacturer's standard front-accessible, sealed keypad and plain-English language digital display; allows complete programming, program copying, operating, monitoring, and diagnostic capability.
    a. Keypad: In addition to required programming and control keys, include keys for HAND, OFF, and AUTO modes.
    b. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: View only; view and operate; and view, operate, and service.
        1) Control Authority: Supports at least four conditions: Off, local manual control at VFC, local automatic control at VFC, and automatic control through a remote source.
3. Historical Logging Information and Displays:
    a. Real-time clock with current time and date.
    b. Running log of total power versus time.

c. Total run time.
d. Fault log, maintaining last four faults with time and date stamp for each.

4. Indicating Devices: Digital display and additional readout devices as required, mounted flush in VFC door and connected to display VFC parameters including, but not limited to:
   a. Output frequency (Hz).
   b. Motor speed (rpm).
   c. Motor status (running, stop, fault).
   d. Motor current (amperes).
   e. Motor torque (percent).
   f. Fault or alarming status (code).
   g. PID feedback signal (percent).
   h. DC-link voltage (V dc).
   i. Set point frequency (Hz).
   j. Motor output voltage (V ac).
5. Control Signal Interfaces:
   a. Electric Input Signal Interface:
      1) A minimum of two programmable analog inputs: 0- to 10-V dc **OR** 4- to 20-mA dc **OR** Operator-selectable "x"- to "y"-mA dc, **as directed**.
      2) A minimum of six multifunction programmable digital inputs.
   b. Pneumatic Input Signal Interface: 3 to 15 psig (20 to 104 kPa).
   c. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals from the BAS or other control systems:
      1) 0- to 10-V dc.
      2) 4- to 20-mA dc.
      3) Potentiometer using up/down digital inputs.
      4) Fixed frequencies using digital inputs.
   d. Output Signal Interface: A minimum of one programmable analog output signal(s) (0- to 10-V dc **OR** 4- to 20-mA dc **OR** operator-selectable "x"- to "y"-mA dc, **as directed**), which can be configured for any of the following:
      1) Output frequency (Hz).
      2) Output current (load).
      3) DC-link voltage (V dc).
      4) Motor torque (percent).
      5) Motor speed (rpm).
      6) Set point frequency (Hz).
   e. Remote Indication Interface: A minimum of two programmable dry-circuit relay outputs (120-V ac, 1 A) for remote indication of the following:
      1) Motor running.
      2) Set point speed reached.
      3) Fault and warning indication (overtemperature or overcurrent).
      4) PID high- or low-speed limits reached.
6. PID Control Interface: Provides closed-loop set point, differential feedback control in response to dual feedback signals. Allows for closed-loop control of fans and pumps for pressure, flow, or temperature regulation.
   a. Number of Loops: One **OR** Two, **as directed**.
7. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display VFC status and alarms and energy usage. Allows VFC to be used with an external system within a multidrop LAN configuration; settings retained within VFC's nonvolatile memory.
   a. Network Communications Ports: Ethernet and RS-422/485.
   b. Embedded BAS Protocols for Network Communications: ASHRAE 135 BACnet **OR** Echelon LonWorks **OR** Johnson Metasys N2 **OR** Modbus/Memobus **OR** Siemens System 600 APOGEE, **as directed**; protocols accessible via the communications ports.

C. Line Conditioning And Filtering

1. Input Line Conditioning: Based on the harmonic analysis study and report, provide input filtering, as required, to limit TDD at input terminals of all **OR** indicated, **as directed**, VFCs to less than 5 **OR** 8, **as directed**, percent and THD(V) to 3 **OR** 5, **as directed**, percent.
   OR
   Input Line Conditioning: Based on the harmonic analysis study and report, provide input filtering, as required, to limit TDD and THD(V) at the defined PCC per IEEE 519.
2. Output Filtering: <**Insert requirements**>.
3. EMI/RFI Filtering: CE marked; certify compliance with IEC 61800-3 for Category C2.

D. Bypass Systems
1. Bypass Operation: Safely transfers motor between power converter output and bypass circuit, manually, automatically, or both. Selector switches set modes and indicator lights indicate mode selected. Unit is capable of stable operation (starting, stopping, and running) with motor completely disconnected from power converter.
2. Bypass Mode: Manual operation only; requires local operator selection at VFC. Transfer between power converter and bypass contactor and retransfer shall only be allowed with the motor at zero speed.
   OR
   Bypass Mode: Field-selectable automatic or manual, allows local and remote transfer between power converter and bypass contactor and retransfer, either via manual operator interface or automatic control system feedback.
3. Bypass Controller: Two-contactor-style bypass allows motor operation via the power converter or the bypass controller; with input isolating switch and barrier arranged to isolate the power converter and permit safe troubleshooting and testing, both energized and de-energized, while motor is operating in bypass mode.
   a. Bypass Contactor: Load-break, IEC **OR** NEMA **as directed**,-rated contactor.
   b. Output Isolating Contactor: Non-load-break, IEC **OR** NEMA, **as directed**,-rated contactor.
   c. Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.
   OR
   Bypass Controller: Three-contactor-style bypass allows motor operation via the power converter or the bypass controller; with input isolating switch and barrier arranged to isolate the power converter input and output and permit safe testing and troubleshooting of the power converter, both energized and de-energized, while motor is operating in bypass mode.
   a. Bypass Contactor: Load-break, IEC **OR** NEMA, **as directed**,-rated contactor.
   b. Input and Output Isolating Contactors: Non-load-break, IEC **OR** NEMA, **as directed**,-rated contactors.
   c. Isolating Switch: Non-load-break switch arranged to isolate power converter and permit safe troubleshooting and testing of the power converter, both energized and de-energized, while motor is operating in bypass mode; pad-lockable, door-mounted handle mechanism.
4. Bypass Contactor Configuration: Full-voltage (across-the-line) **OR** Reduced-voltage (autotransformer), **as directed**, type.
   a. NORMAL/BYPASS selector switch.
   b. HAND/OFF/AUTO selector switch.
   c. NORMAL/TEST Selector Switch: Allows testing and adjusting of VFC while the motor is running in the bypass mode.
   d. Contactor Coils: Pressure-encapsulated type with coil transient suppressors, **as directed**.
      1) Operating Voltage: Depending on contactor NEMA size and line-voltage rating, manufacturer's standard matching control power or line voltage.
      2) Power Contacts: Totally enclosed, double break, and silver-cadmium oxide; assembled to allow inspection and replacement without disturbing line or load wiring.
   e. Control Circuits: 120-V ac; obtained from integral CPT, with primary and secondary fuses, with CPT **OR** control power source, **as directed**, of sufficient capacity to operate all integral devices and remotely located pilot, indicating, and control devices.
      1) CPT Spare Capacity: 50 **OR** 100 **OR** 200, **as directed**, VA.

f. Overload Relays: NEMA ICS 2.
   1) Melting-Alloy Overload Relays:
      a) Inverse-time-current characteristic.
      b) Class 10 **OR** Class 20 **OR** Class 30, **as directed**, tripping characteristic.
      c) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
   2) Bimetallic Overload Relays:
      a) Inverse-time-current characteristic.
      b) Class 10 **OR** Class 20 **OR** Class 30, **as directed**, tripping characteristic.
      c) Heaters in each phase matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
      d) Ambient compensated.
      e) Automatic resetting.
   3) Solid-State Overload Relays:
      a) Switch or dial selectable for motor-running overload protection.
      b) Sensors in each phase.
      c) Class 10 **OR** Class 20 **OR** Class 10/20 selectable, **as directed**, tripping characteristic selected to protect motor against voltage and current unbalance and single phasing.
      d) Class II ground-fault protection, with start and run delays to prevent nuisance trip on starting.
      e) Analog communication module.
   4) NC **OR** NO, **as directed**, isolated overload alarm contact.
   5) External overload reset push button.

E. Optional Features
   1. Multiple-Motor Capability: VFC suitable for variable-speed service to multiple motors. Overload protection shuts down VFC and motors served by it, and generates fault indications, when overload protection activates.
      a. Configure to allow two or more motors to operate simultaneously at the same speed; separate overload relay for each controlled motor.
         OR
         Configure to allow two motors to operate separately; operator selectable via local or remote switch or contact closures; single overload relay for both motors; separate output magnetic contactors for each motor.
         OR
         Configure to allow two motors to operate simultaneously and in a lead/lag mode, with one motor operated at variable speed via the power converter and the other at constant speed via the bypass controller; separate overload relay for each controlled motor.
   2. Damper control circuit with end of travel feedback capability.
   3. Sleep Function: Senses a minimal deviation of a feedback signal and stops the motor. On an increase in speed-command signal deviation, VFC resumes normal operation.
   4. Motor Preheat Function: Preheats motor when idle to prevent moisture accumulation in the motor.
   5. Firefighter's Override (Smoke Purge) Input: On a remote contact closure from the firefighter's control station **OR** smoke-control fan controller, **as directed**, this password-protected input:
      a. Overrides all other local and external inputs (analog/digital, serial communication, and all keypad commands).
      b. Forces VFC to operate motor, without any other run or speed command, at a field-adjustable, preset speed.
         OR
         Forces VFC to transfer to Bypass Mode and operate motor at full speed.
      c. Causes display of Override Mode on the VFC display.
      d. Reset VFC to normal operation on removal of override signal automatically **OR** manually, **as directed**.

6. Remote Indicating Circuit Terminals: Mode selection, controller status, and controller fault.
7. Remote digital operator kit.
8. Communication Port: RS-232 port, USB 2.0 port, or equivalent connection capable of connecting a printer and a notebook computer.

F. Enclosures
1. VFC Enclosures: NEMA 250, to comply with environmental conditions at installed location.
   a. Dry and Clean Indoor Locations: Type 1.
   b. Outdoor Locations: Type 3R **OR** Type 4X, **as directed**.
   c. Kitchen **OR** Wash-Down, **as directed**, Areas: Type 4X, stainless steel.
   d. Other Wet or Damp Indoor Locations: Type 4.
   e. Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: Type 12.
2. Plenum Rating: UL 1995; NRTL certification label on enclosure, clearly identifying VFC as "Plenum Rated."

G. Accessories
1. General Requirements for Control-Circuit and Pilot Devices: NEMA ICS 5; factory installed in VFC enclosure cover unless otherwise indicated.
   a. Push Buttons, Pilot Lights, and Selector Switches: Heavy **OR** Standard, **as directed**,-duty, oiltight, **as directed**, type.
      1) Push Buttons: Covered **OR** Lockable **OR** Recessed **OR** Shielded **OR** Shrouded **OR** Unguarded, **as directed**, types; maintained **OR** momentary, **as directed**.
      2) Pilot Lights: Incandescent **OR** LED **OR** Neon **OR** Resistor **OR** Transformer, **as directed**, types; push to test.
      3) Selector Switches: Rotary type.
      4) Stop and Lockout Push-Button Station: Momentary-break, push-button station with a factory-applied hasp arranged so padlock can be used to lock push button in depressed position with control circuit open.
2. NC **OR** NO **OR** Reversible NC/NO, **as directed**, bypass contactor auxiliary contact(s).
3. Control Relays: Auxiliary and adjustable pneumatic **OR** solid-state, **as directed**, time-delay relays.
4. Phase-Failure, Phase-Reversal, and Undervoltage and Overvoltage Relays: Solid-state sensing circuit with isolated output contacts for hard-wired connections. Provide adjustable undervoltage, overvoltage, and time-delay settings.
   a. Current Transformers: Continuous current rating, basic impulse insulating level (BIL) rating, burden, and accuracy class suitable for connected circuitry. Comply with IEEE C57.13.
5. Supplemental Analog **OR** Digital, **as directed**, Meters:
   a. Elapsed-time meter.
   b. Kilowatt meter.
   c. Kilowatt-hour meter.
6. Breather and drain assemblies, to maintain interior pressure and release condensation in NEMA 250, Type 4 **OR** Type 4X **OR** Type 12, **as directed**, enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.
7. Space heaters, with NC auxiliary contacts, to mitigate condensation in NEMA 250, Type 3R **OR** Type 4X **OR** Type 12, **as directed**, enclosures installed outdoors or in unconditioned interior spaces subject to humidity and temperature swings.
8. Cooling Fan and Exhaust System: For NEMA 250, Type 1 **OR** Type 12, **as directed**; UL 508 component recognized: Supply fan, with composite **OR** stainless steel, **as directed**, intake and exhaust grills and filters, **as directed**; 120-V ac; obtained from integral CPT.
9. Sun shields installed on fronts, sides, and tops of enclosures installed outdoors and subject to direct and extended sun exposure.
10. Spare control-wiring terminal blocks; unwired **OR** wired, **as directed**.

H. Source Quality Control

1. Testing: Test and inspect VFCs according to requirements in NEMA ICS 61800-2.
   a. Test each VFC while connected to its specified motor **OR** a motor that is comparable to that for which the VFC is rated, **as directed**.
   b. Verification of Performance: Rate VFCs according to operation of functions and features specified.
2. VFCs will be considered defective if they do not pass tests and inspections.
3. Prepare test and inspection reports.

1.3 EXECUTION

A. Examination
1. Examine areas, surfaces, and substrates to receive VFCs, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance.
2. Examine VFC before installation. Reject VFCs that are wet, moisture damaged, or mold damaged.
3. Examine roughing-in for conduit systems to verify actual locations of conduit connections before VFC installation.
4. Proceed with installation only after unsatisfactory conditions have been corrected.

B. Harmonic Analysis Study
1. Perform a harmonic analysis study to identify the effects of nonlinear loads and their associated harmonic contributions on the voltages and currents throughout the electrical system. Analyze possible **OR** designated, **as directed**, operating scenarios, including recommendations for VFC input filtering to limit TDD and THD(V) at each VFC **OR** at the defined PCC, **as directed**, to specified levels.
2. Prepare a harmonic analysis study and report complying with IEEE 399 and NETA Acceptance Testing Specification.

C. Installation
1. Coordinate layout and installation of VFCs with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.
2. Wall-Mounting Controllers: Install VFCs on walls with tops at uniform height and with disconnect operating handles not higher than 79 inches (2000 mm) above finished floor unless otherwise indicated, and by bolting units to wall or mounting on lightweight structural-steel channels bolted to wall. For controllers not on walls, provide freestanding racks complying with Division 26 Section "Hangers And Supports For Electrical Systems".
3. Floor-Mounting Controllers: Install VFCs on 4-inch (100-mm) nominal thickness concrete base. Comply with requirements for concrete base specified in Division 03 Section "Cast-in-place Concrete".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.
   b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   d. Install anchor bolts to elevations required for proper attachment to supported equipment.
4. Roof-Mounting Controllers: Install VFC on roofs with tops at uniform height and with disconnect operating handles not higher than 79 inches (2000 mm) above finished roof surface unless otherwise indicated, and by bolting units to curbs or mounting on freestanding, lightweight, structural-steel channels bolted to curbs. Seal roof penetrations after raceways are installed.
   a. Curbs and roof penetrations are specified in Division 07 Section "Roof Accessories".
   b. Structural-steel channels are specified in Division 26 Section "Hangers And Supports For Electrical Systems".

5. Seismic Bracing: Comply with requirements specified in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".
6. Temporary Lifting Provisions: Remove temporary lifting eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.
7. Install fuses in each fusible-switch VFC.
8. Install fuses in control circuits if not factory installed. Comply with requirements in Division 26 Section "Fuses".
9. Install heaters in thermal-overload relays. Select heaters based on actual nameplate full-load amperes after motors have been installed.
10. Install, connect, and fuse thermal-protector monitoring relays furnished with motor-driven equipment.
11. Comply with NECA 1.

D. Identification
1. Identify VFCs, components, and control wiring. Comply with requirements for identification specified in Division 26 Section "Identification For Electrical Systems".
   a. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
   b. Label each VFC with engraved nameplate.
   c. Label each enclosure-mounted control and pilot device.
2. Operating Instructions: Frame printed operating instructions for VFCs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of VFC units.

E. Control Wiring Installation
1. Install wiring between VFCs and remote devices and facility's central-control system, **as directed**. Comply with requirements in Division 26 Section "Control-voltage Electrical Power Cables"
2. Bundle, train, and support wiring in enclosures.
3. Connect selector switches and other automatic control devices where applicable.
   a. Connect selector switches to bypass only those manual- and automatic control devices that have no safety functions when switches are in manual-control position.
   b. Connect selector switches with control circuit in both manual and automatic positions for safety-type control devices such as low- and high-pressure cutouts, high-temperature cutouts, and motor overload protectors.

F. Field Quality Control
1. Perform tests and inspections.
2. Acceptance Testing Preparation:
   a. Test insulation resistance for each VFC element, bus, component, connecting supply, feeder, and control circuit.
   b. Test continuity of each circuit.
3. Tests and Inspections:
   a. Inspect VFC, wiring, components, connections, and equipment installation. Test and adjust controllers, components, and equipment.
   b. Test insulation resistance for each VFC element, component, connecting motor supply, feeder, and control circuits.
   c. Test continuity of each circuit.
   d. Verify that voltages at VFC locations are within 10 percent of motor nameplate rated voltages. If outside this range for any motor, notify Owner before starting the motor(s).
   e. Test each motor for proper phase rotation.
   f. Perform each electrical test and visual and mechanical inspection stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
   g. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

h. Perform the following infrared (thermographic) scan tests and inspections and prepare reports:
   1) Initial Infrared Scanning: After Final Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each VFC. Remove front panels so joints and connections are accessible to portable scanner.
   2) Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each VFC 11 months after date of Final Completion.
   3) Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

i. Test and adjust controls, remote monitoring, and safeties. Replace damaged and malfunctioning controls and equipment.

4. VFCs will be considered defective if they do not pass tests and inspections.
5. Prepare test and inspection reports, including a certified report that identifies the VFC and describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations made after remedial action.

G. Startup Service
1. Perform startup service.
   a. Complete installation and startup checks according to manufacturer's written instructions.

H. Adjusting
1. Program microprocessors for required operational sequences, status indications, alarms, event recording, and display features. Clear events memory after final acceptance testing and prior to Final Completion.
2. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and overload-relay pickup and trip ranges.
3. Adjust the trip settings of MCPs and thermal-magnetic circuit breakers with adjustable, instantaneous trip elements. Initially adjust to six times the motor nameplate full-load amperes and attempt to start motors several times, allowing for motor cool-down between starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping. Do not exceed eight times the motor full-load amperes (or 11 times for NEMA Premium Efficient motors if required). Where these maximum settings do not allow starting of a motor, notify Owner before increasing settings.
4. Set the taps on reduced-voltage autotransformer controllers.
5. Set field-adjustable circuit-breaker trip ranges as specified in Division 26 Section "Overcurrent Protective Device Coordination Study".
6. Set field-adjustable pressure switches.

I. Protection
1. Temporary Heating: Apply temporary heat to maintain temperature according to manufacturer's written instructions until controllers are ready to be energized and placed into service.
2. Replace VFCs whose interiors have been exposed to water or other liquids prior to Final Completion.

J. Demonstration
1. Train Owner's maintenance personnel to adjust, operate, reprogram, and maintain VFCs.

END OF SECTION 26 29 23 00

Task	Specification	Specification Description
26 31 00 00	01 22 16 00	No Specification Required

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SECTION 26 32 13 13 - PACKAGED ENGINE GENERATORS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for packaged engine generators. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes packaged engine-generator sets for emergency **OR** standby, **as directed**, power supply with the following features:
   a. Gas and Diesel engine.
   b. Unit-mounted and Remote-mounting cooling system.
   c. Unit-mounted and Remote-mounting control and monitoring.
   d. Performance requirements for sensitive loads.
   e. Load banks.
   f. Outdoor enclosure.

C. Definitions
1. Operational Bandwidth: The total variation from the lowest to highest value of a parameter over the range of conditions indicated, expressed as a percentage of the nominal value of the parameter.
2. LP: Liquid petroleum.

D. Submittals
1. Product Data: For each type of packaged engine generator and accessory indicated.
2. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Manufacturer Seismic Qualification Certification: Submit certification that day tank, engine-generator set, batteries, battery racks, accessories, and components will withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".
4. Source quality-control test reports.
5. Field quality-control test reports.
6. Operation and maintenance data.
7. Warranty: Special warranty specified in this Section.

E. Quality Assurance
1. Installer Qualifications: Manufacturer's authorized representative who is trained and approved for installation of units required for this Project.
2. Manufacturer Qualifications: A qualified manufacturer. Maintain, within 200 miles (321 km) of Project site, a service center capable of providing training, parts, and emergency maintenance repairs.
3. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
4. Comply with ASME B15.1.
5. Comply with NFPA 37.
6. Comply with NFPA 70.
7. Comply with NFPA 99 for healthcare facilities.
8. Comply with NFPA 110 requirements for Level 1 **OR** 2, **as directed,** emergency power supply system.

9. Comply with UL 2200.
10. Engine Exhaust Emissions: Comply with applicable state and local government requirements.
11. Noise Emission: Comply with applicable state and local government requirements for maximum noise level at adjacent property boundaries due to sound emitted by generator set including engine, engine exhaust, engine cooling-air intake and discharge, and other components of installation.

F. Project Conditions
1. Environmental Conditions: Engine-generator system shall withstand the following environmental conditions without mechanical or electrical damage or degradation of performance capability:
   a. Ambient Temperature: 5 to 40 deg C **OR** Minus 15 to plus 40 deg C, **as directed**.
   b. Relative Humidity: 0 to 95 percent for outdoor units.
   c. Altitude: Sea level to 1000 feet (300 m).
2. Unusual Service Conditions: Engine-generator equipment and installation are required to operate under the following conditions:
   a. High salt-dust content in the air due to sea-spray evaporation.

1.2 PRODUCTS

A. Engine-Generator Set
1. Factory-assembled and -tested, engine-generator set.
2. Mounting Frame: Maintain alignment of mounted components without depending on concrete foundation; and have lifting attachments.
   a. Rigging Diagram: Inscribed on metal plate permanently attached to mounting frame to indicate location and lifting capacity of each lifting attachment and generator-set center of gravity.
3. Capacities and Characteristics:
   a. Power Output Ratings: Nominal ratings as indicated, with capacity as required to operate as a unit as evidenced by records of prototype testing.
   b. Output Connections: Three-phase, three **OR** four, **as directed,** wire.
   c. Nameplates: For each major system component to identify manufacturer's name and address, and model and serial number of component.
4. Generator-Set Performance:
   a. Steady-State Voltage Operational Bandwidth: 3 percent of rated output voltage from no load to full load.
   b. Transient Voltage Performance: Not more than 20 percent variation for 50 percent step-load increase or decrease. Voltage shall recover and remain within the steady-state operating band within three seconds.
   c. Steady-State Frequency Operational Bandwidth: 0.5 percent of rated frequency from no load to full load.
   d. Steady-State Frequency Stability: When system is operating at any constant load within the rated load, there shall be no random speed variations outside the steady-state operational band and no hunting or surging of speed.
   e. Transient Frequency Performance: Less than 5 percent variation for 50 percent step-load increase or decrease. Frequency shall recover and remain within the steady-state operating band within five seconds.
   f. Output Waveform: At no load, harmonic content measured line to line or line to neutral shall not exceed 5 percent total and 3 percent for single harmonics. Telephone influence factor, determined according to NEMA MG 1, shall not exceed 50 percent.
   g. Sustained Short-Circuit Current: For a 3-phase, bolted short circuit at system output terminals, system shall supply a minimum of 250 percent of rated full-load current for not less than 10 seconds and then clear the fault automatically, without damage to generator system components.
   h. Start Time: Comply with NFPA 110, Type 10, system requirements.

5. Generator-Set Performance for Sensitive Loads:
   a. Oversizing generator compared with the rated power output of the engine is permissible to meet specified performance.
      1) Nameplate Data for Oversized Generator: Show ratings required by the Contract Documents rather than ratings that would normally be applied to generator size installed.
   b. Steady-State Voltage Operational Bandwidth: 1 percent of rated output voltage from no load to full load.
   c. Transient Voltage Performance: Not more than 10 percent variation for 50 percent step-load increase or decrease. Voltage shall recover and remain within the steady-state operating band within 0.5 second.
   d. Steady-State Frequency Operational Bandwidth: Plus or minus 0.25 percent of rated frequency from no load to full load.
   e. Steady-State Frequency Stability: When system is operating at any constant load within the rated load, there shall be no random speed variations outside the steady-state operational band and no hunting or surging of speed.
   f. Transient Frequency Performance: Less than 2-Hz variation for 50 percent step-load increase or decrease. Frequency shall recover and remain within the steady-state operating band within three seconds.
   g. Output Waveform: At no load, harmonic content measured line to neutral shall not exceed 2 percent total with no slot ripple. Telephone influence factor, determined according to NEMA MG 1, shall not exceed 50 percent.
   h. Sustained Short-Circuit Current: For a 3-phase, bolted short circuit at system output terminals, system shall supply a minimum of 300 percent of rated full-load current for not less than 10 seconds and then clear the fault automatically, without damage to winding insulation or other generator system components.
   i. Excitation System: Performance shall be unaffected by voltage distortion caused by nonlinear load.
      1) Provide permanent magnet excitation for power source to voltage regulator.
   j. Start Time: Comply with NFPA 110, Type 10, system requirements.

B. Engine
   1. Fuel: Fuel oil, Grade DF-2 **OR** Natural gas with automatic LP-gas standby **OR** Natural gas, **as directed**.
   2. Rated Engine Speed: 1800 rpm.
   3. Maximum Piston Speed for Four-Cycle Engines: 2250 fpm (11.4 m/s).
   4. Lubrication System: The following items are mounted on engine or skid:
      a. Filter and Strainer: Rated to remove 90 percent of particles 5 micrometers and smaller while passing full flow.
      b. Thermostatic Control Valve: Control flow in system to maintain optimum oil temperature. Unit shall be capable of full flow and is designed to be fail-safe.
      c. Crankcase Drain: Arranged for complete gravity drainage to an easily removable container with no disassembly and without use of pumps, siphons, special tools, or appliances.
   5. Engine Fuel System:
      a. Main Fuel Pump For Diesel-Fueled Engine: Mounted on engine. Pump ensures adequate primary fuel flow under starting and load conditions.
      b. Relief-Bypass Valve For Diesel-Fueled Engine: Automatically regulates pressure in fuel line and returns excess fuel to source.
      c. Dual Natural Gas with LP-Gas Backup (Vapor-Withdrawal) System:
         1) Carburetor.
         2) Secondary Gas Regulators: One for each fuel type.
         3) Fuel-Shutoff Solenoid Valves: One for each fuel source.
         4) Flexible Fuel Connectors: One for each fuel source.
   6. Coolant Jacket Heater: Electric-immersion type, factory installed in coolant jacket system. Comply with NFPA 110 requirements for Level 1 equipment for heater capacity.
   7. Governor: Adjustable isochronous, with speed sensing.

8. Cooling System:
   a. Closed loop, liquid cooled, with radiator factory mounted on engine-generator-set mounting frame and integral engine-driven coolant pump.
      1) Coolant: Solution of 50 percent ethylene-glycol-based antifreeze and 50 percent water, with anticorrosion additives as recommended by engine manufacturer.
      2) Size of Radiator: Adequate to contain expansion of total system coolant from cold start to 110 percent load condition.
      3) Expansion Tank: Constructed of welded steel plate and rated to withstand maximum closed-loop coolant system pressure for engine used. Equip with gage glass and petcock.
      4) Temperature Control: Self-contained, thermostatic-control valve modulates coolant flow automatically to maintain optimum constant coolant temperature as recommended by engine manufacturer.
      5) Coolant Hose: Flexible assembly with inside surface of nonporous rubber and outer covering of aging-, ultraviolet-, and abrasion-resistant fabric.
         a) Rating: 50-psig (345-kPa) maximum working pressure with coolant at 180 deg F (82 deg C), and noncollapsible under vacuum.
         b) End Fittings: Flanges or steel pipe nipples with clamps to suit piping and equipment connections.
   b. Closed loop, liquid cooled, with remote radiator and integral engine-driven coolant pump.
      1) Configuration: Vertical **OR** Horizontal, **as directed,** air discharge.
      2) Radiator Core Tubes: Aluminum **OR** Nonferrous-metal construction other than aluminum, **as directed**.
      3) Size of Radiator: Adequate to contain expansion of total system coolant from cold start to 110 percent load condition.
      4) Expansion Tank: Constructed of welded steel plate and rated to withstand maximum closed-loop coolant system pressure for engine used. Equip with gage glass and petcock.
      5) Fan: Driven by multiple belts from engine shaft **OR** totally enclosed electric motor with sealed bearings, **as directed**.
      6) Coolant: Solution of 50 percent ethylene-glycol-based antifreeze and 50 percent water, with anticorrosion additives as recommended by engine manufacturer.
      7) Temperature Control: Self-contained, thermostatic-control valve modulates coolant flow automatically to maintain optimum constant coolant temperature as recommended by engine manufacturer.
9. Muffler/Silencer:
   a. Critical type, sized as recommended by engine manufacturer and selected with exhaust piping system to not exceed engine manufacturer's engine backpressure requirements.
      1) Minimum sound attenuation of 25 dB at 500 Hz.
      2) Sound level measured at a distance of 10 feet (3 m) from exhaust discharge after installation is complete shall be 85 dBA or less.
   b. Residential type, sized as recommended by engine manufacturer and selected with exhaust piping system to not exceed engine manufacturer's engine backpressure requirements.
      1) Minimum sound attenuation of 18 dB at 500 Hz.
      2) Sound level measured at a distance of 10 feet (3 m) from exhaust discharge after installation is complete shall be 95 dBA or less.
   c. Industrial type, sized as recommended by engine manufacturer and selected with exhaust piping system to not exceed engine manufacturer's engine backpressure requirements.
      1) Minimum sound attenuation of 12 dB at 500 Hz.
      2) Sound level measured at a distance of 25 feet (8 m) from exhaust discharge after installation is complete shall be 87 dBA or less.
10. Air-Intake Filter: Standard **OR** Heavy, **as directed,**-duty, engine-mounted air cleaner with replaceable dry-filter element and "blocked filter" indicator.
11. Starting System: 12 **OR** 24, **as directed,**-V electric, with negative ground.

a. Components: Sized so they will not be damaged during a full engine-cranking cycle with ambient temperature at maximum specified in Part 1 "Project Conditions" Article.
b. Cranking Motor: Heavy-duty unit that automatically engages and releases from engine flywheel without binding.
c. Cranking Cycle: As required by NFPA 110 for system level specified **OR** 60 seconds, **as directed**.
d. Battery: Adequate capacity within ambient temperature range specified in Part 1.1 "Project Conditions" Article to provide specified cranking cycle at least twice **OR** three times, **as directed**, without recharging.
e. Battery Cable: Size as recommended by engine manufacturer for cable length indicated. Include required interconnecting conductors and connection accessories.
f. Battery Compartment: Factory fabricated of metal with acid-resistant finish and thermal insulation. Thermostatically controlled heater shall be arranged to maintain battery above 10 deg C regardless of external ambient temperature within range specified in Part 1.1 "Project Conditions" Article. Include accessories required to support and fasten batteries in place.
g. Battery-Charging Alternator: Factory mounted on engine with solid-state voltage regulation and 35-A minimum continuous rating.
h. Battery Charger: Current-limiting, automatic-equalizing and float-charging type. Unit shall comply with UL 1236.
   1) Operation: Equalizing-charging rate of 10 A shall be initiated automatically after battery has lost charge until an adjustable equalizing voltage is achieved at battery terminals. Unit shall then be automatically switched to a lower float-charging mode and shall continue to operate in that mode until battery is discharged again.
   2) Automatic Temperature Compensation: Adjust float and equalize voltages for variations in ambient temperature from minus 40 deg C to plus 60 deg C to prevent overcharging at high temperatures and undercharging at low temperatures.
   3) Automatic Voltage Regulation: Maintain constant output voltage regardless of input voltage variations up to plus or minus 10 percent.
   4) Ammeter and Voltmeter: Flush mounted in door. Meters shall indicate charging rates.
   5) Safety Functions: Sense abnormally low battery voltage and close contacts providing low battery voltage indication on control and monitoring panel. Sense high battery voltage and loss of ac input or dc output of battery charger. Either condition shall close contacts that provide a battery-charger malfunction indication at system control and monitoring panel.
   6) Enclosure and Mounting: NEMA 250, Type 1, wall-mounted cabinet.

C. Fuel Oil Storage
1. Comply with NFPA 30.
2. Day Tank: Comply with UL 142, freestanding, factory-fabricated fuel tank assembly, with integral, float-controlled transfer pump and the following features:
   a. Containment: Integral rupture basin with a capacity of 150 percent of nominal capacity of day tank.
      1) Leak Detector: Locate in rupture basin and connect to provide audible and visual alarm in the event of day-tank leak.
   b. Tank Capacity: As recommended by engine manufacturer for an uninterrupted period of 4 hours' operation at 100 percent of rated power output of engine-generator system without being refilled.
   c. Pump Capacity: Exceeds maximum flow of fuel drawn by engine-mounted fuel supply pump at 110 percent of rated capacity, including fuel returned from engine.
   d. Low-Level Alarm Sensor: Liquid-level device operates alarm contacts at 25 percent of normal fuel level.
   e. High-Level Alarm Sensor: Liquid-level device operates alarm and redundant fuel shutoff contacts at midpoint between overflow level and 100 percent of normal fuel level.

f. Piping Connections: Factory-installed fuel supply and return lines from tank to engine; local fuel fill, vent line, overflow line; and tank drain line with shutoff valve.
g. Redundant High-Level Fuel Shutoff: Actuated by high-level alarm sensor in day tank to operate a separate motor device that disconnects day-tank pump motor. Sensor shall signal solenoid valve, located in fuel suction line between fuel storage tank and day tank, to close. Both actions shall remain in shutoff state until manually reset. Shutoff action shall initiate an alarm signal to control panel but shall not shut down engine-generator set.

3. Base-Mounted Fuel Oil Tank: Factory installed and piped, complying with UL 142 fuel oil tank. Features include the following:
   a. Tank level indicator.
   b. Capacity: Fuel for eight hours' continuous operation at 100 percent rated power output.
   c. Vandal-resistant fill cap.
   d. Containment Provisions: Comply with requirements of authorities having jurisdiction.

D. Control And Monitoring
1. Automatic Starting System Sequence of Operation: When mode-selector switch on the control and monitoring panel is in the automatic position, remote-control contacts in one or more separate automatic transfer switches initiate starting and stopping of generator set. When mode-selector switch is switched to the on position, generator set starts. The off position of same switch initiates generator-set shutdown. When generator set is running, specified system or equipment failures or derangements automatically shut down generator set and initiate alarms.
2. Manual Starting System Sequence of Operation: Switching on-off switch on the generator control panel to the on position starts generator set. The off position of same switch initiates generator-set shutdown. When generator set is running, specified system or equipment failures or derangements automatically shut down generator set and initiate alarms.
3. Configuration:
   a. Operating and safety indications, protective devices, basic system controls, and engine gages shall be grouped in a common control and monitoring panel mounted on the generator set. Mounting method shall isolate the control panel from generator-set vibration.
   b. Operating and safety indications, protective devices, basic system controls, and engine gages shall be grouped in a common wall-mounted control and monitoring panel.
   c. Operating and safety indications, protective devices, basic system controls, engine gages, instrument transformers, generator disconnect switch or circuit breaker, and other indicated components shall be grouped in a combination control and power panel. Control and monitoring section of panel shall be isolated from power sections by steel barriers. Panel features shall include the following:
      1) Wall-Mounting Cabinet Construction: Rigid, self-supporting steel unit complying with NEMA ICS 6. Power bus shall be copper. Bus, bus supports, control wiring, and temperature rise shall comply with UL 891.
      2) Switchboard Construction: Freestanding unit complying with Division 26 Section "Switchboards".
      3) Switchgear Construction: Freestanding unit complying with Division 26 Section "Low-voltage Switchgear".
      4) Current and Potential Transformers: Instrument accuracy class.
4. Indicating and Protective Devices and Controls: As required by NFPA 110 for Level 1 **OR** 2, **as directed,** system, and the following:
   a. AC voltmeter.
   b. AC ammeter.
   c. AC frequency meter.
   d. DC voltmeter (alternator battery charging).
   e. Engine-coolant temperature gage.
   f. Engine lubricating-oil pressure gage.
   g. Running-time meter.
   h. Ammeter-voltmeter, phase-selector switch(es).

i. Generator-voltage adjusting rheostat.
j. Fuel tank derangement alarm.
k. Fuel tank high-level shutdown of fuel supply alarm.
l. Generator overload.

5. Indicating and Protective Devices and Controls:
   a. AC voltmeter.
   b. AC ammeter.
   c. AC frequency meter.
   d. DC voltmeter (alternator battery charging).
   e. Engine-coolant temperature gage.
   f. Engine lubricating-oil pressure gage.
   g. Running-time meter.
   h. Ammeter-voltmeter, phase-selector switch(es).
   i. Generator-voltage adjusting rheostat.
   j. Start-stop switch.
   k. Overspeed shutdown device.
   l. Coolant high-temperature shutdown device.
   m. Coolant low-level shutdown device.
   n. Oil low-pressure shutdown device.
   o. Fuel tank derangement alarm.
   p. Fuel tank high-level shutdown of fuel supply alarm.
   q. Generator overload.
6. Supporting Items: Include sensors, transducers, terminals, relays, and other devices and include wiring required to support specified items. Locate sensors and other supporting items on engine or generator, unless otherwise indicated.
7. Connection to Data Link: A separate terminal block, factory wired to Form C dry contacts, for each alarm and status indication is reserved for connections for data-link transmission of indications to remote data terminals. Data system connections to terminals are covered in Division 26 Section "Electrical Power Monitoring And Control".
8. Common Remote Audible Alarm:
   a. Comply with NFPA 110 requirements for Level 1 systems. Include necessary contacts and terminals in control and monitoring panel.
      1) Overcrank shutdown.
      2) Coolant low-temperature alarm.
      3) Control switch not in auto position.
      4) Battery-charger malfunction alarm.
      5) Battery low-voltage alarm.
   b. Common Remote Audible Alarm for manually starting systems or for automatically starting systems not specified to comply with NFPA 110, Level 1, but where some remote alarm functions are needed. Signal the occurrence of any events listed below without differentiating between event types. Connect so that after an alarm is silenced, clearing of initiating condition will reactivate alarm until silencing switch is reset.
      1) Engine high-temperature shutdown.
      2) Lube-oil, low-pressure shutdown.
      3) Overspeed shutdown.
      4) Remote emergency-stop shutdown.
      5) Engine high-temperature prealarm.
      6) Lube-oil, low-pressure prealarm.
      7) Fuel tank, low-fuel level.
      8) Low coolant level.
9. Remote Alarm Annunciator: Comply with NFPA 99. An LED labeled with proper alarm conditions shall identify each alarm event and a common audible signal shall sound for each alarm condition. Silencing switch in face of panel shall silence signal without altering visual indication. Connect so that after an alarm is silenced, clearing of initiating condition will reactivate alarm until silencing switch is reset. Cabinet and faceplate are surface- or flush-mounting type to suit mounting conditions indicated.

10. Remote Emergency-Stop Switch: Flush; wall mounted, unless otherwise indicated; and labeled. Push button shall be protected from accidental operation.

E. Generator Overcurrent And Fault Protection
1. Generator Circuit Breaker:
   a. Molded-case, thermal-magnetic type; 100 percent rated; complying with NEMA AB 1 and UL 489.
      1) Tripping Characteristic: Designed specifically for generator protection.
      2) Trip Rating: Matched to generator rating.
      3) Shunt Trip: Connected to trip breaker when generator set is shut down by other protective devices.
      4) Mounting: Adjacent to or integrated with control and monitoring panel.
   b. Molded-case, electronic-trip type; 100 percent rated; complying with UL 489.
      1) Tripping Characteristics: Adjustable long-time and short-time delay and instantaneous.
      2) Trip Settings: Selected to coordinate with generator thermal damage curve.
      3) Shunt Trip: Connected to trip breaker when generator set is shut down by other protective devices.
      4) Mounting: Adjacent to or integrated with control and monitoring panel.
   c. Insulated-case, electronic-trip type; 100 percent rated; complying with UL 489.
   d. Tripping Characteristics: Adjustable long-time and short-time delay and instantaneous.
   e. Trip Settings: Selected to coordinate with generator thermal damage curve.
   f. Shunt Trip: Connected to trip breaker when generator set is shut down by other protective devices.
   g. Mounting: Adjacent to or integrated with control and monitoring panel.
2. Generator Disconnect Switch: Molded-case type, 100 percent rated.
   a. Rating: Matched to generator output rating.
   b. Shunt Trip: Connected to trip switch when signaled by generator protector or by other protective devices.
3. Generator Protector: Microprocessor-based unit shall continuously monitor current level in each phase of generator output, integrate generator heating effect over time, and predict when thermal damage of alternator will occur. When signaled by generator protector or other generator-set protective devices, a shunt-trip device in the generator disconnect switch shall open the switch to disconnect the generator from load circuits. Protector shall perform the following functions:
   a. Initiates a generator overload alarm when generator has operated at an overload equivalent to 110 percent of full-rated load for 60 seconds. Indication for this alarm is integrated with other generator-set malfunction alarms.
   b. Under single or three-phase fault conditions, regulates generator to 300 percent of rated full-load current for up to 10 seconds.
   c. As overcurrent heating effect on the generator approaches the thermal damage point of the unit, protector switches the excitation system off, opens the generator disconnect device, and shuts down the generator set.
   d. Senses clearing of a fault by other overcurrent devices and controls recovery of rated voltage to avoid overshoot.
   e. Ground-Fault Indication: Comply with NFPA 70, "Emergency System" signals for ground-fault. Integrate ground-fault alarm indication with other generator-set alarm indications.

F. Generator, Exciter, And Voltage Regulator
1. Comply with NEMA MG 1.
2. Drive: Generator shaft shall be directly connected to engine shaft. Exciter shall be rotated integrally with generator rotor.
3. Electrical Insulation: Class H or Class F.
4. Stator-Winding Leads: Brought out to terminal box to permit future reconnection for other voltages if required.

5. Construction shall prevent mechanical, electrical, and thermal damage due to vibration, overspeed up to 125 percent of rating, and heat during operation at 110 percent of rated capacity.
6. Enclosure: Dripproof.
7. Instrument Transformers: Mounted within generator enclosure.
8. Voltage Regulator: Solid-state type, separate from exciter, providing performance as specified.
   a. Adjusting rheostat on control and monitoring panel shall provide plus or minus 5 percent adjustment of output-voltage operating band.
9. Strip Heater: Thermostatically controlled unit arranged to maintain stator windings above dew point.
10. Windings: Two-thirds pitch stator winding and fully linked amortisseur winding.
11. Subtransient Reactance: 12 percent, maximum.

G. Load Bank
1. Description: Permanent, outdoor, weatherproof, remote-controlled, forced-air-cooled, resistive **OR** resistive and reactive, **as directed,** unit capable of providing a balanced 3-phase, delta-connected load to generator set at 100 percent rated-system capacity, at 80 percent power factor, lagging. Unit may be composed of separate resistive and reactive load banks controlled by a common control panel. Unit shall be capable of selective control of load in 25 percent steps and with minimum step changes of approximately 5 and 10 percent available.
2. Resistive Load Elements: Corrosion-resistant chromium alloy with ceramic and steel supports. Elements shall be double insulated and designed for repetitive on-off cycling. Elements shall be mounted in removable aluminized-steel heater cases.
3. Reactive Load Elements: Epoxy-encapsulated reactor coils.
4. Load-Bank Heat Dissipation: Integral fan with totally enclosed motor shall provide uniform cooling airflow through load elements. Airflow and coil operating current shall be such that, at maximum load, with ambient temperature at the upper end of specified range, load-bank elements operate at not more than 50 percent of maximum continuous temperature rating of resistance elements.
5. Load Element Switching: Remote-controlled contactors switch groups of load elements. Contactor coils are rated 120 V. Contactors shall be located in a separate NEMA 250, Type 3R enclosure within load-bank enclosure, accessible from exterior through hinged doors with tumbler locks.
6. Contactor Enclosures: Heated by thermostatically controlled strip heaters to prevent condensation.
7. Load-Bank Enclosures: NEMA 250, Type 3R, complying with NEMA ICS 6. Louvers at cooling-air intake and discharge openings shall prevent entry of rain and snow. Openings for airflow shall be screened with 1/2-inch- (13-mm-) square, galvanized-steel mesh. Reactive load bank shall include automatic shutters at air intake and discharge.
8. Protective Devices: Power input circuits to load banks shall be fused, and fuses shall be selected to coordinate with generator circuit breaker. Fuse blocks shall be located in contactor enclosure. Cooling airflow and overtemperature sensors shall automatically shut down and lock out load bank until manually reset. Safety interlocks on access panels and doors shall disconnect load power, control, and heater circuits. Fan motor shall be separately protected by overload and short-circuit devices. Short-circuit devices shall be noninterchangeable fuses with 200,000-A interrupting capacity.
9. Remote-Control Panel: Separate from load bank in NEMA 250, Type 1 enclosure with a control power switch and pilot light, and switches controlling groups of load elements.
10. Control Sequence: Control panel may be preset for adjustable single-step loading of generator during automatic exercising.

H. Outdoor Generator-Set Enclosure
1. Description:
   a. Vandal-resistant, weatherproof steel housing, wind resistant up to 100 mph (160 km/h). Multiple panels shall be lockable and provide adequate access to components requiring maintenance. Panels shall be removable by one person without tools. Instruments and control shall be mounted within enclosure.

b. Prefabricated or preengineered walk-in enclosure with the following features:
   1) Construction: Galvanized-steel, metal-clad, integral structural-steel-framed building erected on concrete foundation.
   2) Structural Design and Anchorage: Comply with ASCE 7 for wind loads.
   3) Space Heater: Thermostatically controlled and sized to prevent condensation.
   4) Louvers: Equipped with bird screen and filter arranged to permit air circulation when engine is not running while excluding exterior dust, birds, and rodents.
   5) Hinged Doors: With padlocking provisions.
   6) Ventilation: Louvers equipped with bird screen and filter arranged to permit air circulation while excluding exterior dust, birds, and rodents.
   7) Thermal Insulation: Manufacturer's standard materials and thickness selected in coordination with space heater to maintain winter interior temperature within operating limits required by engine-generator-set components.
   8) Muffler Location: Within **OR** External to, **as directed,** enclosure.

2. Engine Cooling Airflow through Enclosure: Maintain temperature rise of system components within required limits when unit operates at 110 percent of rated load for 2 hours with ambient temperature at top of range specified in system service conditions.
   a. Louvers: Fixed-engine, cooling-air inlet and discharge. Storm-proof and drainable louvers prevent entry of rain and snow.
   b. Automatic Dampers: At engine cooling-air inlet and discharge. Dampers shall be closed to reduce enclosure heat loss in cold weather when unit is not operating.
3. Interior Lights with Switch: Factory-wired, vaporproof-type fixtures within housing; arranged to illuminate controls and accessible interior. Arrange for external electrical connection.
   a. AC lighting system and connection point for operation when remote source is available.
   b. DC lighting system for operation when remote source and generator are both unavailable.
4. Convenience Outlets: Factory wired, GFCI. Arrange for external electrical connection.

I. Motors
1. General requirements for motors are specified in Division 23 Section "Common Motor Requirements For Hvac Equipment".
   a. Motor Sizes: Minimum size as indicated. If not indicated, large enough so driven load will not require motor to operate in service factor range above 1.0.
   b. Controllers, Electrical Devices, and Wiring: Electrical devices and connections are specified in Division 22.

J. Vibration Isolation Devices
1. Elastomeric Isolator Pads: Oil- and water-resistant elastomer or natural rubber, arranged in single or multiple layers, molded with a nonslip pattern and galvanized-steel baseplates of sufficient stiffness for uniform loading over pad area, and factory cut to sizes that match requirements of supported equipment.
   a. Material: Standard neoprene **OR** Natural rubber **OR** Bridge-bearing neoprene, complying with AASHTO M 251, **as directed**.
   b. Durometer Rating: 30 **OR** 40 **OR** 45 **OR** 50 **OR** 60 **OR** 65 **OR** 70, **as directed**.
   c. Number of Layers: One **OR** Two **OR** Three **OR** Four, **as directed**.
2. Restrained Spring Isolators: Freestanding, steel, open-spring isolators with seismic restraint.
   a. Housing: Steel with resilient vertical-limit stops to prevent spring extension due to wind loads or if weight is removed; factory-drilled baseplate bonded to 1/4-inch- (6-mm-) thick, elastomeric isolator pad attached to baseplate underside; and adjustable equipment mounting and leveling bolt that acts as blocking during installation.
   b. Outside Spring Diameter: Not less than 80 percent of compressed height of the spring at rated load.
   c. Minimum Additional Travel: 50 percent of required deflection at rated load.
   d. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
   e. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

K. Finishes
1. Indoor and Outdoor Enclosures and Components: Manufacturer's standard finish over corrosion-resistant pretreatment and compatible primer.

L. Source Quality Control
1. Prototype Testing: Factory test engine-generator set using same engine model, constructed of identical or equivalent components and equipped with identical or equivalent accessories.
   a. Tests: Comply with NFPA 110, Level 1 Energy Converters and with IEEE 115.
   b. Report factory test results within 10 days of completion of test.

1.3 EXECUTION

A. Installation
1. Comply with packaged engine-generator manufacturers' written installation and alignment instructions and with NFPA 110.
2. Install packaged engine generator to provide access, without removing connections or accessories, for periodic maintenance.
3. Install packaged engine generator with elastomeric isolator pads **OR** restrained spring isolators, **as directed,** having a minimum deflection of 1 inch (25 mm) on 4-inch- (100-mm-) high concrete base. Secure sets to anchor bolts installed in concrete bases. Concrete base construction is specified in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".
4. Install remote radiator with elastomeric isolator pads **OR** restrained spring isolators, **as directed,** having a minimum deflection of 1 inch (25 mm) on concrete base on grade **OR** roof equipment supports on roof, **as directed**.
5. Install Schedule 40, black steel piping with welded joints for cooling water piping between engine-generator set and heat exchanger **OR** remote radiator, **as directed**. Piping materials and installation requirements are specified in Division 23 Section "Hydronic Piping".
6. Install Schedule 40, black steel piping with welded joints and connect to engine muffler. Install thimble at wall. Piping shall be same diameter as muffler outlet. Flexible connectors and steel piping materials and installation requirements are specified in Division 23 Section "Hydronic Piping".
   a. Install condensate drain piping to muffler drain outlet full size of drain connection with a shutoff valve, stainless-steel flexible connector, and Schedule 40, black steel pipe with welded joints. Flexible connectors and piping materials and installation requirements are specified in Division 23 Section "Hydronic Piping".
7. Electrical Wiring: Install electrical devices furnished by equipment manufacturers but not specified to be factory mounted.
8. Piping installation requirements are specified in Division 21. Drawings indicate general arrangement of piping and specialties.
9. Connect fuel, cooling-system, and exhaust-system piping adjacent to packaged engine generator to allow service and maintenance.
10. Connect cooling-system water piping to engine-generator set and remote radiator **OR** heat exchanger, **as directed** with flexible connectors.
11. Connect engine exhaust pipe to engine with flexible connector.
12. Connect fuel piping to engines with a gate valve and union and flexible connector.
    a. Natural-gas piping, valves, and specialties for gas distribution are specified in Division 23 Section "Facility Natural-gas Piping".
    b. LP-gas piping, valves, and specialties for gas piping are specified in Division 23 Section "Facility Liquefied-petroleum Gas Piping".
13. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
14. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".
15. Identify system components according to Division 23 Section "Identification For Hvac Piping And Equipment" and Division 26 Section "Identification For Electrical Systems".

B. Field Quality Control
1. Perform tests and inspections and prepare test reports.
   a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
2. Tests and Inspections:
   a. Perform tests recommended by manufacturer and each electrical test and visual and mechanical inspection (except those indicated to be optional) for "AC Generators and for Emergency Systems" specified in NETA Acceptance Testing Specification. Certify compliance with test parameters.
   b. NFPA 110 Acceptance Tests: Perform tests required by NFPA 110 that are additional to those specified here including, but not limited to, single-step full-load pickup test.
   c. Battery Tests: Equalize charging of battery cells according to manufacturer's written instructions. Record individual cell voltages.
      1) Measure charging voltage and voltages between available battery terminals for full-charging and float-charging conditions. Check electrolyte level and specific gravity under both conditions.
      2) Test for contact integrity of all connectors. Perform an integrity load test and a capacity load test for the battery.
      3) Verify acceptance of charge for each element of the battery after discharge.
      4) Verify that measurements are within manufacturer's specifications.
   d. Battery-Charger Tests: Verify specified rates of charge for both equalizing and float-charging conditions.
   e. System Integrity Tests: Methodically verify proper installation, connection, and integrity of each element of engine-generator system before and during system operation. Check for air, exhaust, and fluid leaks.
   f. Exhaust-System Back-Pressure Test: Use a manometer with a scale exceeding 40-inch wg (120 kPa). Connect to exhaust line close to engine exhaust manifold. Verify that back pressure at full-rated load is within manufacturer's written allowable limits for the engine.
   g. Exhaust Emissions Test: Comply with applicable government test criteria.
   h. Voltage and Frequency Transient Stability Tests: Use recording oscilloscope to measure voltage and frequency transients for 50 and 100 percent step-load increases and decreases, and verify that performance is as specified.
   i. Harmonic-Content Tests: Measure harmonic content of output voltage under 25 percent and at 100 percent of rated linear load. Verify that harmonic content is within specified limits.
   j. Noise Level Tests: Measure A-weighted level of noise emanating from generator-set installation, including engine exhaust and cooling-air intake and discharge, at four locations on the property line, and compare measured levels with required values.
3. Coordinate tests with tests for transfer switches and run them concurrently.
4. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
5. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
6. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
7. Remove and replace malfunctioning units and retest **OR** reinspect, **as directed,** as specified above.
8. Retest: Correct deficiencies identified by tests and observations and retest until specified requirements are met.
9. Report results of tests and inspections in writing. Record adjustable relay settings and measured insulation resistances, time delays, and other values and observations. Attach a label or tag to each tested component indicating satisfactory completion of tests.

C. Demonstration

1. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain packaged engine generators.

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Task	Specification	Specification Description
26 32 13 19	26 32 13 13	Packaged Engine Generators
26 32 13 26	26 32 13 13	Packaged Engine Generators
26 32 29 00	26 32 13 13	Packaged Engine Generators

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SECTION 26 33 43 00 - CENTRAL BATTERY INVERTERS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for central battery inverters. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes slow-transfer, fast-transfer, and UPS central battery inverters with the following features:
   a. Output distribution section.
   b. Internal maintenance bypass/isolation switch.
   c. External maintenance bypass/isolation switch.
   d. Multiple output voltages.
   e. Emergency-only circuits.
   f. Remote monitoring provisions.

C. Definitions
1. LCD: Liquid-crystal display.
2. LED: Light-emitting diode.
3. THD: Total harmonic distortion.
4. UPS: Uninterruptible power supply.

D. Submittals
1. Product Data: For the following:
   a. Electrical ratings, including the following:
      1) Capacity to provide power during failure of normal ac.
      2) Inverter voltage regulation and THD of output current.
      3) Rectifier data.
      4) Transfer time of transfer switch.
      5) Data for specified optional features.
   b. Transfer switch.
   c. Inverter.
   d. Battery charger.
   e. Batteries.
   f. Battery monitoring.
   g. Battery-cycle warranty monitor.
2. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, components, and location and identification of each field connection. Show access, workspace, and clearance requirements; details of control panels; and battery arrangement.
   a. Wiring Diagrams: Detail internal and interconnecting wiring; and power, signal, and control wiring.
   b. Elevation and details of control and indication displays.
   c. Output distribution section.
3. Manufacturer Seismic Qualification Certification: Submit certification that central battery inverter equipment will withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".
4. Operation and Maintenance Data.

E. Quality Assurance

1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Central Battery Inverter System: UL 924 and UL 1778, **as directed**, listed.
3. Comply with NFPA 70 and NFPA 101.

F. Delivery, Storage, And Handling
1. Deliver equipment in fully enclosed vehicles.
2. Store equipment in spaces having environments controlled within manufacturers' written instructions for ambient temperature and humidity conditions for non-operating equipment.

G. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace batteries that fail in materials or workmanship within specified warranty period. Special warranty, applying to batteries only, applies to materials only, on a prorated basis, for period specified.
   a. Warranty Period: Include the following warranty periods, from date of Final Completion:
      1) Premium, Valve-Regulated, Recombinant, Lead-Calcium Batteries:
         a) Full Warranty: One year.
         b) Pro Rata: 19 years.
      2) Standard, Valve-Regulated, Recombinant, Lead-Calcium Batteries:
         a) Full Warranty: One year.
         b) Pro Rata: Nine years.
      3) Nickel-Cadmium, Wet-Cell Batteries:
         a) Full Warranty: Five years.
         b) Pro Rata: 15 years.
      4) Lead-Calcium, Wet-Cell Batteries:
         a) Full Warranty: One year.
         b) Pro Rata: Nine years.
      5) Lead-Antimony, Wet-Cell Batteries:
         a) Full Warranty: One year.
         b) Pro Rata: Nine years.

1.2 PRODUCTS

A. Inverter Performance Requirements
1. Slow-Transfer Central Battery Inverters: Automatically sense loss of normal ac supply and use an electromechanical switch to transfer loads. Transfer in one second or less from normal supply to battery-inverter supply.
   a. Operation: Unit supplies power to output circuits from a single, external, normal supply source. Unit automatically transfers load from normal source to internal battery/inverter source. Retransfer to normal is automatic when normal power is restored.
2. Fast-Transfer Central Battery Inverters: Automatically sense loss of normal ac supply and use a solid-state switch to transfer loads. Transfer in 0.004 second or less from normal supply to battery-inverter supply.
   a. Operation: Unit supplies power to output circuits from a single, external, normal supply source. Unit automatically transfers load from normal source to internal battery/inverter source. Retransfer to normal is automatic when normal power is restored.
3. UPS-Type Central Battery Inverters: Continuously provide ac power to connected electrical system.
   a. Automatic Operation:
      1) Normal Conditions: Supply the load with ac power flowing from normal ac power input terminals, through rectifier-charger and inverter, with battery connected in parallel with rectifier-charger output.

2) Abnormal Supply Conditions: If normal ac supply deviates from specified and adjustable voltage, voltage waveform, or frequency limits, battery supplies constant, regulated, inverter ac power output to the load without switching or disturbance.
3) If normal power fails, battery continues supply-regulated ac power through the inverter to the load without switching or disturbance.
4) When power is restored at normal supply terminals of system, controls automatically synchronize inverter with the external source before transferring the load. Rectifier-charger then supplies power to the load through the inverter and simultaneously recharges battery.
5) If battery becomes discharged and normal supply is available, rectifier-charger charges battery. When battery is fully charged, rectifier-charger automatically shifts to float-charge mode.
6) If any element of central battery inverter system fails and power is available at normal supply terminals of system, static bypass transfer switch transfers the load to normal ac supply circuit without disturbance or interruption of supply.
7) If a fault occurs in system supplied by central battery inverter and current flows in excess of the overload rating of central battery inverter system, static bypass transfer switch operates to bypass fault current to normal ac supply circuit for fault clearing.
8) When fault has cleared, static bypass transfer switch returns the load to central battery inverter system.
9) If battery is disconnected, central battery inverter continues to supply power to the load with no degradation of its regulation of voltage and frequency of output bus.

b. Manual Operation:
1) Turning inverter off causes static bypass transfer switch to transfer the load directly to normal ac supply circuit without disturbance or interruption.
2) Turning inverter on causes static bypass transfer switch to transfer the load to inverter.

4. Maximum Acoustical Noise: <**Insert value**> dB, "A" weighting, emanating from any UPS component under any condition of normal operation, measured 39 inches (990 mm) from nearest surface of component enclosure.

B. Service Conditions
1. Environmental Conditions: Inverter system shall be capable of operating continuously in the following environmental conditions without mechanical or electrical damage or degradation of operating capability:
a. Ambient Temperature for Electronic Components: 32 to 98 deg F (0 to 37 deg C).
b. Relative Humidity: 0 to 95 percent, noncondensing.
c. Altitude: Sea level to 4000 feet (1220 m).

C. Inverters
1. Description: Solid-state type, with the following operational features:
a. Automatically regulate output voltage to within plus or minus 5 percent.
b. Automatically regulate output frequency to within plus or minus 1 Hz, from no load to full load at unit power factor over the operating range of battery voltage.
c. Output Voltage Waveform of Unit: Sine wave with maximum 10 percent THD throughout battery operating-voltage range, from no load to full load.
1) THD may not exceed 5 percent when serving a resistive load of 100 percent of unit rating.
d. Output Protection: Current-limiting and short-circuit protection.
OR
Output Protection: Ferroresonant transformer to provide inherent overload and short-circuit protection.
e. Surge Protection: Panelboard **OR** Auxiliary panel, **as directed**, suppressors specified in Division 26 Section "Transient-voltage Suppression For Low-voltage Electrical Power Circuits".

f. Overload Capability: 125 percent for 10 minutes; 150 percent surge.
g. Brownout Protection: Produces rated power without draining batteries when input voltage is down to 75 percent of normal.

D. Battery Charger
1. Description: Solid-state, automatically maintaining batteries in fully charged condition when normal power is available. With LED indicators for "float" and "high-charge" modes.

E. Batteries
1. Description: Premium, valve-regulated, recombinant, lead-calcium **OR** Standard, valve-regulated, recombinant, lead-calcium **OR** Nickel-cadmium, wet-cell **OR** Lead-calcium, wet-cell **OR** Lead-antimony, wet-cell, **as directed**, batteries.
a. Capable of sustaining full-capacity output of inverter unit for minimum of 90 minutes.

F. Enclosures
1. NEMA 250, Type 1 steel cabinets with access to components through hinged doors with flush tumbler lock and latch.
2. Finish: Manufacturer's standard baked-enamel finish over corrosion-resistant prime treatment.

G. Seismic Requirements
1. Central battery inverter assemblies, subassemblies, components, fastenings, supports, and mounting and anchorage devices shall be designed and fabricated to withstand seismic forces, **as directed**. The term "withstand" is defined in the "Manufacturer Seismic Qualification Certification" Paragraph in Part 1.1 "Submittals" Article.

H. Control And Indication
1. Description: Group displays, indications, and basic system controls on common control panel on front of central battery inverter enclosure.
2. Minimum displays, indicating devices, and controls shall include those in lists below. Provide sensors, transducers, terminals, relays, and wiring required to support listed items. Alarms shall include an audible signal and a visual display.
3. Indications: Labeled LED **OR** Plain-language messages on a digital LCD or LED, **as directed**.
a. Quantitative Indications:
1) Input voltage, each phase, line to line.
2) Input current, each phase, line to line.
3) System output voltage, each phase, line to line.
4) System output current, each phase.
5) System output frequency.
6) DC bus voltage.
7) Battery current and direction (charge/discharge).
8) Elapsed time-discharging battery.
b. Basic Status Condition Indications:
1) Normal operation.
2) Load-on bypass.
3) Load-on battery.
4) Inverter off.
5) Alarm condition exists.
c. Alarm Indications:
1) Battery system alarm.
2) Control power failure.
3) Fan failure.
4) Overload.
5) Battery-charging control faulty.
6) Input overvoltage or undervoltage.
7) Approaching end of battery operation.

8) Battery undervoltage shutdown.
9) Inverter fuse blown.
10) Inverter transformer overtemperature.
11) Inverter overtemperature.
12) Static bypass transfer switch overtemperature.
13) Inverter power supply fault.
14) Inverter output overvoltage or undervoltage.
15) System overload shutdown.
16) Inverter output contactor open.
17) Inverter current limit.

d. Controls:
1) Inverter on-off.
2) Start.
3) Battery test.
4) Alarm silence/reset.
5) Output-voltage adjustment.

4. Dry-form "C" contacts shall be available for remote indication of the following conditions:
a. Inverter on battery.
b. Inverter on-line.
c. Inverter load-on bypass.
d. Inverter in alarm condition.
e. Inverter off (maintenance bypass closed).

5. Include the following minimum array:
a. Ready, normal-power on light.
b. Charge light.
c. Inverter supply load light.
d. Battery voltmeter.
e. AC output voltmeter with minimum accuracy of 2 percent of full scale.
f. Load ammeter.
g. Test switch to simulate ac failure.

6. Enclosure: Steel, with hinged lockable doors, suitable for wall **OR** floor, **as directed**, mounting. Manufacturer's standard corrosion-resistant finish.

I. Optional Features
1. Multiple Output Voltages: Supply unit branch circuits at different voltage levels if required. Transform voltages internally as required to produce indicated output voltages.
2. Emergency-Only Circuits: Automatically energize only when normal supply has failed. Disconnect emergency-only circuits when normal power is restored.
3. Maintenance Bypass/Isolation Switch: Load is supplied, bypassing central battery inverter system. Normal supply, electromechanical transfer switch, and system load terminals are completely disconnected from external circuits.
4. Maintenance Bypass/Isolation Switch: Switch is interlocked so it cannot be operated unless static bypass transfer switch is in bypass mode. Switch provides manual selection among the following three conditions without interrupting supply to the load during switching:
a. Full Isolation: Load is supplied, bypassing central battery inverter system. Normal ac input circuit, static bypass transfer switch, and central battery inverter load terminals are completely disconnected from external circuits.
b. Maintenance Bypass: Load is supplied, bypassing central battery inverter system. Central battery inverter ac supply terminals are energized to permit operational checking, but system load terminals are isolated from the load.
c. Normal: Normal central battery inverter ac supply terminals are energized and the load is supplied either through static bypass transfer switch and central battery inverter rectifier-charger and inverter or through battery and inverter.

J. Output Distribution Section

1. Panelboard: Comply with Division 26 Section "Panelboards" except provide assembly integral to equipment cabinet.

K. System Monitoring And Alarms
1. Remote Status and Alarm Panel: Labeled LEDs on panel faceplate shall indicate five basic status conditions. Audible signal indicates alarm conditions. Silencing switch in face of panel silences signal without altering visual indication.
   a. Cabinet and Faceplate: Surface or flush mounted to suit mounting conditions indicated.
2. Provisions for Remote Computer Monitoring: Communication module in unit control panel provides capability for remote monitoring of status, parameters, and alarms specified in Part 1.2 "Control and Indication" Article. Remote computer and connecting signal wiring will be provided by the Owner. Include the following features:
   a. Connectors and network interface units or modems for data transmission via RS-232 link.
   b. Software shall be designed to control and monitor inverter system functions and to provide on-screen explanations, interpretations, diagnosis, action guidance, and instructions for use of monitoring indications and development of reports. Include capability for storage and analysis of power-line transient records. Software shall be compatible with requirements in Division 26 Section "Electrical Power Monitoring And Control" and the operating system and configuration of the Owner-furnished computers.
3. Battery Ground-Fault Detector: Initiates alarm when resistance to ground of positive or negative bus of battery is less than 5000 ohms.
   a. Annunciation of Alarms: At inverter system control panel.
4. Battery-Cycle Warranty Monitoring: Electronic device, acceptable to battery manufacturer as a basis for warranty action, for monitoring charge-discharge cycle history of batteries covered by cycle-life warranty.
   a. Basic Functional Performance: Automatically measures and records each discharge event, classifies it according to duration category, and totals discharges according to warranty criteria, displaying remaining warranted battery life on integral LCD.
   b. Additional monitoring functions and features shall include the following:
      1) Measuring and recording of total voltage at battery terminals; providing alarm for excursions outside proper float voltage level.
      2) Monitoring of ambient temperature at battery and initiating an alarm if temperature deviates from normally acceptable range.
      3) Keypad on device front panel provides access to monitored data using front panel display.
      4) Alarm contacts arranged to provide local **OR** remote, **as directed**, alarm for battery discharge events **OR** abnormal temperature **OR** abnormal battery voltage or temperature, **as directed**.
      5) Memory device to store recorded data in nonvolatile electronic memory.
      6) RS-232 port to permit downloading of data to a portable personal computer.
      7) Modem to make measurements and recorded data accessible to remote personal computer via telephone line. Computer will be provided by the Owner.

L. Source Quality Control
1. Factory test complete inverter system, including battery, before shipment. Include the following:
   a. Functional test and demonstration of all functions, controls, indicators, sensors, and protective devices.
   b. Full-load test.
   c. Transient-load response test.
   d. Overload test.
   e. Power failure test.
2. Observation of Test: Give 14 days' advance notice of tests and provide access for the Owner's representative to observe tests at the Owner's option.
3. Report test results. Include the following data:

a. Description of input source and output loads used. Describe actions required to simulate source load variation and various operating conditions and malfunctions.
b. List of indications, parameter values, and system responses considered satisfactory for each test action. Include tabulation of actual observations during test.
c. List of instruments and equipment used in factory tests.

1.3 EXECUTION

A. Installation
1. Install system components on floor **OR** concrete base, **as directed**, and attach by bolting.
a. Design each fastener and support to carry load indicated by seismic requirements and according to seismic-restraint details. See Division 26 Section "Vibration And Seismic Controls For Electrical Systems" for seismic-restraint requirements.
b. Concrete Bases: 4 inches (100 mm) high, reinforced, with chamfered edges. Extend base no more than 3 inches (75 mm) in all directions beyond the maximum dimensions of switchgear unless otherwise indicated or unless required for seismic anchor support. Construct concrete bases according to Division 26 Section "Hangers And Supports For Electrical Systems".
c. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
d. Install anchor bolts according to anchor-bolt manufacturer's written instructions.
e. Use 3000-psi (20.7-MPa), 28-day compressive-strength concrete and reinforcement as specified in Division 03 Section "Cast-in-place Concrete".
2. Maintain minimum clearances and workspace at equipment according to manufacturer's written instructions and NFPA 70.

B. Connections
1. Connections: Interconnect system components. Make connections to supply and load circuits according to manufacturer's wiring diagrams, unless otherwise indicated.
2. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
a. Separately Derived Systems: Make grounding connections to grounding electrodes and bonding connections to metallic piping systems as indicated; comply with NFPA 70.
3. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

C. Identification
1. Identify equipment and components according to Division 26 Section "Identification For Electrical Systems".

D. Field Quality Control
1. Perform tests and inspections and prepare test reports.
a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
2. Tests and Inspections:
a. Inspect interiors of enclosures for integrity of mechanical and electrical connections, component type and labeling verification, and ratings of installed components.
b. Test manual and automatic operational features and system protective and alarm functions.
c. Test communication of status and alarms to remote monitoring equipment.
d. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specifications. Certify compliance with test parameters.

e. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

3. Remove and replace malfunctioning units and retest as specified above.

E. Startup Service

1. Engage a factory-authorized service representative to perform startup service.
2. Verify that central battery inverter is installed and connected according to the Contract Documents.
3. Verify that electrical wiring installation complies with manufacturer's submittal and installation requirements in Division 22.
4. Complete installation and startup checks according to manufacturer's written instructions.

F. Adjusting And Cleaning

1. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
2. Install new filters in each equipment cabinet within 14 days from date of Final Completion.

END OF SECTION 26 33 43 00

SECTION 26 33 43 00a - NURSE CALL

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for nurse call. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section includes visual/tone and audiovisual/voice nurse-call system.

C. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
   a. Detail equipment cabinets and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   b. Cabling Diagrams: Single-line block diagrams showing cabling interconnection of all components for this specific equipment. Include cable type for each interconnection.
   c. Station Installation Details: For built-in equipment, dimensioned and to scale.
3. Qualification Data: For qualified Installer.
4. Field quality-control reports.
5. Operation and Maintenance Data: For nurse-call equipment to include in emergency, operation, and maintenance manuals.
6. Warranty: Sample of special warranty.

D. Quality Assurance
1. Installer Qualifications: Manufacturer's authorized representative who is trained and approved for installation of units required for this Project.
2. Compatibility: System shall be capable of integration with any brand of phone system (wired or wireless), staff locating system, CCTV, and fire-alarm system.
3. Electrical Components, Devices, and Accessories: Listed and labeled according to UL 1069 as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

E. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace batteries that fail in materials or workmanship within specified warranty period. Special warranty for batteries applies to materials only, on a prorated basis for specified period.
   a. Warranty Period: Include the following warranty periods, from date of Final Completion:
      1) Nickel-Cadmium Batteries, Lithium Batteries, and Wet-Cell Batteries:
         a) Full Warranty: Five years.
         b) Pro Rata: 15 years.

1.2 PRODUCTS

A. Nurse-Call System General Requirements
1. Station Zones: Able to program 256 station zones for each master station in the network with eight priority levels and addressable visual and audible annunciation of audible devices such as smoke detectors and door contacts.
2. System shall provide integrated and centralized "Code Blue" and "Staff Emergency" calls.

3. Expansion Capability: Equipment ratings, housing volume, spare keys, switches, relays, annunciator modules, terminals, and cable conductor quantities adequate to increase the number of stations in the future by 25 percent above those indicated without adding internal or external components or main trunk cable conductors.
4. Existing System Compatibility: Functionally and electrically compatible with existing system so components and wiring operate as an extension or upgrade of the existing system and existing or upgraded functional performance of the existing system applies to the entire final system. Colors, tones, types, and durations of signal manifestation shall be common among new and existing systems.
5. Resistance to Electrostatic Discharge: System, components, and cabling, and the selection, arrangement, and connection of materials and circuits, shall be protected against damage or diminished performance when subjected to electrostatic discharges of up to 25,000 V in an environment with a relative humidity of 20 percent or less.
6. Equipment: Microprocessor, electronic, modular.
7. Master Nurse-Call Station: Programmed via a PC.
8. Wall-Mounted Component Connection Method: Components connect to system wiring in back boxes with factory-wired plug connectors.
9. Telephone Interface: Permit use of wired and wireless telephones to execute nurse-call master station functions.
10. Third-Party Pager Interface: Programmable to send tone, numeric, and alphanumeric message to pocket pagers or personal digital assistants and to use industry standard-protocol, RS-485 interface.

B. Visual/Tone Nurse-Call System
1. Operational Requirements:
   a. Patient Station Call: Lights a steady call-placed lamp on the station, steady lamps in the zone light and corridor dome light associated with the patient's room, and steady lamps at the central annunciator and other system display devices and displays message on master and staff/duty stations. At the same time, it sounds a programmed tone at intervals, at the respective annunciator and master and staff/duty stations. Legends at the central annunciator and master station identify the calling station.
   b. Pull-Cord-Call Station Call: Flashes a call-placed lamp on the station and distinctive-color lamps in the zone light and corridor dome light and at the central annunciator and staff/duty stations. At the same time, it sounds a programmed tone at intervals, at the central annunciator and master and staff/duty stations. A legend at the master station identifies the calling station, priority as programmed, and bed identification.
   c. Emergency-Call Station Call: Produces the same responses as pull-cord-call station calls except rapidly flashing red emergency digital display and tone repetition rates are more frequent, tone frequency is higher, and lamps in the zone light and corridor dome light are a different color. Indicator lamps may be extinguished and the system reset only at the calling station. Displays message on pocket pagers, sounds programmed tone on phones, and displays message on display equipped phones.
   d. System Reset: Operating reset button at the originating station cancels signals associated with the call. Illuminates a green digital display on the patient station and log presence on the master station.
   e. Cord-Set Removal: Initiates a patient station call when the cord set is removed from the jack in the patient station faceplate. Displays location and "cord removed" message on master station, pocket pagers, and display equipped phones. Inserting a cord-set plug or a dummy plug into the jack and operating the station reset button resets the call.
   f. Patient Control Unit: Controls entertainment volume and channel selection. Nurse button on the unit initiates a patient station call. Integral speaker reproduces entertainment sound.
   g. Emergency Bath Station Call: Illuminates the digital display on the emergency bath station; rapidly flashes white dome lamp; displays location, priority, and bath on master

station; and sounds programmed tone on master station display equipped phones and pocket pagers.

h. Staff/Duty Station Operation: Operation shall be identified to patient station except the message staff shall display on all devices when the staff call button is activated.

i. Privacy Key Activation: When privacy key is activated on patient station, the system shall disconnect the patient station microphone and slowly flash yellow privacy digital display on the patient station. Displays "privacy" on master station when selecting this room/bed.

2. Central Annunciator:
   a. Lamp type.
   b. Lamp Legends: Machine lettered and legible from a distance of at least 48 inches (1200 mm) when a call is present. Legend shall identify initiating station and priority of call.
   c. Power-on Indicator: Digital, or push-to-test switch.
   d. Audible Signal: Electronic tone.
3. Central Equipment Cabinet:
   a. Lockable metal.
   b. Houses power supplies, controls, terminal strips, and other components.
   c. Power-on indicator lamp.
   d. Battery Backup Unit: Sealed nickel-cadmium, wet-cell battery supplies power through an automatic switch when normal power fails, for a period of not less than six minutes at rated output. System shall lose no unanswered calls or calls in progress during the transfer operation.
      1) Automatic retransfer to normal power, after a 15-minute time delay.
      2) Two-rate battery charger with an automatic trickle rate and a recharge rate.
4. Single-Patient Station: Call-placed lamp, reset push button, and polarized receptacle matching cord-set plug; mounted in a single faceplate.
5. Dual-Patient Station: Single call-placed lamp, single reset push button, and two polarized receptacles matching cord-set plug; mounted in a single faceplate.
6. Ambulatory-Patient Station: Call push-button switch, call-placed lamp, and reset push button; mounted in a single faceplate.
7. Staff/Duty Stations: A minimum of two call lamps, one for routine calls and one for emergency calls; and an audible tone signal device.

C. Audiovisual/Voice Nurse-Call System
1. Operational Requirements:
   a. Station Selection from Master Station: Capable of selectively communicating with other stations or groups of stations on its system by touch screen, mouse click, or manual switch; and capable of programming up to 256 stations for each master station in the network.
   b. Master Station Privacy: Capable of conversing with individual stations in complete privacy.
   c. Called Station:
      1) Capable of hands-free and two-way conversation.
      2) Pressing "talk/listen" key shall cause the annunciation tone to cease.
      3) Pressing "cancel" key terminates normal calls and conversations.
      4) Terminating of high-priority level 1 **OR** 2 **OR** 3 **OR** 4, **as directed**, shall not be allowed except at calling station location and shall send "remind" message if the call is not acknowledged at point of origin in programmed time frame.
   d. Annunciation:
      1) At the master station, a programmable tone announces an incoming call; an annunciator light or digital display identifies the calling station and indicates the priority of the call.
      2) Call type indications include alarm assist, bath, bed, code, communication fault, cord out, door, emergency, and fire.
      3) Memory lamps or lighted displays identify stations selected for outgoing calls.
   e. System Reset at Master Station: A normal, incoming call can be canceled, associated lights and audible tones extinguished, and the system reset when the station switch is returned to the normal position.

f. Patient Station Calls:
   1) Lights the call-placed lamp at patient station, zone, and corridor dome lights.
   2) Sounds a tone and lights the call lights at staff/duty stations and actuates annunciation at the master station.
   3) When the calling station is selected at the master station, the patient can converse with the master station without moving and without raising or directing the voice.
   4) During voice communications, entertainment audio at the calling station is automatically muted.

g. Pull-Cord-Call Station Calls and Emergency-Call Station Calls:
   1) Lights call-placed lamp and corridor dome light and flashes zone light.
   2) Master station tone pulses and annunciator light for that room flashes.
   3) When master station acknowledges the call by touch screen or switch, the tone stops but lights continue to flash until the call is canceled at the initiating point.

h. Code Blue and Staff/Duty Station Calls:
   1) Lights the call-placed lamp at the station and actuates annunciation at the master station.
   2) When the called station is selected at the master station, the caller and the master station operator can converse.
   3) Code Blue: Unique sound and light pattern indicating the highest priority emergency.
   4) Staff Station: Unique sound and light pattern indicating an emergency.
   5) Duty Station: Sound and light pattern indicating a call to the nurse station.

i. Handset Operation: Lifting the handset on master station disconnects speaker/microphone and transfers conversation to the handset.

j. Station Privacy: No patient or staff/duty station can be remotely monitored without lighting a warning lamp at the monitored station.

k. Patient Station Cord-Set Removal:
   1) A patient station call is initiated as described above when a patient station cord-set plug is removed from the jack in the station faceplate.
   2) Tone stops but lights continue to flash until the call is canceled at the initiating point or the plug is reinserted or replaced with a dummy plug when the master station call button for the station is pressed.

l. Patient Control Unit:
   1) Controls entertainment volume and channel selection.
   2) Speaker is used for both nurse communication and entertainment sound.
   3) Entertainment sound is automatically muted when station is communicating with master station.
   4) Nurse button on the unit initiates a patient station call.

m. Selective Paging: Master station is capable of initiating a message to selected groups of stations or speakers simultaneously by using station group switches.

n. Staff Reminder:
   1) Master station can initiate a staff reminder that a patient requires direct staff response by operating a reminder control while in contact with the patient station.
   2) This reminder will light a distinctive-color lamp in the corridor dome light at the patient's room and in the appropriate zone lights.
   3) Reminder calls are canceled by operating a staff reminder cancel switch in the patient's room.

o. Call Priority Indication:
   1) Capable of eight call priority levels in addition to normal.
   2) Call priority switch near each patient station, or integral with the master station, shall control priority status of the call transmitted by individual stations.
   3) Switch selects one of the following status levels:
      a) Normal: No change to the normal call initiation and canceling sequence.

b) Emergency: Call initiation produces signals and indications identical to those of emergency-call stations. Indicator lamps are extinguished and the system is reset only at the originating station.

c) Priority: System response is the same for emergency status except voice communication between the master station and the calling station is locked in from the time of call initiation until the system is reset at the originating station.

p. Additional Call:

1) Waiting display window on the master station similar to current call window displays incoming calls.
2) Master station shall have a call-overflow indicator when incoming calls exceed <**Insert number**> calls.
3) System shall store unlimited number of incoming calls.
4) System shall be capable of automatically answering incoming calls in order of priority.

q. Calling Intercom Stations:

1) Master station shall be capable of calling any intercom station using the handset or the hands-free speaker/microphone.
2) Receipt of a call at the intercom station shall be preceded by an optional pre-announce tone.
3) If there is a call in process, system shall place the active call on automatic hold while the new call is placed, then reestablish the previous call when the new call has ended.

r. Privacy Override:

1) Temporarily deactivates the "Privacy" mode of a called station by calling the station and instructing the called party to press the call-cord button.
2) On completion of the conversation, the called station shall automatically return to the "Privacy" mode.
3) When in "Privacy" mode, a called station shall be capable of hearing the master station; however, the master station shall not be capable of hearing the called station; a privacy message shall be indicated on the master station display.

s. Master-Station-to-Master-Station Calls:

1) Master stations shall be capable of calling other master stations using the handset.
2) Calls from master stations shall be answered using the handset only.
3) Busy master stations shall be indicated by a master station intercom busy tone.

t. Voice Paging:

1) Capable of voice paging to all stations using a single "All Call" key. The page shall be preceded by an optional pre-announce tone, **as directed**.
2) Capable of voice paging to eight user-defined groups of stations by selecting the group and then the "All Call" key. The page shall be proceeded by a pre-announce tone, **as directed**.
3) Capable of voice paging to all staff/duty stations and all patient stations where staff has registered presence using a single "Public Address (PA)/Staff" key. The page shall be proceeded by a pre-announce tone, **as directed**.
4) Capable of voice paging through a third-party PA system.
5) Capable of including or excluding any station from the voice paging function(s).
6) Automatically places an active station call on hold during any page and reestablishes the connection at the end of the page.
7) Automatically cancels a page if the talk mode is inactive for more than 15 seconds.

u. Station Monitor:

1) An audio monitor feature shall allow a user to sequentially or simultaneously listen to one or all stations that are included in the user-created list.
2) Master station display shall indicate which station is being monitored when in sequential mode.
3) The dwell time each station is monitored shall be user programmable.
4) The user shall be able to stop the monitoring sequence by activating a "pause" key.

5) The user shall be able to manually sequence through stations using a "next" key.

v. Night Service:
1) Functions shall be adaptable for nighttime staffing levels, patient traffic, and day/night operations.
2) Staff Follow:
a) Capable of locating roving staff; forwarding visual and audible annunciation of incoming calls to station(s) where personnel have registered presence.
b) Master station shall display locations where staff have registered presence.
c) Incorporates a programmable timer that automatically cancels a forgotten staff presence registration.
3) Tones:
a) Deactivates audio signals from a duty station and mini-master display telephones.
b) Capable of changing the tone volume at the master and duty stations.
c) Satellite function shall permit the user to deactivate audio signals from duty stations and other remote annunciator devices.
4) Transfer:
a) Permits one nurse station to take control of all or individually selected bed call cords from another nurse station. It shall be possible to view transfer status of a nurse station.
b) Includes a minimum of three transfer modes to allow one nurse station to take control or share calls and operations from another nurse station.
i. Parallel Transfer Mode: Permits both nurse stations to share all calls and operations.
ii. Supervised Transfer Mode: Permits the transferred nurse station to share all calls and operations with the controlling nurse station; however, the controlling nurse station calls are not shared with the transferring station.
iii. Capture Transfer Mode: Transfers all calls and operations from the transferred nurse station to the controlling nurse station.
iv. Transferred station shall have no control over calls, and its display shall indicate calls have been transferred to another station.
c) Includes two "patient swing" modes to allow one nurse station to take control or share calls from one or many calls from another nurse station.
i. Supervised Transfer Mode: Permits the transferred calls to be shared with the controlling nurse station.
ii. Capture Transfer Mode: Transfers all calls from the call cord from the transferred nurse station to the controlling nurse station.
iii. Transferred station has no control over those transferred calls.

w. Service Request:
1) Permits users to assign a service request to a substation, at programmable priority level.
2) Displays service request on the nurse station display and light the green flashing corridor lamp at the respective substation and automatically generate a service reminder request.
3) Cancels service requests only at the initiating point.
4) Recall calls shall sound and be displayed at the master station if the service request has not been cancelled at the initiating point within the programmed period of time.

x. Call Reminder Function:
1) Automatically generates a reminder call for a patient- or staff-initiated, high-priority 2 **OR** 3 **OR** 4, **as directed**, request that has had the call tones silenced, allowing time to physically attend to the request and cancel the call at the initiating point.
2) Regenerated calls shall display the same tones and visual indications and priority as the original call and shall also display a "regenerated call" message.
3) Capable of manually adding low-priority calls to the reminder list.

4) "Call Reminder" function and reminder timer shall be programmable by call priority.

y. Hide Function: Prevents a selected station from displaying calls or generating tones on the nurse station.

z. Door Control Function: Capable of being programmed to enable the user to remotely activate electric door locks.

aa. Test and Diagnostics Feature:
1) Able to automatically diagnose system faults and categorize them as warnings, communication errors, or fatal errors.
2) Warnings shall indicate possible system problems.
3) Communication errors shall indicate the inability of the master station to communicate with a substation or another nurse-call station.
4) Fatal errors shall indicate a major hardware or software failure.

bb. User-Configured System Programming - Access Code Not Required:
1) Patient call-cord priority levels.
2) Monitor list.
3) "All Call" list.
4) Master station communication parameters (volume, filtering, talk/listen, sensitivity).
5) Master and duty station call annunciation tone volume.
6) Date/time.
7) Staff-follow operating mode.
8) Transfer type.
9) Pocket pager list assignment.
10) Presence mode.

cc. User-Configured System Programming - Access Code Required:
1) Master station number.
2) Room device type.
3) Room number.
4) Bed number.
5) Bed alpha or numeric.
6) Reminder duration.
7) Staff presence registration cancel duration.
8) Display language.
9) Paging group assignment(s).
10) Zone group assignments.
11) Monitoring duration.
12) Pocket pager number.
13) Call tone assignment by priority.
14) Pretone activation.
15) Call tones minimum volume.
16) Clock mode (12 h/24 h).

2. Master Station:

a. Speaker/microphone unit with operating controls.

b. Indicator lamps with legends or by digital display designate identification and priority of calling stations and called stations.

c. Pulse rate of incoming-call lights denotes priority of calls awaiting response.

d. Station Selection Controls: Touchpad select stations for two-way voice communications.

e. Signal Tones: Programmable to announce incoming calls.

f. Pulse rate and frequency of tone identify the highest priority call awaiting response at one time.

g. Volume Control: Regulates incoming-call volume.

h. Privacy Handset with Hook Switch: Of the type that does not require push-to-talk switch attached to each station unless otherwise indicated.

i. Staff Reminder Control: Initiates flashing of corresponding corridor dome lights for patients requiring service. Permits scanning equipment to indicate which patients are currently in reminder status.

j. Call Priority Selection: Controls associated with patient-station selection switches determine the priority displayed when a call is initiated at a patient station.

3. Central Equipment Cabinet:
   a. Lockable metal.
   b. Houses amplifiers, tone generators, power supplies, controls, terminal strips, and other components.
   c. Amplifier: With fidelity and overall gain necessary to achieve the sound-transmission and reproduction characteristics specified, considering interoperability with the installed speakers/microphones and wiring.
      1) Power Output: Not less than 3 W at a total harmonic distortion not exceeding 5 percent.
      2) Hum and Noise: 60 dB below full output with normal input open.
      3) Volume Control: Concealed within the amplifier unit to control the volume of sound reproduced at all stations.
      4) Protection: Circuit to prevent damage to the amplifier in case of shorted or open circuit.
   d. Selective Paging Amplifiers: Plug-in card mounted in central equipment cabinet, rated 15 W.
   e. System Power Supply:
      1) 24-V dc for operation of the call system.
      2) Equipment Rating: Suitable for continuous operation between 32 and 120 deg F (0 and 49 deg C), from a primary line voltage between 105- to 125-V ac, 60 Hz.
      3) Output: Regulated 24-V dc with protection against overloads. Line-to-load regulation shall not exceed 2-1/2 percent with ripple and noise remaining below the 10-mV, rms level.
      4) Overload Protection: Electronic fold-back circuit set to limit the volt-ampere output to less than 100 VA during overloaded or shorted output. Restore power output automatically on removal of overload without resetting circuit breakers or replacing fuses.
   f. Power-on indicator lamp.
   g. Surge Protector Device: Comply with Division 26 Section "Transient-voltage Suppression For Low-voltage Electrical Power Circuits" for auxiliary panel suppressors, with digital indicator lights for power and protection status.
   h. Battery Backup Unit: Sealed nickel-cadmium, wet-cell battery supplies power through an automatic switch when normal power fails, for a period of not less than six minutes at rated output.
      1) Automatic retransfer to normal power, after a 15-minute time delay.
      2) Two-rate battery charger with an automatic trickle rate and a recharge rate.
4. Speaker/Microphones:
   a. Type: Permanent-magnet, dynamic or ceramic, protected against dust and humidity.
   b. Sound Reproduction: Sound level of 90 dB plus or minus 3 dB at a distance of 48 inches (1220 mm) on the axis without overdriving or distorting any frequencies between 300 and 3000 Hz when installed in an enclosure or in the pillow speaker.
   c. Power Handling Capacity: Not susceptible to damage from overdriving within the range of power available from the amplifier.
   d. Impedance Matching: Coordinated and matched to the input and output circuits of the amplifier, both for single connection and for group monitoring, to provide the sound reproduction specified. Subsystems or components shall not be combined, which could cause unacceptable distortion such as feedback between pillow speakers and unmuted room speaker/microphone combinations. This protection shall extend throughout the entire range of operation (volume control) of all components.
5. Single-Patient Station: Speaker/microphone with 2-inch (50-mm) dynamic cone, a polarized receptacle to match the cord-set plug, monitor lamp, reset switch, and call-placed lamp; assembled under a single faceplate.
6. Dual-Patient Station:

a. Speaker/microphone with 2-inch (50-mm) dynamic cone, two polarized receptacles to match cord-set plugs, monitor lamp, and reset switch; assembled under a single faceplate.
b. Single call-placed lamp serves both beds.
OR
Dual call-placed lamps, one for each bed.

7. Staff/Duty Stations: Audible call-tone signal device, speaker/microphone with 2-inch (50-mm) dynamic cone, monitor lamp, reset switch, routine-call lamp, emergency-call lamp, and call push button; assembled under a single faceplate.
8. Code Blue Station: Audible call-tone signal device, speaker/microphone with 2-inch (50-mm) dynamic cone, monitor lamp, reset switch, Code Blue emergency-call lamp, and call push button; assembled under a single faceplate.
9. Ambulatory-Patient Station: Speaker/microphone with 2-inch (50-mm) dynamic cone, monitor lamp, reset switch, call-placed lamp, and call push button; assembled under a single faceplate.
10. Selective Paging Speakers: 8-inch (200-mm) cone type with 1-inch (25-mm) voice coil and minimum 5-oz. (140-g) ceramic magnet, multitap matching transformer, flush-mounted steel back-box, and white enamel-finished metal ceiling grille.
11. Call Priority Switch Station: Three-position, tamper-resistant priority selection switch. Positions designated by labeling "Normal," "Emergency," and "Priority."
12. Staff Reminder Cancel Switch Station: Momentary contact.

D. System Components
1. Emergency-Call Station: Locking-type push button, labeled "Push to Call Help"; reset trigger to release push button and cancel call; and call-placed lamp, mounted in a single faceplate.
2. Emergency-Bath Station:
   a. Consists of a sliding, chemical-resistant, ABS red fascia marked with the word "URGENT" in bold letters.
   b. Capable of being activated with nylon pull cord or by sliding the face of the unit downwards.
   c. Activation of the station shall illuminate a reassurance digital display on the face of the unit in addition to notifying the master station.
   d. Water resistant and able to withstand routine cleaning and chemical disinfectants.
   e. Uses magnetic reed switch technology for reliability and corrosion resistance.
   f. Mounts on a single-gang electrical box wire to the respective patient station or input controller.
3. Code Blue Station:
   a. Consists of a sliding, chemical-resistant, ABS blue fascia marked with the word "CODE" in bold letters.
   b. Capable of being activated with nylon pull cord or by sliding the face of the unit downwards.
   c. Activation of the station shall illuminate a reassurance digital display on the face of the unit in addition to notifying the master station.
   d. Water resistant and able to withstand routine cleaning and chemical disinfectants.
   e. Uses magnetic reed switch technology for reliability and corrosion resistance.
   f. Mounts on a single-gang electrical box wire to the respective patient station or input controller.
4. Staff, Emergency Station:
   a. Consists of a sliding, chemical-resistant, ABS red fascia marked with the word "EMERGENCY" in bold letters.
   b. Capable of being activated with nylon pull cord or by sliding the face of the unit downwards.
   c. Activation of the station shall illuminate a reassurance digital display on the face of the unit in addition to notifying the master station.
   d. Mounts on a single-gang electrical box wire to the input controller.
5. Pull-Cord-Call Station:
   a. Pull-Down Switch: Lever-locking type, labeled "Pull Down to Call Help."
   b. Reset trigger.

c. Call-placed lamp.
d. Water-resistant construction.

6. Patient Control Unit:
   a. Equipped with plug and 96-inch- (2400-mm-) long white cord.
   b. Ethylene oxide, sterilizable.
   c. Light-Control Switch: Arranged for independent on-off control of patient's up and down light.
   d. Integral Speaker: 2 inches (50 mm), with 0.35-oz. (9.9-g) magnet, rated 0.2 W.
   e. Controls: Speaker volume, TV control, and nurse call.
   f. Housing: High-impact white plastic.
   g. Attachment: Stainless-steel bed clamp with permanently attached polyester film strap.
   h. Quantity: 12 units for every 10 patient beds.
7. Call-Button Cord Set:
   a. Plug and 72-inch (1800-mm) white cord; cord set shall be resistant to medical gas environment equipped with momentary-action, call-button switch.
   b. Ethylene oxide, sterilizable.
   c. Washable cord.
   d. Palladium switch contacts in high-impact white housing with cord-set strain relief.
   e. Attachment: Stainless-steel bed clamp with permanently attached polyester film strap.
   f. Quantity: Three cord sets for every 10 patient beds.
8. Geriatric Call-Button Cord Set:
   a. Plug and 72-inch (1800-mm) white cord.
   b. Resistant to medical gas environment equipped with momentary-action, light-pressure switch in soft outer jacket.
   c. Ethylene oxide, sterilizable.
   d. Washable cord.
   e. Palladium switch contacts in high-impact white housing with cord-set strain relief.
   f. Attachment: Stainless-steel bed clamp with permanently attached polyester film strap.
   g. Quantity: Two cord sets for every 10 patient beds.
9. Squeeze-Bulb Switch Cord Set:
   a. Plug and 72-inch (1800-mm) washable tube with white cord set.
   b. Resistant to medical gas environment; washable; equipped with neoprene squeeze-bulb activator, and plug-mounted, momentary contact switch.
   c. Ethylene oxide, sterilizable.
   d. Attachment: Stainless-steel bed clamp with permanently attached polyester film strap.
   e. Quantity: Two cord sets for every 10 patient beds.
10. Breath Call Cord:
    a. Flexible PVC jacketed cable and a momentary contact air-pressure sensitive switch.
    b. Cord: 108 inches (2700 mm) long.
    c. Include an adjustable arm for clamping and suitable for use in oxygen atmospheres.
    d. Include 12 replacement straws.
11. Pillow Speakers:
    a. Eight-conductor, DIN, flexible PVC jacketed cable.
    b. Contain nurse-call button, volume control, speaker, and channel control in molded flame-retardant ABS housing.
    c. Cord: 96 inches (2400 mm) long with sheet clip.
12. Call-Button Plug:
    a. Designed to plug into patient station cord-set receptacle.
    b. Button switches call circuit.
    c. Two plugs for every 10 patient beds.
13. Dummy Plugs:
    a. Designed to plug into patient station cord-set receptacle when call-button plug or patient cord set is not used.
    b. Three plugs for every 10 patient beds.
14. Indicator Lamps: Digital type with rated life of 20 years unless otherwise indicated.

15. Station Faceplates:
    a. Stainless steel, a minimum of 0.0375 inch (0.95 mm) thick.
    b. Finish: Brushed.
    c. Machine-engraved labeling identifies indicator lamps and controls.

    OR

    Station Faceplates:
    a. High-impact plastic.
    b. Color: Beige.
    c. Molded or machine-engraved labeling identifies indicator lamps and controls.
16. Corridor Dome Lights and Zone Lights:
    a. Three-lamp signal lights.
    b. Lamps: Front replaceable without tools, low voltage with rated life of 7500 hours. Barriers are such that only one color is displayed at a time.
    c. Lenses: Heat-resistant, shatterproof, translucent polymer that will not deform, discolor, or craze when exposed to hospital cleaning agents.
    d. Filters: Two per unit, amber and red.
17. Cable:
    a. Conductors: Jacketed single and multiple, twisted-pair copper cables.
    b. Sizes and Types: As recommended by equipment manufacturer.
    c. Cable for Use in Plenums: Listed and labeled for plenum installation.
18. Grounding Components: Comply with requirements in Division 26 Section "Grounding And Bonding For Electrical Systems".

E. Software Requirements
1. Telephone System Interface:
    a. Permits use of wired and/or wireless telephones to execute nurse-call master station.
    b. Two-way communication with patient and staff stations.
    c. Two-way communication with the master nurse station.
    d. "All Call," group call, and staff call paging.
    e. Capable of being programmed to forward calls destined for a master nurse station to any connected telephone.
    f. Telephones connected to the telephone interface shall have the same call tone ring patterns as those generated at the master nurse station.
    g. Telephones having a display shall indicate the call type, priority code, and the calling station number of incoming calls.
    h. Telephones shall be capable of initiating a service request for a particular patient station, logging calls on the master station's reminder list, and activating door lock mechanisms associated with a call station.
    i. Capable of routine setup and configuration changes using the keypads on display telephone and/or the master station.
2. Display Telephones:
    a. Digital telephones for use as mini-master nurse-call stations.
    b. Digital display shall indicate the call type, priority code, and calling station number of incoming calls.
    c. Ring patterns shall be identical to those generated at the master station.
    d. Capable of two-way communication with patient and staff stations and the master station, and other telephones interfaced with the system.
    e. Capable of placing or answering outside calls when interfaced with the facility telephone system.
    f. Capable of "All Call," group call, and staff call paging and of initiating service requests, logging calls to the reminder list, and activating optional door controls.
3. Third-Party Pocket Pager Interface:
    a. Equipped with a standalone pocket pager interface.
    b. Connects with the facility paging system and transmit alphanumeric messages to the pocket pagers as preprogrammed in the system.
4. Statistical Software:

a. Includes a data statistical software package that stores, sorts, and analyzes activities occurring on the nurse-call system network.
b. Windows based and operated on a PC that is connected to the nurse-call system network.
c. Stores events on the PC's hard disk. Accumulation of these stored events shall make up the database that is used to generate reports and statistics.
d. Events stored by the software shall include date, day of week, time, ward, priority, and room number.
e. Capable of assigning a patient name to bed number.
f. Stored events shall include, but not be limited to, calls placed, call priority, calls cancelled at the nurse station, calls cancelled at the point of origin, regenerated calls, calls answered, calls sent to pager interface, staff presence registration, staff presence cancellation, service request, service cancellation, and system and network error messages.

5. Data Analysis Software:
   a. Capable of analyzing the stored information and generating computed analysis.
   b. Analysis of the database can be conducted by specifying one, many, or all of the following parameters of the database: date, day of week, time, wards, priority, and room number.
   c. Analysis shall include, but not be limited to, total number of calls placed, average call response time (from call placed to call cancellation), total number of presence registrations, average presence time in a room, total number of service requests, average response time (from audio answer to call cancellation), and average ring time (from call placed to audio answer).
6. Statistical Software Package:
   a. Capable of displaying multiple calls/events on a PC monitor or on a RS-485 data-bus-driven digital display panel.
   b. Calls from patient or staff stations and associated devices shall be displayed by priority. Display shall be customizable as follows:
      1) Choice of color by type of call.
      2) Choice of display size (character size).
      3) Choice of priority levels, type of events, points of origin.
      4) Identification of facility.
      5) Identification of ward.
      6) Identification of patient with specific patient information.

F. Conductors And Cables
1. Audio Cables:
   a. Conductors: Jacketed, twisted-pair and twisted-multipair, untinned solid copper. Sizes as recommended by system manufacturer, but no smaller than No. 22 AWG.
   b. Insulation: Thermoplastic, not less than 1/32 inch (0.8 mm) thick.
   c. Shielding: For speaker/microphone leads and elsewhere where recommended by manufacturer; No. 34 AWG, tinned, soft-copper strands formed into a braid or equivalent foil.
   d. Minimum Shielding Coverage on Conductors: 60 percent.
   e. Plenum Cable: Listed and labeled for plenum installation.
2. Data Cable and Hardware: Category 5e **OR** Category 6, **as directed**, UTP and UTP hardware. Comply with requirements in Division 27 Section "Communications Horizontal Cabling".
3. Power Conductors and Cables: Copper, solid, No. 20 AWG. Comply with requirements in Division 26 Section "Low-voltage Electrical Power Conductors And Cables".
4. Grounding Conductors and Cables: Copper, stranded, No. 16 AWG. Comply with requirements in Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

1.3 EXECUTION

A. Installation
1. Wiring Method:

a. Install cables in raceways and cable trays except within consoles, cabinets, desks, and counters and except in accessible ceiling spaces and in gypsum board partitions where unenclosed wiring method may be used, **as directed**.
   1) Install plenum cable in environmental air spaces, including plenum ceilings.
   2) Conceal raceway and cables except in unfinished spaces.
b. Cable Trays: Comply with requirements in Division 27 Section "Communications Horizontal Cabling".
c. Conduit and Boxes: Comply with requirements in Division 26 Section "Raceway And Boxes For Electrical Systems". Flexible metal conduit shall not be used, **as directed**.
   1) Outlet boxes shall be no smaller than 2 inches (50 mm) wide, 3 inches (75 mm) high, and 2-1/2 inches (64 mm) deep.

2. Install cables without damaging conductors, shield, or jacket.
3. Do not bend cables, while handling or installing, to radii smaller than as recommended by manufacturer.
4. Pull cables without exceeding cable manufacturer's recommended pulling tensions.
   a. Pull cables simultaneously if more than one is being installed in same raceway.
   b. Use pulling compound or lubricant if necessary. Use compounds that will not damage conductor or insulation.
   c. Use pulling means, including fish tape, cable, rope, and basket-weave wire or cable grips, that will not damage media or raceway.
5. Install exposed raceways and cables parallel and perpendicular to surfaces or exposed structural members, and follow surface contours. Secure and support cables by straps, staples, or similar fittings designed and installed so as not to damage cables. Secure cable at intervals not exceeding 30 inches (760 mm) and not more than 6 inches (150 mm) from cabinets, boxes, or fittings.
6. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Provide and use lacing bars and distribution spools.
7. Separation of Wires: Separate speaker/microphone, line-level, speaker-level, and power-wiring runs. Run in separate raceways or, if exposed or in same enclosure, provide 12-inch (300-mm) minimum separation between conductors to speaker/microphones and adjacent parallel power and telephone wiring. Provide separation as recommended by equipment manufacturer for other conductors.
8. Splices, Taps, and Terminations: Make splices, taps, and terminations on numbered terminal strips in junction, pull, and outlet boxes; terminal cabinets; and equipment enclosures. Install terminal cabinets where there are splices, taps, or terminations for eight or more conductors.
9. Impedance and Level Matching: Carefully match input and output impedances and signal levels at signal interfaces. Provide matching networks if required.
10. Identification of Conductors and Cables: Comply with requirements in Division 27 Section "Communications Horizontal Cabling" for cable administration, cable schedule, and cable and wire identification.
11. Equipment Identification:
    a. Comply with requirements in Division 26 Section "Identification For Electrical Systems" for equipment labels and signs and labeling installation requirements.
    b. Label stations, controls, and indications using approved consistent nomenclature.

B. Existing Systems
   1. Examine existing systems for proper operation, compatibility with new equipment, and deficiencies. If discrepancies or impairments to successful connection and operation of interconnected equipment are found, report them and do not proceed with installation until directed. Schedule existing systems' examination so there is reasonable time to resolve problems without delaying construction.

C. Grounding
   1. Ground cable shields and equipment to eliminate shock hazard and to minimize ground loops, common-mode returns, noise pickup, cross talk, and other signal impairments.

2. Signal Ground Terminal: Locate at main equipment cabinet. Isolate from power system and equipment grounding except at connection to main building ground bus.
3. Grounding Provisions: Comply with requirements in Division 26 Section "Grounding And Bonding For Electrical Systems".

D. Field Quality Control
1. Perform tests and inspections.
2. Tests and Inspections:
   a. Schedule tests a minimum of seven days in advance.
   b. Report: Submit a written record of test results.
   c. Operational Test: Perform an operational system test and demonstrate proper operations, adjustment, and sensitivity of each station. Perform tests that include originating station-to-station and "All Call" messages and pages at each nurse-call station. Verify proper routing, volume levels, and freedom from noise and distortion. Test each available message path from each station on the system. Meet the following criteria:
      1) Speaker Output: 90 dB plus or minus 3 dB, 300 to 3000 Hz, reference level threshold of audibility 0 dB at 0.02 mPa of sound pressure.
      2) Gain from patient's bedside station to nurse station, with distortion less than 65 dB (plus or minus 3 dB, 300 to 3000 Hz).
      3) Signal-to-Noise Ratio: Hum and noise level at least 45 dB below full output.
   d. Test Procedure:
      1) Frequency Response: Determine frequency response of two transmission paths by transmitting and recording audio tones.
      2) Signal-to-Noise Ratio: Measure the ratio of signal to noise of the complete system at normal gain settings using the following procedure: Disconnect a speaker/microphone and replace it in the circuit with a signal generator using a 1000-Hz signal. Measure the ratio of signal to noise and repeat the test for four speaker microphones.
      3) Distortion Test: Measure distortion at normal gain settings and rated power. Feed signals at frequencies of 300, 400, 1000, and 3000 Hz into each nurse-call equipment amplifier, and measure the distortion in the amplifier output.
3. Retesting: Rectify deficiencies indicated by tests and completely retest work affected by such deficiencies at Contractor's expense. Verify, by the system test, that the total system meets these Specifications and complies with applicable standards. Report results in writing.
4. Inspection: Verify that units and controls are properly labeled and interconnecting wires and terminals are identified.
5. Prepare test and inspection reports.

E. Adjusting
1. Occupancy Adjustments: When requested within 12 months of date of Final Completion, provide on-site assistance in adjusting sound levels and controls to suit actual occupied conditions. Provide up to three visits to Project during other-than-normal operating hours for this purpose.

F. Demonstration
1. Train Owner's maintenance personnel and caregiver staff to adjust, operate, and maintain nurse-call equipment.

END OF SECTION 26 33 43 00a

SECTION 26 33 43 00b - PUBLIC ADDRESS AND MASS NOTIFICATION SYSTEMS

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of public address and mass notification systems. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Preamplifiers.
b. Power amplifiers.
c. Transfer to standby amplifier.
d. Microphones.
e. Volume limiter/compressors.
f. Control console.
g. Equipment cabinet.
h. Equipment rack.
i. Telephone paging adapters.
j. Tone generator.
k. Monitor panel.
l. Loudspeakers.
m. Noise-operated gain controllers.
n. Microphone and headphone outlets.
o. Battery backup power unit.
p. Conductors and cables.
q. Raceways.

C. Definitions
1. Channels: Separate parallel signal paths, from sources to loudspeakers or loudspeaker zones, with separate amplification and switching that permit selection between paths for speaker alternative program signals.
2. VU: Volume unit.
3. Zone: Separate group of loudspeakers and associated supply wiring that may be arranged for selective switching between different channels.

D. Performance Requirements
1. Delegated Design: Design supports and seismic restraints for control consoles, equipment cabinets and racks, and components, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
2. Seismic Performance: Supports and seismic restraints for control consoles, equipment cabinets and racks, and components shall withstand the effects of earthquake motions determined according to SEI/ASCE 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

E. Submittals
1. Product Data: For each type of product indicated.
2. Shop Drawings: For supports and seismic restraints for control consoles, equipment cabinets and racks, and components. Include plans, elevations, sections, details, and attachments to other work.

a. Detail equipment assemblies and indicate dimensions, weights, required clearances, method of field assembly, components, and location and size of each field connection.
b. Console layouts.
c. Control panels.
d. Rack arrangements.
e. Calculations: For sizing backup battery.
f. Wiring Diagrams: For power, signal, and control wiring.
1) Identify terminals to facilitate installation, operation, and maintenance.
2) Single-line diagram showing interconnection of components.
3) Cabling diagram showing cable routing.

3. Delegated-Design Submittal: For supports and seismic restraints for control consoles, equipment cabinets and racks, and components indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
a. Detail fabrication and assembly of supports and seismic restraints for control consoles, equipment cabinets and racks, and components.

4. Seismic Qualification Certificates: For control consoles, equipment cabinets and racks, accessories, and components, from manufacturer.
a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

5. Field quality-control reports.
6. Operation and maintenance data.

F. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. Comply with NFPA 70.

1.2 PRODUCTS

A. Functional Description Of System
1. System Functions:
a. Selectively connect any zone to any available signal channel.
b. Selectively control sound from microphone outlets and other inputs.
c. "All-call" feature shall connect the all-call sound signal simultaneously to all zones regardless of zone or channel switch settings.
d. Telephone paging adapter shall allow paging by dialing an extension from any local telephone instrument and speaking into the telephone.
e. Produce a program-signal tone that is amplified and sounded over all speakers, overriding signals currently being distributed.
f. Reproduce high-quality sound that is free of noise and distortion at all loudspeakers at all times during equipment operation including standby mode with inputs off; output free of non-uniform coverage of amplified sound.

B. General Equipment And Material Requirements
1. Compatibility of Components: Coordinate component features to form an integrated system. Match components and interconnections for optimum performance of specified functions.
2. Equipment: Comply with UL 813. Equipment shall be modular, using solid-state components, and fully rated for continuous duty unless otherwise indicated. Select equipment for normal operation on input power usually supplied at 110 to 130 V, 60 Hz.

3. Equipment Mounting: Where rack, cabinet, or console mounting is indicated, equipment shall be designed to mount in a 19-inch (483-mm) housing complying with TIA/EIA-310-D.
4. Weather-Resistant Equipment: Listed and labeled by a qualified testing agency for duty outdoors or in damp locations.

C. Preamplifiers
1. Preamplifier: Separately mounted.
2. Preamplifier: Integral to power amplifier.
3. Output Power: Plus 4 dB above 1 mW at matched power-amplifier load.
4. Total Harmonic Distortion: Less than 1 percent.
5. Frequency Response: Within plus or minus 2 dB from 20 to 20,000 Hz.
6. Input Jacks: Minimum of two. One matched for low-impedance microphone; the other matchable to cassette deck, CD player, or radio tuner signals without external adapters.
7. Minimum Noise Level: Minus 55 dB below rated output.
8. Controls: On-off, input levels, and master gain.

D. Power Amplifiers
1. Mounting: Console **OR** Rack, **as directed**.
2. Output Power: 70-V balanced line. 80 percent of the sum of wattage settings of connected for each station and speaker connected in all-call mode of operation, plus an allowance for future stations.
3. Total Harmonic Distortion: Less than 3 percent at rated power output from 50 to 12,000 Hz.
4. Minimum Signal-to-Noise Ratio: 60 dB, at rated output.
5. Frequency Response: Within plus or minus 2 dB from 50 to 12,000 Hz.
6. Output Regulation: Less than 2 dB from full to no load.
7. Controls: On-off, input levels, and low-cut filter.
8. Input Sensitivity: Matched to preamplifier and to provide full-rated output with sound-pressure level of less than 10 dynes/sq. cm impinging on speaker microphone or handset transmitter.

E. Transfer To Standby Amplifier
1. Monitoring Circuit and Sensing Relay: Detect reduction in output of power amplifier of 40 percent or more and, in such event, transfer load and signal automatically to standby amplifier.

F. Microphones
1. Paging Microphone:
   a. Type: Dynamic, with cardioid **OR** omni, **as directed**, polar characteristic.
   b. Impedance: 150 ohms.
   c. Frequency Response: Uniform, 50 to 14,000 Hz.
   d. Output Level: Minus 58 dB, minimum.
   e. Finish: Satin chrome.
   f. Cable: C25J.
   g. Mounting: Desk stand with integral-locking, press-to-talk switch.

G. Volume Limiter/Compressor
1. Minimum Performance Requirements:
   a. Frequency Response: 45 to 15,000 Hz, plus or minus 1 dB minimum.
   b. Signal Reduction Ratio: At least a 10:1 and 5:1 selectable capability.
   c. Distortion: 1 percent, maximum.
   d. Rated Output: Minimum of plus 14 dB.
   e. Inputs: Minimum of two inputs with variable front-panel gain controls and VU or decibel meter for input adjustment.
   f. Rack mounting.

H. Control Console
1. Cabinet: Modular, desktop **OR** desk style, **as directed**; complying with TIA/EIA-310-D.

2. Housing: Steel, 0.0478 inch (1.2 mm) minimum, with removable front and rear panels. Side panels are removable for interconnecting side-by-side mounting.
3. Panel for Equipment and Controls: Rack mounted.
4. Controls:
   a. Switching devices to select signal sources for distribution channels.
   b. Program selector switch to select source for each program channel.
   c. Switching devices to select zones for paging.
   d. All-call selector switch.
5. Indicators: A visual annunciation for each distribution channel to indicate source being used.
6. Self-Contained Power and Control Unit: A single assembly of basic control, electronics, and power supply necessary to accomplish specified functions.
7. Spare Positions: 20 percent spare zone control and annunciation positions on console.
8. Microphone jack.

I. Equipment Cabinet
1. Comply with TIA/EIA-310-D.
2. House amplifiers and auxiliary equipment at each location.
3. Cabinet Housing:
   a. Constructed of 0.0478-inch (1.2-mm) steel, minimum, with front- and rear-locking doors and standard TIA/EIA-310-D-compliant, 19-inch (483-mm) racks.
   b. Arranged for floor or wall mounting as indicated.
   c. Sized to house all equipment indicated, plus spare capacity.
   d. Include 20 percent minimum spare capacity for future equipment in addition to space required for future cassette deck and CD player.
4. Power Provisions: A single switch in cabinet shall disconnect cabinet power distribution system and electrical outlets, which shall be uniformly spaced to accommodate ac-power cords for each item of equipment.
5. Ventilation: A low-noise fan for forced-air cabinet ventilation. Fan shall be equipped with a filtered input vent and shall be connected to operate from 105- to 130-V ac, 60 Hz; separately fused and switched; arranged to be powered when main cabinet power switch is on.

J. Equipment Rack
1. Racks: 19 inches (483 mm) standard, complying with TIA/EIA-310-D.
2. Power-Supply Connections: Compatible plugs and receptacles.
3. Enclosure Panels: Ventilated rear and sides and solid top. Use louvers in panels to ensure adequate ventilation.
4. Finish: Uniform, baked-enamel factory finish over rust-inhibiting primer.
5. Power-Control Panel: On front of equipment housing, with master power on-off switch and pilot light; and with socket for 5-A cartridge fuse for rack equipment power.
6. Service Light: At top rear of rack with an adjacent control switch.
7. Vertical Plug Strip: Grounded receptacles, 12 inches (300 mm) o.c.; the full height of rack.
8. Maintenance Receptacles: Duplex convenience outlets supplied independent of vertical plug strip and located in front and bottom rear of rack.
9. Spare Capacity: 20 percent in rack for future equipment.

K. Telephone Paging Adapter
1. Adapters shall accept voice signals from telephone extension dialing access and automatically provide amplifier input and program override for preselected zones.
   a. Minimum Frequency Response: Flat, 200 to 2500 Hz.
   b. Impedance Matching: Adapter matches telephone line to public address equipment input.
   c. Rack mounting.

L. Tone Generator
1. Generator shall provide clock and program interface with public address and mass notification system.

2. Signals: Minimum of seven distinct, audible signal types including wail, warble, high/low, alarm, repeating and single-stroke chimes, and tone.
3. Pitch Control: Chimes and tone.
4. Volume Control: All outputs.
5. Activation-Switch Network: Establishes priority and hierarchy of output signals produced by different activation setups.
6. Mounting: Rack.

M. Monitor Panel
1. Monitor power amplifiers.
2. Components: VU or dB meter, speaker with volume control, and multiple-position rotary selector switch.
3. Selector Switch and Volume Control: Selective monitoring of output of each separate power amplifier via VU or dB meter and speaker.
4. Mounting: Rack.

N. Loudspeakers
1. Cone-Type Loudspeakers:
   a. Minimum Axial Sensitivity: 91 dB at one meter, with 1-W input.
   b. Frequency Response: Within plus or minus 3 dB from 50 to 15,000 Hz.
   c. Size: 8 inches (200 mm) with 1-inch (25-mm) voice coil and minimum 5-oz. (140-g) ceramic magnet.
   d. Minimum Dispersion Angle: 100 degrees.
   e. Rated Output Level: 10 W.
   f. Matching Transformer: Full-power rated with four taps. Maximum insertion loss of 0.5 dB.
   g. Surface-Mounting Units: Ceiling, wall, or pendant mounting, as indicated, in steel back boxes, acoustically dampened. Front face of at least 0.0478-inch (1.2-mm) steel and whole assembly rust proofed and shop primed for field painting.
   h. Flush-Ceiling-Mounting Units: In steel back boxes, acoustically dampened. Metal ceiling grille with white baked enamel.
2. Horn-Type Loudspeakers:
   a. Type: Single-horn units, double-reentrant design, with minimum full-range power rating of 15 W.
   b. Matching Transformer: Full-power rated with four standard taps. Maximum insertion loss of 0.5 dB.
   c. Frequency Response: Within plus or minus 3 dB from 250 to 12,000 Hz.
   d. Dispersion Angle: 130 by 110 degrees.
   e. Mounting: Integral bracket.
   f. Units in Hazardous (Classified) Locations: Listed and labeled for environment in which they are located.

O. Noise-Operated Gain Controller
1. Gain controller shall be designed to continuously sense space noise level and automatically adjust signal level to local speakers.
2. Frequency Response: 20 to 20,000 Hz, plus or minus 1 dB.
3. Level Adjustment Range: 20 dB minimum.
4. Maximum Distortion: 1 percent.
5. Control: Permits adjustment of sensing level of device.

P. Outlets
1. Volume Attenuator Station: Wall-plate-mounted autotransformer type with paging priority feature.
   a. Wattage Rating: 10 W unless otherwise indicated.
   b. Attenuation per Step: 3 dB, with positive off position.
   c. Insertion Loss: 0.4 dB maximum.

d. Attenuation Bypass Relay: Single pole, double throw. Connected to operate and bypass attenuation when all-call, paging, program signal, or prerecorded message features are used. Relay returns to normal position at end of priority transmission.
e. Label: "PA Volume."

2. Microphone Outlet: Three-pole, polarized, locking-type, microphone receptacles in single-gang boxes. Equip wall outlets with brushed stainless-steel device plates. Equip floor outlets with gray tapered rubber or plastic cable nozzles and fixed outlet covers.
3. Headphone Outlet (for the Hearing Impaired): Microphone receptacles in single-gang boxes. Equip wall outlets with brushed stainless-steel device plates. Equip floor outlets with gray tapered rubber or plastic cable nozzles and fixed-outlet covers.

Q. Battery Backup Power Unit
1. Unit shall be rack mounted, consisting of time-delay relay, sealed lead-calcium battery, battery charger, on-off switch, "normal" and "emergency" indicating lights, and adequate capacity to supply maximum equipment power requirements for one hour of continuous full operation.
2. Unit shall supply public address equipment with 12- to 15-V dc power automatically during an outage of normal 120-V ac power.
3. Battery shall be on float charge when not supplying system and to transfer automatically to supply system after three to five seconds of continuous outage of normal power, as sensed by time-delay relay.
4. Unit shall automatically retransfer system to normal supply when normal power has been reestablished for three to five seconds continuously.

R. Conductors And Cables
1. Jacketed, twisted pair and twisted multipair, untinned solid copper.
a. Insulation for Wire in Conduit: Thermoplastic, not less than 1/32 inch (0.8 mm) thick.
b. Microphone Cables: Neoprene jacketed, not less than 2/64 inch (0.8 mm) thick, over shield with filled interstices. Shield No. 34 AWG, tinned, soft-copper strands formed into a braid or approved equivalent foil. Shielding coverage on conductors is not less than 60 percent.
c. Plenum Cable: Listed and labeled for plenum installation.

S. Raceways
1. Conduit and Boxes: Comply with Division 26 Section "Raceway And Boxes For Electrical Systems". Flexible metal conduit shall not be used, unless directed otherwise.
a. Outlet boxes shall be not less than 2 inches (50 mm) wide, 3 inches (75 mm) high, and 2-1/2 inches (64 mm) deep.

1.3 EXECUTION

A. Wiring Methods
1. Wiring Method: Install cables in raceways and cable trays except within consoles, cabinets, desks, and counters, and except in accessible ceiling spaces and in gypsum board partitions where unenclosed wiring method may be used, **as directed**. Conceal raceway and cables except in unfinished spaces.
a. Install plenum cable in environmental air spaces, including plenum ceilings.
b. Comply with requirements for raceways and boxes specified in Division 26 Section "Raceway And Boxes For Electrical Systems".
2. Wiring Method: Conceal conductors and cables in accessible ceilings, walls, and floors where possible.
3. Wiring within Enclosures: Bundle, lace, and train cables to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Provide and use lacing bars and distribution spools.

B. Installation Of Raceways
   1. Comply with requirements in Division 26 Section "Raceway And Boxes For Electrical Systems" for installation of conduits and wireways.
   2. Install manufactured conduit sweeps and long-radius elbows whenever possible.

C. Installation Of Cables
   1. Comply with NECA 1.
   2. General Cable Installation Requirements:
      a. Terminate conductors; no cable shall contain unterminated elements. Make terminations only at outlets and terminals.
      b. Splices, Taps, and Terminations: Arrange on numbered terminal strips in junction, pull, and outlet boxes; terminal cabinets; and equipment enclosures. Cables may not be spliced.
      c. Secure and support cables at intervals not exceeding 30 inches (760 mm) and not more than 6 inches (150 mm) from cabinets, boxes, fittings, outlets, racks, frames, and terminals.
      d. Bundle, lace, and train conductors to terminal points without exceeding manufacturer's limitations on bending radii. Install lacing bars and distribution spools.
      e. Do not install bruised, kinked, scored, deformed, or abraded cable. Do not splice cable between termination, tap, or junction points. Remove and discard cable if damaged during installation and replace it with new cable.
      f. Cold-Weather Installation: Bring cable to room temperature before dereeling. Heat lamps shall not be used.
   3. Open-Cable Installation:
      a. Install cabling with horizontal and vertical cable guides in telecommunications spaces with terminating hardware and interconnection equipment.
      b. Suspend speaker cable not in a wireway or pathway a minimum of 8 inches (200 mm) above ceiling by cable supports not more than 60 inches (1524 mm) apart.
      c. Cable shall not be run through structural members or be in contact with pipes, ducts, or other potentially damaging items.
   4. Separation of Wires: Separate speaker-microphone, line-level, speaker-level, and power wiring runs. Install in separate raceways or, where exposed or in same enclosure, separate conductors at least 12 inches (300 mm) apart for speaker microphones and adjacent parallel power and telephone wiring. Separate other intercommunication equipment conductors as recommended by equipment manufacturer.

D. Installation
   1. Match input and output impedances and signal levels at signal interfaces. Provide matching networks where required.
   2. Identification of Conductors and Cables: Color-code conductors and apply wire and cable marking tape to designate wires and cables so they identify media in coordination with system wiring diagrams.
   3. Equipment Cabinets and Racks:
      a. Group items of same function together, either vertically or side by side, and arrange controls symmetrically. Mount monitor panel above the amplifiers.
      b. Arrange all inputs, outputs, interconnections, and test points so they are accessible at rear of rack for maintenance and testing, with each item removable from rack without disturbing other items or connections.
      c. Blank Panels: Cover empty space in equipment racks so entire front of rack is occupied by panels.
   4. Volume Limiter/Compressor: Equip each zone with a volume limiter/compressor. Install in central equipment cabinet. Arrange to provide a constant input to power amplifiers.
   5. Wall-Mounted Outlets: Flush mounted.
   6. Floor-Mounted Outlets: Conceal in floor and install cable nozzles through outlet covers. Secure outlet covers in place. Trim with carpet in carpeted areas.

7. Conductor Sizing: Unless otherwise indicated, size speaker circuit conductors from racks to loudspeaker outlets not smaller than No. 18 AWG and conductors from microphone receptacles to amplifiers not smaller than No. 22 AWG.
8. Weatherproof Equipment: For units that are mounted outdoors, in damp locations, or where exposed to weather, install consistent with requirements of weatherproof rating.
9. Speaker-Line Matching Transformer Connections: Make initial connections using tap settings indicated on Drawings.
10. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

E. Grounding
1. Ground cable shields and equipment to eliminate shock hazard and to minimize ground loops, common-mode returns, noise pickup, cross talk, and other impairments.
2. Signal Ground Terminal: Locate at main equipment cabinet. Isolate from power system and equipment grounding.
3. Install grounding electrodes as specified in Division 26 Section "Grounding And Bonding For Electrical Systems".

F. Field Quality Control
1. Perform tests and inspections.
   a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
2. Tests and Inspections:
   a. Schedule tests with at least seven days' advance notice of test performance.
   b. After installing public address and mass notification systems and after electrical circuitry has been energized, test for compliance with requirements.
   c. Operational Test: Perform tests that include originating program and page messages at microphone outlets, preamplifier program inputs, and other inputs. Verify proper routing and volume levels and that system is free of noise and distortion.
   d. Signal-to-Noise Ratio Test: Measure signal-to-noise ratio of complete system at normal gain settings as follows:
      1) Disconnect microphone at connector or jack closest to it and replace it in the circuit with a signal generator using a 1000-Hz signal. Replace all other microphones at corresponding connectors with dummy loads, each equal in impedance to microphone it replaces. Measure signal-to-noise ratio.
      2) Repeat test for each separately controlled zone of loudspeakers.
      3) Minimum acceptance ratio is 50 dB.
   e. Distortion Test: Measure distortion at normal gain settings and rated power. Feed signals at frequencies of 50, 200, 400, 1000, 3000, 8000, and 12,000 Hz into each preamplifier channel. For each frequency, measure distortion in the paging and all-call amplifier outputs. Maximum acceptable distortion at any frequency is 3 percent total harmonics.
   f. Acoustic Coverage Test: Feed pink noise into system using octaves centered at 500 and 4000 Hz. Use sound-level meter with octave-band filters to measure level at five locations in each zone. For spaces with seated audiences, maximum permissible variation in level is plus or minus 2 dB. In addition, the levels between locations in same zone and between locations in adjacent zones must not vary more than plus or minus 3 dB.
   g. Power Output Test: Measure electrical power output of each power amplifier at normal gain settings of 50, 1000, and 12,000 Hz. Maximum variation in power output at these frequencies must not exceed plus or minus 1 dB.
   h. Signal Ground Test: Measure and report ground resistance at pubic address equipment signal ground. Comply with testing requirements specified in Division 26 Section "Grounding And Bonding For Electrical Systems".

3. Inspection: Verify that units and controls are properly labeled and interconnecting wires and terminals are identified. Prepare a list of final tap settings of paging speaker-line matching transformers.
4. Public address and mass notification systems will be considered defective if they do not pass tests and inspections.
5. Prepare test and inspection reports.
    a. Include a record of final speaker-line matching transformer-tap settings, and signal ground-resistance measurement certified by Installer.

END OF SECTION 26 33 43 00b

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SECTION 26 33 53 00 - STATIC UNINTERRUPTIBLE POWER SUPPLY

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for static uninterruptible power supply. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Three-phase, on-line, double-conversion, static-type, UPS units with the following features:
1) Surge suppression.
2) Input harmonics reduction.
3) Rectifier-charger.
4) Inverter.
5) Static bypass transfer switch.
6) Battery and battery disconnect device.
7) Internal and External maintenance bypass/isolation switch.
8) Output isolation transformer.
9) Remote UPS monitoring provisions.
10) Battery monitoring.
11) Remote monitoring.

C. Definitions
1. EMI: Electromagnetic interference.
2. LCD: Liquid-crystal display.
3. LED: Light-emitting diode.
4. PC: Personal computer.
5. THD: Total harmonic distortion.
6. UPS: Uninterruptible power supply.

D. Performance Requirements
1. Seismic Performance: UPS shall withstand the effects of earthquake motions determined according to ASCE/SEI 7, **as directed**.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

E. Submittals
1. Product Data: For each type of product indicated. Include data on features, components, ratings, and performance.
2. Shop Drawings: For UPS. Include plans, elevations, sections, details, and attachments to other work.
a. Detail equipment assemblies and indicate dimensions, weights, components, and location and identification of each field connection. Show access, workspace, and clearance requirements; details of control panels; and battery arrangement.
b. Wiring Diagrams: For power, signal, and control wiring.
3. Seismic Qualification Certificates: For UPS equipment, from manufacturer.
a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

4. Factory Test Reports: Comply with specified requirements.
5. Field quality-control reports.
6. Operation and maintenance data.
7. Warranties: Sample of special warranties.

F. Quality Assurance

1. Testing Agency Qualifications: Member company of NETA or an NRTL.
   a. Testing Agency's Field Supervisor: Currently certified by NETA to supervise on-site testing.
2. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
3. UL Compliance: Listed and labeled under UL 1778 by an NRTL.
4. NFPA Compliance: Mark UPS components as suitable for installation in computer rooms according to NFPA 75.

G. Warranty

1. Special Battery Warranties: Specified form in which manufacturer and Installer agree to repair or replace UPS system storage batteries that fail in materials or workmanship within specified warranty period.
   a. Warranted Cycle Life for Valve-Regulated, Lead-Calcium Batteries: Equal to or greater than that represented in manufacturer's published table, including figures corresponding to the following, based on annual average battery temperature of 77 deg F (25 deg C):

Discharge Rate	Discharge Duration	Discharge End Voltage	Cycle Life
8 hours	8 hours	1.67	6 cycles
30 minutes	30 minutes	1.67	20 cycles
15 minutes	45 seconds	1.67	120 cycles

OR

Warranted Cycle Life for Premium Valve-Regulated, Lead-calcium Batteries: Equal to or greater than that represented in manufacturer's published table, including figures corresponding to the following, based on annual average battery temperature of 77 deg F (25 deg C):

Discharge Rate	Discharge Duration	Discharge End Voltage	Cycle Life
8 hours	8 hours	1.67	40 cycles
30 minutes	30 minutes	1.67	125 cycles
15 minutes	1.5 minutes	1.67	750 cycles

OR

Warranted Cycle Life for Flooded Batteries: Equal to or greater than that represented in manufacturer's published table, including figures corresponding to the following, based on annual average battery temperature of 77 deg F (25 deg C):

Discharge Rate	Discharge Duration	Discharge End Voltage	Cycle Life
8 hours	8 hours	1.75	40 cycles
1 hour	1 hour	1.75	80 cycles
15 minutes	45 seconds	1.67	2700 cycles

2. Special UPS Warranties: Specified form in which manufacturer and Installer agree to repair or replace components that fail in materials or workmanship within Two **OR** Three, **as directed**, years from date of Final Completion.

1.2 PRODUCTS

A. Operational Requirements
1. Automatic operation includes the following:
   a. Normal Conditions: Load is supplied with power flowing from the normal power input terminals, through the rectifier-charger and inverter, with the battery connected in parallel with the rectifier-charger output.
   b. Abnormal Supply Conditions: If normal supply deviates from specified and adjustable voltage, voltage waveform, or frequency limits, the battery supplies energy to maintain constant, regulated inverter power output to the load without switching or disturbance.
   c. If normal power fails, energy supplied by the battery through the inverter continues supply-regulated power to the load without switching or disturbance.
   d. When power is restored at the normal supply terminals of the system, controls automatically synchronize the inverter with the external source before transferring the load. The rectifier-charger then supplies power to the load through the inverter and simultaneously recharges the battery.
   e. If the battery becomes discharged and normal supply is available, the rectifier-charger charges the battery. On reaching full charge, the rectifier-charger automatically shifts to float-charge mode.
   f. If any element of the UPS system fails and power is available at the normal supply terminals of the system, the static bypass transfer switch switches the load to the normal ac supply circuit without disturbance or interruption.
   g. If a fault occurs in the system supplied by the UPS, and current flows in excess of the overload rating of the UPS system, the static bypass transfer switch operates to bypass the fault current to the normal ac supply circuit for fault clearing.
   h. When the fault has cleared, the static bypass transfer switch returns the load to the UPS system.
   i. If the battery is disconnected, the UPS continues to supply power to the load with no degradation of its regulation of voltage and frequency of the output bus.
2. Manual operation includes the following:
   a. Turning the inverter off causes the static bypass transfer switch to transfer the load directly to the normal ac supply circuit without disturbance or interruption.
   b. Turning the inverter on causes the static bypass transfer switch to transfer the load to the inverter.
3. Maintenance Bypass/Isolation Switch Operation: Switch is interlocked so it cannot be operated unless the static bypass transfer switch is in the bypass mode. Device provides manual selection among the three conditions in subparagraphs below without interrupting supply to the load during switching:
   a. Full Isolation: Load is supplied, bypassing the UPS. Normal UPS ac input circuit, static bypass transfer switch, and UPS load terminals are completely disconnected from external circuits.
   b. Maintenance Bypass: Load is supplied, bypassing the UPS. UPS ac supply terminals are energized to permit operational checking, but system load terminals are isolated from the load.
   c. Normal: Normal UPS ac supply terminals are energized and the load is supplied through either the static bypass transfer switch and the UPS rectifier-charger and inverter, or the battery and the inverter.
4. Environmental Conditions: The UPS shall be capable of operating continuously in the following environmental conditions without mechanical or electrical damage or degradation of operating capability, except battery performance.
   a. Ambient Temperature for Electronic Components: 32 to 104 deg F (0 to 40 deg C).

b. Ambient Temperature for Battery: 41 to 95 deg F (5 to 35 deg C).
c. Relative Humidity: 0 to 95 percent, noncondensing.
d. Altitude: Sea level to 4000 feet (1220 m).

B. Performance Requirements
1. The UPS shall perform as specified in this article while supplying rated full-load current, composed of any combination of linear and nonlinear load, up to 100 percent nonlinear load with a load crest factor of 3.0, under the following conditions or combinations of the following conditions:
   a. Inverter is switched to battery source.
   b. Steady-state ac input voltage deviates up to plus or minus 10 percent from nominal voltage.
   c. Steady-state input frequency deviates up to plus or minus 5 percent from nominal frequency.
   d. THD of input voltage is 15 percent or more with a minimum crest factor of 3.0, and the largest single harmonic component is a minimum of 5 percent of the fundamental value.
   e. Load is 30 **OR** 50 **OR** 100, **as directed**, percent unbalanced continuously.
2. Minimum Duration of Supply: If battery is sole energy source supplying rated full UPS load current at 80 percent power factor, duration of supply is five **OR** 10 **OR** 15, **as directed**, minutes.
3. Input Voltage Tolerance: System steady-state and transient output performance remains within specified tolerances when steady-state ac input voltage varies plus 10, minus 15 **OR** 20 **OR** 30, **as directed**, percent from nominal voltage.
4. Overall UPS Efficiency:

NOMINAL OVERALL UPS EFFICIENCY RATINGS

SIZE RANGE OF UPS UNITS	EFFICIENCY AT 100% RATED LOAD	EFFICIENCY AT 75% RATED LOAD	EFFICIENCY AT 50% RATED LOAD
30 kVA and Smaller	86	85	84
37.5 to 74 kVA	89	88	87
75 to 124 kVA	90	88	87
125 to 224 kVA	90	89	88
225 kVA and Larger	90	89	88

5. Maximum Acoustical Noise:

NOMINAL OVERALL UPS AUDIBLE NOISE RATINGS

SIZE RANGE OF UPS UNITS	MAXIMUM NOISE VALUE	DISTANCE AT WHICH MEASURED
10 kVA and Smaller	58 dB	36 inches (900 mm)
20 to 125 kVA	60 dB	48 inches (1200 mm)
150 to 300 kVA	78 dB	48 inches (1200 mm)
300 kVA and Larger	83 dB	48 inches (1200 mm)

6. Maximum Energizing Inrush Current: Six **OR** Eight, **as directed**, times the full-load current.
7. Maximum AC Output-Voltage Regulation for Loads up to 50 Percent Unbalanced: Plus or minus 2 percent over the full range of battery voltage.
8. Output Frequency: 60 Hz, plus or minus 0.5 percent over the full range of input voltage, load, and battery voltage.
9. Limitation of harmonic distortion of input current to the UPS shall be as follows:

a. Description: Either a tuned harmonic filter or an arrangement of rectifier-charger circuits shall limit THD to 5 **OR** 10, **as directed**, percent, maximum, at rated full UPS load current, for power sources with X/R ratio between 2 and 30.
OR
Description: THD is limited to a maximum of 32 percent, at rated full UPS load current, for power sources with X/R ratio between 2 and 30.

10. Maximum Harmonic Content of Output-Voltage Waveform: 5 percent rms total and 3 percent rms for any single harmonic, for 100 percent rated nonlinear load current with a load crest factor of 3.0.
OR
Maximum Harmonic Content of Output-Voltage Waveform: 5 percent rms total and 3 percent rms for any single harmonic, for rated full load with THD up to 50 percent, with a load crest factor of 3.0.
11. Minimum Overload Capacity of UPS at Rated Voltage: 125 percent of rated full load for 10 minutes, and 150 percent for 30 seconds in all operating modes.
12. Maximum Output-Voltage Transient Excursions from Rated Value: For the following instantaneous load changes, stated as percentages of rated full UPS load, voltage shall remain within stated percentages of rated value and recover to, and remain within, plus or minus 2 percent of that value within 100 ms:
    a. 50 Percent: Plus or minus 5 percent.
    b. 100 Percent: Plus or minus 5 percent.
    c. Loss of AC Input Power: Plus or minus 1 percent.
    d. Restoration of AC Input Power: Plus or minus 1 percent.
13. Input Power Factor: A minimum of 0.70 **OR** 0.85, **as directed**, lagging when supply voltage and current are at nominal rated values and the UPS is supplying rated full-load current.
14. EMI Emissions: Comply with FCC Rules and Regulations and with 47 CFR 15 for Class A equipment.

C. UPS Systems
1. Electronic Equipment: Solid-state devices using hermetically sealed, semiconductor elements. Devices include rectifier-charger, inverter, static bypass transfer switch, and system controls.
2. Enclosures: Comply with NEMA 250, Type 1, unless otherwise indicated.
3. Control Assemblies: Mount on modular plug-ins, readily accessible for maintenance.
4. Surge Suppression: Protect internal UPS components from surges that enter at each ac power input connection including main disconnect switch, static bypass transfer switch, and maintenance bypass/isolation switch, **as directed**. Protect rectifier-charger, inverter, controls, and output components.
    a. Use factory-installed surge suppressors tested according to IEEE C62.41.1 and IEEE C62.41.2, Category B **OR** Category C, **as directed**.
    b. Additional Surge Protection: Protect internal UPS components from low-frequency, high-energy voltage surges described in IEEE C62.41.1 and IEEE C62.41.2. Design the circuits connecting with external power sources and select circuit elements, conductors, conventional surge suppressors, and rectifier components and controls so input assemblies will have adequate mechanical strength and thermal and current-carrying capacity to withstand stresses imposed by 40-Hz, 180 percent voltage surges described in IEEE C62.41.1 and IEEE C62.41.2.
5. Maintainability Features (for units rated more than approximately 100 kVA): Mount rectifier-charger and inverter sections and the static bypass transfer switch on modular plug-ins, readily accessible for maintenance.
6. Capacity Upgrade Capability: Arrange wiring, controls, and modular component plug-in provisions to permit future 25 percent increase in UPS capacity.
7. Seismic-Restraint Design: UPS assemblies, subassemblies, and components (and fastenings and supports, mounting, and anchorage devices for them) shall be designed and fabricated to withstand static and seismic forces.
8. UPS Cabinet Ventilation: Redundant fans or blowers draw in ambient air near the bottom of cabinet and discharge it near the top rear.

9. Output Circuit Neutral Bus, Conductor, and Terminal Ampacity (for a UPS with heavy nonlinear loading): Rated phase current times a multiple of 1.73, minimum.

D. Rectifier-Charger
1. Capacity: Adequate to supply the inverter during rated full output load conditions and simultaneously recharge the battery from fully discharged condition to 95 percent of full charge within 10 times the rated discharge time for duration of supply under battery power at full load.
2. Output Ripple: Limited by output filtration to less than 0.5 percent of rated current, peak to peak.
3. Control Circuits: Immune to frequency variations within rated frequency ranges of normal and emergency power sources.
   a. Response Time: Field adjustable for maximum compatibility with local generator-set power source.
4. Battery Float-Charging Conditions: Comply with battery manufacturer's written instructions for battery terminal voltage and charging current required for maximum battery life.

E. Inverter
1. Description: Pulse-width modulated, with sinusoidal output.
   OR
   Description (if the UPS may be supplied power from a standby engine-generator set): Pulse-width modulated, with sinusoidal output. Include a bypass phase synchronization window adjustment to optimize compatibility with local engine-generator-set power source.

F. Static Bypass Transfer Switch
1. Description: Solid-state switching device providing uninterrupted transfer. A contactor or electrically operated circuit breaker automatically provides electrical isolation for the switch.
2. Switch Rating: Continuous duty at the rated full UPS load current, minimum.

G. Battery

ALTERNATIVE BATTERY TYPES FOR UPS SYSTEMS

TYPE	NOMINAL LIFE EXPECTANCY (YEARS)*	TYPICAL WARRANTY (YEARS)*		MINIMUM NOMINAL MAINTENANCE INTERVAL	APPROX. INITIAL COST FACTOR**	SPECIAL FEATURES
		FULL	PRO RATA			
Premium quality, valve regulated, recombinant, lead calcium	20	1	19	1 year	2.5	Spill proof.
Standard quality, valve regulated, recombinant, lead calcium	10	1	9	1 year	1.0	Spill proof.
Nickel cadmium, flooded	25	5	15	3 years	4.0	Can operate in high ambient temperatures. Can be completely discharged without damage.
Lead calcium, flooded	20	1	9	6 months	2.5	-
*Life expectancy and warranty data apply to installations where batteries are considered to be in a "float-service"						

application. Use the data only as a general guide because UPS batteries are typically considered to be in a separate service application category that accounts for the numerous discharges of varying duration they experience.

**Cost includes an allowance for space requirements and environmental control.

1. Description: Valve-regulated, recombinant, lead-calcium units, factory assembled in an isolated compartment of UPS cabinet, complete with battery disconnect switch.
   a. Arrange for drawout removal of battery assembly from cabinet for testing and inspecting.

   OR

   Description: Valve-regulated, premium, heavy-duty, recombinant, lead-calcium units; factory assembled in an isolated compartment or in a separate matching cabinet, complete with battery disconnect switch.
   a. Arrange for drawout removal of battery assembly from cabinet for testing and inspecting.

   OR

   Description: Flooded, lead-calcium, heavy-duty industrial units in styrene acrylonitrile containers mounted on three-tier, **as directed**, acid-resistant, painted steel racks. Assembly includes battery disconnect switch, intercell connectors, hydrometer syringe, and thermometer with specific gravity-correction scales.
2. Seismic-Restraint Design: Battery racks, cabinets, assemblies, subassemblies, and components (and fastenings and supports, mounting, and anchorage devices for them) shall be designed and fabricated to withstand static and seismic forces.

H. Controls And Indications
1. Description: Group displays, indications, and basic system controls on a common control panel on front of UPS enclosure.
2. Minimum displays, indicating devices, and controls include those in lists below. Provide sensors, transducers, terminals, relays, and wiring required to support listed items. Alarms include audible signals and visual displays.
3. Indications: Labeled LED **OR** Plain-language messages on a digital LCD or LED, **as directed**.
   a. Quantitative indications shall include the following:
      1) Input voltage, each phase, line to line.
      2) Input current, each phase, line to line.
      3) Bypass input voltage, each phase, line to line.
      4) Bypass input frequency.
      5) System output voltage, each phase, line to line.
      6) System output current, each phase.
      7) System output frequency.
      8) DC bus voltage.
      9) Battery current and direction (charge/discharge).
      10) Elapsed time discharging battery.
   b. Basic status condition indications shall include the following:
      1) Normal operation.
      2) Load-on bypass.
      3) Load-on battery.
      4) Inverter off.
      5) Alarm condition.
   c. Alarm indications shall include the following:
      1) Bypass ac input overvoltage or undervoltage.
      2) Bypass ac input overfrequency or underfrequency.
      3) Bypass ac input and inverter out of synchronization.
      4) Bypass ac input wrong-phase rotation.
      5) Bypass ac input single-phase condition.
      6) Bypass ac input filter fuse blown.
      7) Internal frequency standard in use.
      8) Battery system alarm.
      9) Control power failure.
      10) Fan failure.

11) UPS overload.
12) Battery-charging control faulty.
13) Input overvoltage or undervoltage.
14) Input transformer overtemperature.
15) Input circuit breaker tripped.
16) Input wrong-phase rotation.
17) Input single-phase condition.
18) Approaching end of battery operation.
19) Battery undervoltage shutdown.
20) Maximum battery voltage.
21) Inverter fuse blown.
22) Inverter transformer overtemperature.
23) Inverter overtemperature.
24) Static bypass transfer switch overtemperature.
25) Inverter power supply fault.
26) Inverter transistors out of saturation.
27) Identification of faulty inverter section/leg.
28) Inverter output overvoltage or undervoltage.
29) UPS overload shutdown.
30) Inverter current sensor fault.
31) Inverter output contactor open.
32) Inverter current limit.

d. Controls shall include the following:
1) Inverter on-off.
2) UPS start.
3) Battery test.
4) Alarm silence/reset.
5) Output-voltage adjustment.

4. Dry-form "C" contacts shall be available for remote indication of the following conditions:
a. UPS on battery.
b. UPS on-line.
c. UPS load-on bypass.
d. UPS in alarm condition.
e. UPS off (maintenance bypass closed).

5. Emergency Power Off Switch: Capable of local operation and operation by means of activation by external dry contacts.

I. Maintenance Bypass/Isolation Switch
1. Description: Manually operated switch or arrangement of switching devices with mechanically actuated contact mechanism arranged to route the flow of power to the load around the rectifier-charger, inverter, and static bypass transfer switch.
a. Switch shall be electrically and mechanically interlocked to prevent interrupting power to the load when switching to bypass mode.
b. Switch shall electrically isolate other UPS components to permit safe servicing.
2. Comply with NEMA PB 2 and UL 891.
3. Switch Rating: Continuous duty at rated full UPS load current.
4. Mounting Provisions: Internal to system cabinet **OR** Separate wall- or floor-mounted unit, **as directed**.
5. Key interlock requires unlocking maintenance bypass/isolation switch before switching from normal position with key that is released only when the UPS is bypassed by the static bypass transfer switch. Lock is designed specifically for mechanical and electrical component interlocking.

J. Output Isolation Transformer

1. Description: Shielded unit **OR** Unit, **as directed**, with low forward transfer impedance up to 3 kHz, minimum. Include the following features:
   a. Comply with applicable portions of UL 1561, including requirements for nonlinear load current-handling capability for a K-factor of approximately 4 **OR** 9 **OR** 13 **OR** 20, **as directed**.
   b. Output Impedance at Fundamental Frequency: Between 3 and 4 percent.
   c. Regulation: 5 percent, maximum, at rated nonlinear load current.
   d. Full-Load Efficiency at Rated Nonlinear Load Current: 96 percent, minimum.
   e. Electrostatic Shielding of Windings: Independent for each winding.
   f. Coil Leads: Physically arranged for minimum interlead capacitance.
   g. Shield Grounding Terminal: Separately mounted; labeled "Shield Ground."
   h. Capacitive Coupling between Primary and Secondary: 33 picofarads, maximum, over a frequency range of 20 Hz to 1 MHz.

K. Output Distribution Section
1. Panelboards: Comply with Division 26 Section "Panelboards" except provide assembly integral to UPS cabinet.

L. Monitoring By Remote Status And Alarm Panel
1. Description: Labeled LEDs on panel faceplate indicate five basic status conditions. Audible signal indicates alarm conditions. Silencing switch in face of panel silences signal without altering visual indication.
   a. Cabinet and Faceplate: Surface or flush mounted to suit mounting conditions indicated.

M. Monitoring By Remote Computer
1. Description: Communication module in unit control panel provides capability for remote monitoring of status, parameters, and alarms specified in "Controls and Indications" Article. The remote computer and the connecting signal wiring are not included in this Section. Include the following features:
   a. Connectors and network interface units or modems for data transmission via RS-232 link.
   b. Software designed for control and monitoring of UPS functions and to provide on-screen explanations, interpretations, diagnosis, action guidance, and instructions for use of monitoring indications and development of meaningful reports. Permit storage and analysis of power-line transient records. Designs for Windows applications, software, and computer are not included in this Section.
   c. Software and Hardware: Compatible with that specified in Division 26 Section "Electrical Power Monitoring And Control".

N. Basic Battery Monitoring
1. Battery Ground-Fault Detector: Initiates alarm when resistance to ground of positive or negative bus of battery is less than 5000 ohms.
2. Battery compartment smoke/high-temperature detector initiates an alarm when smoke or a temperature greater than 75 deg C occurs within the compartment.
3. Annunciation of Alarms: At UPS control panel.

O. Additional Battery Monitoring
1. Monitoring features and components shall include the following:
   a. Factory-wired sensing leads to cell and battery terminals and cell temperature sensors.
   b. Connections for data transmission via RS-232 link, network interface and, **as directed**, modem and, **as directed**, external signal wiring to computer **OR** electrical power monitoring and control equipment, **as directed**. External signal wiring and computer are not specified in this Section.
   c. PC-based software designed to store and analyze battery data. Software compiles reports on individual-cell parameters and total battery performance trends, and provides data for scheduling and prioritizing battery maintenance.

2. Performance: Automatically measures and electronically records the following parameters on a routine schedule and during battery discharge events. During discharge events, records measurements timed to nearest second; includes measurements of the following parameters:
   a. Total battery voltage and ambient temperature.
   b. Individual-cell voltage, impedance, and temperature. During battery-discharging events such as utility outages, measures battery and cell voltages timed to nearest second.
   c. Individual-cell electrolyte levels.

P. Battery-Cycle Warranty Monitoring
1. Description: Electronic device, acceptable to battery manufacturer as a basis for warranty action, for monitoring of charge-discharge cycle history of batteries covered by cycle-life warranties.
2. Performance: Automatically measures and records each discharge event, classifies it according to duration category, and totals discharges according to warranty criteria, displaying remaining warranted battery life on front panel display.
3. Additional monitoring functions and features shall include the following:
   a. Measuring and Recording: Total voltage at battery terminals; initiates alarm for excursions outside the proper float-voltage level.
   b. Monitors: Ambient temperature at battery; initiates alarm if temperature deviates from normally acceptable range.
   c. Keypad on Device Front Panel: Provides access to monitored data using front panel display.
   d. Alarm Contacts: Arranged to initiate local **OR** remote, **as directed**, alarm for battery discharge events **OR** abnormal temperature **OR** abnormal battery voltage or temperature, **as directed**.
   e. Memory: Stores recorded data in nonvolatile electronic memory.
   f. RS-232 Port: Permits downloading of data to a portable PC.
   g. Modem: Makes measurements and recorded data accessible to a remote PC via telephone line. Computer is not specified in this Section.

Q. Source Quality Control
1. Factory test complete UPS system before shipment. Use actual batteries that are part of final installation **OR** simulated battery testing, **as directed**. Include the following:
   a. Test and demonstration of all functions, controls, indicators, sensors, and protective devices.
   b. Full-load test.
   c. Transient-load response test.
   d. Overload test.
   e. Power failure test.
2. Observation of Test: Give 14 days' advance notice of tests and provide opportunity for Owner's representative to observe tests at Owner's choice.
3. Report test results. Include the following data:
   a. Description of input source and output loads used. Describe actions required to simulate source load variation and various operating conditions and malfunctions.
   b. List of indications, parameter values, and system responses considered satisfactory for each test action. Include tabulation of actual observations during test.
   c. List of instruments and equipment used in factory tests.

1.3 EXECUTION

A. Installation
1. Equipment Mounting: Install UPS on concrete base. Comply with requirements for concrete base specified in Division 03 Section "Cast-in-place Concrete".
   a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around the full perimeter of concrete base.

b. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
d. Install anchor bolts to elevations required for proper attachment to supported equipment.

2. Maintain minimum clearances and workspace at equipment according to manufacturer's written instructions and NFPA 70.
3. Connections: Interconnect system components. Make connections to supply and load circuits according to manufacturer's wiring diagrams unless otherwise indicated.

B. Grounding
1. Separately Derived Systems: If not part of a listed power supply for a data-processing room, comply with NFPA 70 requirements for connecting to grounding electrodes and for bonding to metallic piping near isolation transformer.

C. Identification
1. Identify components and wiring according to Division 26 Section "Identification For Electrical Systems".
a. Identify each battery cell individually.

D. Battery Equalization
1. Equalize charging of battery cells according to manufacturer's written instructions. Record individual-cell voltages.

E. Field Quality Control
1. Perform tests and inspections.
a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
2. Tests and Inspections:
a. Comply with manufacturer's written instructions.
b. Inspect interiors of enclosures, including the following:
1) Integrity of mechanical and electrical connections.
2) Component type and labeling verification.
3) Ratings of installed components.
c. Inspect batteries and chargers according to requirements in NETA Acceptance Testing Specifications.
d. Test manual and automatic operational features and system protective and alarm functions.
e. Test communication of status and alarms to remote monitoring equipment.
f. Load the system using a variable-load bank to simulate kilovolt amperes, kilowatts, and power factor of loads for unit's rating. Use instruments calibrated within the previous six months according to NIST standards.
1) Simulate malfunctions to verify protective device operation.
2) Test duration of supply on emergency, low-battery voltage shutdown, and transfers and restoration due to normal source failure.
3) Test harmonic content of input and output current less than 25, 50, and 100 percent of rated loads.
4) Test output voltage under specified transient-load conditions.
5) Test efficiency at 50, 75, and 100 percent of rated loads.
6) Test remote status and alarm panel functions.
7) Test battery-monitoring system functions.
3. Seismic-restraint tests and inspections shall include the following:
a. Inspect type, size, quantity, arrangement, and proper installation of mounting or anchorage devices.

b. Test mounting and anchorage devices according to requirements in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".

4. The UPS system will be considered defective if it does not pass tests and inspections.
5. Record of Tests and Inspections: Maintain and submit documentation of tests and inspections, including references to manufacturers' written instructions and other test and inspection criteria. Include results of tests, inspections, and retests.
6. Prepare test and inspection reports.

F. Demonstration

1. Train Owner's maintenance personnel to adjust, operate, and maintain the UPS.

END OF SECTION 26 33 53 00

Task	Specification	Specification Description
26 33 53 00	26 33 43 00	Central Battery Inverters
26 35 33 00	26 09 23 00b	Electrical Power Monitoring And Control
26 35 53 00	26 32 13 13	Packaged Engine Generators

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SECTION 26 36 13 00 - TRANSFER SWITCHES

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for transfer switches. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. This Section includes transfer switches rated 600 V and less, including the following:
   a. Automatic transfer switches.
   b. Bypass/isolation switches.
   c. Nonautomatic transfer switches.
   d. Remote annunciation systems.
   e. Remote annunciation and control systems.

C. Submittals
1. Product Data: Include rated capacities, weights, operating characteristics, furnished specialties, and accessories.
2. Shop Drawings: Dimensioned plans, elevations, sections, and details showing minimum clearances, conductor entry provisions, gutter space, installed features and devices, and material lists for each switch specified.
3. Manufacturer Seismic Qualification Certification: Submit certification that transfer switches accessories, and components will withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems". Include the following:
4. Field quality-control test reports.
5. Operation and maintenance data.

D. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
2. Comply with NEMA ICS 1.
3. Comply with NFPA 70.
4. Comply with NFPA 99.
5. Comply with NFPA 110.
6. Comply with UL 1008 unless requirements of these Specifications are stricter.

E. Project Conditions
1. Interruption of Existing Electrical Service: Do not interrupt electrical service to facilities occupied by the Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service:
   a. Notify the Owner no fewer than seven days in advance of proposed interruption of electrical service.

1.2 PRODUCTS

A. General Transfer-Switch Product Requirements
1. Indicated Current Ratings: Apply as defined in UL 1008 for continuous loading and total system transfer, including tungsten filament lamp loads not exceeding 30 percent of switch ampere rating, unless otherwise indicated.

2. Tested Fault-Current Closing and Withstand Ratings: Adequate for duty imposed by protective devices at installation locations in Project under the fault conditions indicated, based on testing according to UL 1008.
   a. Where transfer switch includes internal fault-current protection, rating of switch and trip unit combination shall exceed indicated fault-current value at installation location.
3. Solid-State Controls: Repetitive accuracy of all settings shall be plus or minus 2 percent or better over an operating temperature range of minus 20 to plus 70 deg C.
4. Resistance to Damage by Voltage Transients: Components shall meet or exceed voltage-surge withstand capability requirements when tested according to IEEE C62.41. Components shall meet or exceed voltage-impulse withstand test of NEMA ICS 1.
5. Electrical Operation: Accomplish by a nonfused, momentarily energized solenoid or electric-motor-operated mechanism, mechanically and electrically interlocked in both directions.
6. Switch Characteristics: Designed for continuous-duty repetitive transfer of full-rated current between active power sources.
   a. Limitation: Switches using molded-case switches or circuit breakers or insulated-case circuit-breaker components are not acceptable.
   b. Switch Action: Double throw; mechanically held in both directions.
   c. Contacts: Silver composition or silver alloy for load-current switching. Conventional automatic transfer-switch units, rated 225 A and higher, shall have separate arcing contacts.
7. Neutral Switching. Where four-pole switches are indicated, provide neutral pole switched simultaneously with phase poles **OR** overlapping neutral contacts, **as directed**.
8. Neutral Terminal: Solid and fully rated, unless otherwise indicated.
9. Oversize Neutral: Ampacity and switch rating of neutral path through units indicated for oversize neutral shall be double the nominal rating of circuit in which switch is installed.
10. Heater: Equip switches exposed to outdoor temperatures and humidity, and other units indicated, with an internal heater. Provide thermostat within enclosure to control heater.
11. Battery Charger: For generator starting batteries.
    a. Float type rated 2 **OR** 10, **as directed,** A.
    b. Ammeter to display charging current.
    c. Fused ac inputs and dc outputs.
12. Annunciation, Control, and Programming Interface Components: Devices at transfer switches for communicating with remote programming devices, annunciators, or annunciator and control panels shall have communication capability matched with remote device.
13. Factory Wiring: Train and bundle factory wiring and label, consistent with Shop Drawings, either by color-code or by numbered or lettered wire and cable tape markers at terminations. Color-coding and wire and cable tape markers are specified in Division 26 Section "Identification For Electrical Systems".
    a. Designated Terminals: Pressure type, suitable for types and sizes of field wiring indicated.
    b. Power-Terminal Arrangement and Field-Wiring Space: Suitable for top, side, or bottom entrance of feeder conductors as indicated.
    c. Control Wiring: Equipped with lugs suitable for connection to terminal strips.
14. Enclosures: General-purpose NEMA 250, Type 1 **OR** 3R **OR** 12, **as directed**, complying with NEMA ICS 6 and UL 508, unless otherwise indicated.

B. Automatic Transfer Switches
   1. Comply with Level 1 equipment according to NFPA 110.
   2. Switching Arrangement: Double-throw type, incapable of pauses or intermediate position stops during normal functioning, unless otherwise indicated.
   3. Manual Switch Operation: Under load, with door closed and with either or both sources energized. Transfer time is same as for electrical operation. Control circuit automatically disconnects from electrical operator during manual operation.
   4. Manual Switch Operation: Unloaded. Control circuit automatically disconnects from electrical operator during manual operation.

5. Signal-Before-Transfer Contacts: A set of normally open/normally closed dry contacts operates in advance of retransfer to normal source. Interval is adjustable from 1 to 30 seconds.
6. Digital Communication Interface: Matched to capability of remote annunciator or annunciator and control panel.
7. Transfer Switches Based on Molded-Case-Switch Components: Comply with NEMA AB 1, UL 489, and UL 869A.
8. Automatic Closed-Transition Transfer Switches: Include the following functions and characteristics:
    a. Fully automatic make-before-break operation.
    b. Load transfer without interruption, through momentary interconnection of both power sources not exceeding 100 ms.
    c. Initiation of No-Interruption Transfer: Controlled by in-phase monitor and sensors confirming both sources are present and acceptable.
        1) Initiation occurs without active control of generator.
        2) Controls ensure that closed-transition load transfer closure occurs only when the 2 sources are within plus or minus 5 electrical degrees maximum, and plus or minus 5 percent maximum voltage difference.
    d. Failure of power source serving load initiates automatic break-before-make transfer.
9. In-Phase Monitor: Factory-wired, internal relay controls transfer so it occurs only when the two sources are synchronized in phase. Relay compares phase relationship and frequency difference between normal and emergency sources and initiates transfer when both sources are within 15 electrical degrees, and only if transfer can be completed within 60 electrical degrees. Transfer is initiated only if both sources are within 2 Hz of nominal frequency and 70 percent or more of nominal voltage.
10. Motor Disconnect and Timing Relay: Controls designate starters so they disconnect motors before transfer and reconnect them selectively at an adjustable time interval after transfer. Control connection to motor starters is through wiring external to automatic transfer switch. Time delay for reconnecting individual motor loads is adjustable between 1 and 60 seconds, and settings are as indicated. Relay contacts handling motor-control circuit inrush and seal currents are rated for actual currents to be encountered.
11. Programmed Neutral Switch Position: Switch operator has a programmed neutral position arranged to provide a midpoint between the two working switch positions, with an intentional, time-controlled pause at midpoint during transfer. Pause is adjustable from 0.5 to 30 seconds minimum and factory set for 0.5 second, unless otherwise indicated. Time delay occurs for both transfer directions. Pause is disabled unless both sources are live.
12. Automatic Transfer-Switch Features:
    a. Undervoltage Sensing for Each Phase of Normal Source: Sense low phase-to-ground voltage on each phase. Pickup voltage shall be adjustable from 85 to 100 percent of nominal, and dropout voltage is adjustable from 75 to 98 percent of pickup value. Factory set for pickup at 90 percent and dropout at 85 percent.
    b. Adjustable Time Delay: For override of normal-source voltage sensing to delay transfer and engine start signals. Adjustable from zero to six seconds, and factory set for one second.
    c. Voltage/Frequency Lockout Relay: Prevent premature transfer to generator. Pickup voltage shall be adjustable from 85 to 100 percent of nominal. Factory set for pickup at 90 percent. Pickup frequency shall be adjustable from 90 to 100 percent of nominal. Factory set for pickup at 95 percent.
    d. Time Delay for Retransfer to Normal Source: Adjustable from 0 to 30 minutes, and factory set for 10 minutes to automatically defeat delay on loss of voltage or sustained undervoltage of emergency source, provided normal supply has been restored.
    e. Test Switch: Simulate normal-source failure.
    f. Switch-Position Pilot Lights: Indicate source to which load is connected.
    g. Source-Available Indicating Lights: Supervise sources via transfer-switch normal- and emergency-source sensing circuits.
        1) Normal Power Supervision: Green light with nameplate engraved "Normal Source Available."

2) Emergency Power Supervision: Red light with nameplate engraved "Emergency Source Available."

h. Unassigned Auxiliary Contacts: Two normally open, single-pole, double-throw contacts for each switch position, rated 10 A at 240-V ac.

i. Transfer Override Switch: Overrides automatic retransfer control so automatic transfer switch will remain connected to emergency power source regardless of condition of normal source. Pilot light indicates override status.

j. Engine Starting Contacts: One isolated and normally closed, and one isolated and normally open; rated 10 A at 32-V dc minimum.

k. Engine Shutdown Contacts: Instantaneous; shall initiate shutdown sequence at remote engine-generator controls after retransfer of load to normal source.

l. Engine Shutdown Contacts: Time delay adjustable from zero to five minutes, and factory set for five minutes. Contacts shall initiate shutdown at remote engine-generator controls after retransfer of load to normal source.

m. Engine-Generator Exerciser: Solid-state, programmable-time switch starts engine generator and transfers load to it from normal source for a preset time, then retransfers and shuts down engine after a preset cool-down period. Initiates exercise cycle at preset intervals adjustable from 7 to 30 days. Running periods are adjustable from 10 to 30 minutes. Factory settings are for 7-day exercise cycle, 20-minute running period, and 5-minute cool-down period. Exerciser features include the following:

1) Exerciser Transfer Selector Switch: Permits selection of exercise with and without load transfer.

2) Push-button programming control with digital display of settings.

3) Integral battery operation of time switch when normal control power is not available.

C. Bypass/Isolation Switches

1. Comply with requirements for Level 1 equipment according to NFPA 110.

2. Description: Manual type, arranged to select and connect either source of power directly to load, isolating transfer switch from load and from both power sources. Include the following features for each combined automatic transfer switch and bypass/isolation switch:

a. Means to lock bypass/isolation switch in the position that isolates transfer switch with an arrangement that permits complete electrical testing of transfer switch while isolated. While isolated, interlocks prevent transfer-switch operation, except for testing or maintenance.

b. Drawout Arrangement for Transfer Switch: Provide physical separation from live parts and accessibility for testing and maintenance operations.

c. Bypass/Isolation Switch Current, Voltage, Closing, and Short-Circuit Withstand Ratings: Equal to or greater than those of associated automatic transfer switch, and with same phase arrangement and number of poles.

d. Contact temperatures of bypass/isolation switches shall not exceed those of automatic transfer-switch contacts when they are carrying rated load.

e. Operability: Constructed so load bypass and transfer-switch isolation can be performed by 1 person in no more than 2 operations in 15 seconds or less.

f. Legend: Manufacturer's standard legend for control labels and instruction signs shall describe operating instructions.

g. Maintainability: Fabricate to allow convenient removal of major components from front without removing other parts or main power conductors.

3. Interconnection of Bypass/Isolation Switches with Automatic Transfer Switches: Factory-installed copper bus bars; plated at connection points and braced for the indicated available short-circuit current.

D. Nonautomatic Transfer Switches

1. Operation: Electrically actuated by push buttons designated "Normal Source" and "Alternate Source." Switch shall be capable of transferring load in either direction with either or both sources energized.

2. Operation: Electrically actuated by push buttons designated "Normal Source" and "Alternate Source." In addition, removable manual handle provides quick-make, quick-break manual-switching action. Switch shall be capable of electrically or manually transferring load in either direction with either or both sources energized. Control circuit disconnects from electrical operator during manual operation.
3. Double-Throw Switching Arrangement: Incapable of pauses or intermediate position stops during switching sequence.
4. Nonautomatic Transfer-Switch Accessories:
   a. Pilot Lights: Indicate source to which load is connected.
   b. Source-Available Indicating Lights: Supervise sources via transfer-switch normal- and alternate-source sensing circuits.
      1) Normal Power Supervision: Green light with nameplate engraved "Normal Source Available."
      2) Emergency Power Supervision: Red light with nameplate engraved "Alternate Source Available."
   c. Unassigned Auxiliary Contacts: One set of normally closed contacts for each switch position, rated 10 A at 240-V ac.

E. Remote Annunciator System
1. Functional Description: Remote annunciator panel shall annunciate conditions for indicated transfer switches. Annunciation shall include the following:
   a. Sources available, as defined by actual pickup and dropout settings of transfer-switch controls.
   b. Switch position.
   c. Switch in test mode.
   d. Failure of communication link.
2. Annunciator Panel: LED-lamp type with audible signal and silencing switch.
   a. Indicating Lights: Grouped for each transfer switch monitored.
   b. Label each group, indicating transfer switch it monitors, location of switch, and identity of load it serves.
   c. Mounting: Flush, modular, steel cabinet, unless otherwise indicated.
   d. Lamp Test: Push-to-test or lamp-test switch on front panel.

F. Remote Annunciator And Control System
1. Functional Description: Include the following functions for indicated transfer switches:
   a. Indication of sources available, as defined by actual pickup and dropout settings of transfer-switch controls.
   b. Indication of switch position.
   c. Indication of switch in test mode.
   d. Indication of failure of digital communication link.
   e. Key-switch or user-code access to control functions of panel.
   f. Control of switch-test initiation.
   g. Control of switch operation in either direction.
   h. Control of time-delay bypass for transfer to normal source.
2. Malfunction of annunciator, annunciation and control panel, or communication link shall not affect functions of automatic transfer switch. In the event of failure of communication link, automatic transfer switch automatically reverts to stand-alone, self-contained operation. Automatic transfer-switch sensing, controlling, or operating function shall not depend on remote panel for proper operation.
3. Remote Annunciation and Control Panel: Solid-state components. Include the following features:
   a. Controls and indicating lights grouped together for each transfer switch.
   b. Label each indicating light control group. Indicate transfer switch it controls, location of switch, and load it serves.
   c. Digital Communication Capability: Matched to that of transfer switches supervised.
   d. Mounting: Flush, modular, steel cabinet, unless otherwise indicated.

G. Source Quality Control
1. Factory test and inspect components, assembled switches, and associated equipment. Ensure proper operation. Check transfer time and voltage, frequency, and time-delay settings for compliance with specified requirements. Perform dielectric strength test complying with NEMA ICS 1.

1.3 EXECUTION

A. Installation
1. Design each fastener and support to carry load indicated by seismic requirements and according to seismic-restraint details. See Division 26 Section "Hangers And Supports For Electrical Systems".
2. Floor-Mounting Switch: Anchor to floor by bolting.
a. Concrete Bases: 4 inches (100 mm) high, reinforced, with chamfered edges. Extend base no more than 4 inches (100 mm) in all directions beyond the maximum dimensions of switch, unless otherwise indicated or unless required for seismic support. Construct concrete bases according to Division 26 Section "Hangers And Supports For Electrical Systems".
3. Annunciator and Control Panel Mounting: Flush in wall, unless otherwise indicated.
4. Identify components according to Division 26 Section "Identification For Electrical Systems".
5. Set field-adjustable intervals and delays, relays, and engine exerciser clock.

B. Connections
1. Wiring to Remote Components: Match type and number of cables and conductors to control and communication requirements of transfer switches as recommended by manufacturer. Increase raceway sizes at no additional cost to Owner if necessary to accommodate required wiring.
2. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".
3. Connect wiring according to Division 26 Section "Low-voltage Electrical Power Conductors And Cables".

C. Field Quality Control
1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections. Report results in writing.
2. Perform tests and inspections and prepare test reports.
a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installation, including connections, and to assist in testing.
b. After installing equipment and after electrical circuitry has been energized, test for compliance with requirements.
c. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
d. Measure insulation resistance phase-to-phase and phase-to-ground with insulation-resistance tester. Use test voltages and procedure recommended by manufacturer. Comply with manufacturer's specified minimum resistance.
1) Check for electrical continuity of circuits and for short circuits.
2) Inspect for physical damage, proper installation and connection, and integrity of barriers, covers, and safety features.
3) Verify that manual transfer warnings are properly placed.
4) Perform manual transfer operation.
e. After energizing circuits, demonstrate interlocking sequence and operational function for each switch at least three times.

1) Simulate power failures of normal source to automatic transfer switches and of emergency source with normal source available.
2) Simulate loss of phase-to-ground voltage for each phase of normal source.
3) Verify time-delay settings.
4) Verify pickup and dropout voltages by data readout or inspection of control settings.
5) Perform contact-resistance test across main contacts and correct values exceeding 500 microhms and values for 1 pole deviating by more than 50 percent from other poles.
6) Verify proper sequence and correct timing of automatic engine starting, transfer time delay, retransfer time delay on restoration of normal power, and engine cool-down and shutdown.

f. Ground-Fault Tests: Coordinate with testing of ground-fault protective devices for power delivery from both sources.
1) Verify grounding connections and locations and ratings of sensors.

3. Coordinate tests with tests of generator and run them concurrently.
4. Report results of tests and inspections in writing. Record adjustable relay settings and measured insulation and contact resistances and time delays. Attach a label or tag to each tested component indicating satisfactory completion of tests.
5. Remove and replace malfunctioning units and retest as specified above.
6. Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each switch. Remove all access panels so joints and connections are accessible to portable scanner.
   a. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each switch 11 months after date of Substantial Completion.
   b. Instrument: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
   c. Record of Infrared Scanning: Prepare a certified report that identifies switches checked and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

D. Demonstration
1. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain transfer switches and related equipment as specified below.
2. Coordinate this training with that for generator equipment.

END OF SECTION 26 36 13 00

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Task	Specification	Specification Description
26 36 13 00	26 24 13 00a	Enclosed Switches And Circuit Breakers
26 36 23 00	26 24 13 00a	Enclosed Switches And Circuit Breakers
26 36 23 00	26 36 13 00	Transfer Switches

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SECTION 26 43 13 00 - TRANSIENT VOLTAGE SUPPRESSION

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for transient voltage suppression. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section includes field-mounted TVSS for low-voltage (120 to 600 V) power distribution and control equipment.

C. Definitions
1. ATS: Acceptance Testing Specifications.
2. SVR: Suppressed voltage rating.
3. TVSS: Transient voltage surge suppressor(s), both singular and plural; also, transient voltage surge suppression.

D. Submittals
1. Product Data: For each type of product indicated. Include rated capacities, operating weights, electrical characteristics, furnished specialties, and accessories.
2. Field quality-control reports.
3. Operation and maintenance data.
4. Warranties: Sample of special warranties.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a testing agency, and marked for intended location and application.
2. Comply with IEEE C62.41.2 and test devices according to IEEE C62.45.
3. Comply with NEMA LS 1.
4. Comply with UL 1283, **as directed**, and UL 1449.
5. Comply with NFPA 70.

F. Project Conditions
1. Interruption of Existing Electrical Service: Do not interrupt electrical service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:
   a. Notify Owner no fewer than two days in advance of proposed electrical service interruptions.
   b. Do not proceed with interruption of electrical service without Owner's written permission.
2. Service Conditions: Rate TVSS devices for continuous operation under the following conditions unless otherwise indicated:
   a. Maximum Continuous Operating Voltage: Not less than 115 percent of nominal system operating voltage.
   b. Operating Temperature: 30 to 120 deg F (0 to 50 deg C).
   c. Humidity: 0 to 85 percent, noncondensing.
   d. Altitude: Less than 20,000 feet (6090 m) above sea level.

G. Warranty
1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of surge suppressors that fail in materials or workmanship within Five years from date of Final Completion.

2. Special Warranty for Cord-Connected, Plug-in Surge Suppressors: Manufacturer's standard form in which manufacturer agrees to repair or replace electronic equipment connected to circuits protected by surge suppressors.

1.2 PRODUCTS

A. Service Entrance Suppressors
1. Surge Protection Devices:
   a. Non-modular.
   b. LED indicator lights for power and protection status.
   c. Audible alarm, with silencing switch, to indicate when protection has failed.
   d. Form-C contacts rated at 5 A and 250-V ac, one normally open and one normally closed, for remote monitoring of protection status. Contacts shall reverse on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.

   OR

   Surge Protection Devices:
   e. Comply with UL 1449.
   f. Modular design (with field-replaceable modules) **OR** Non-modular design, **as directed**.
   g. Fuses, rated at 200-kA interrupting capacity.
   h. Fabrication using bolted compression lugs for internal wiring.
   i. Integral disconnect switch (if a fused switch or circuit breaker is not provided for the TVSS in the panelboard and the TVSS will not have a direct bus bar connection).
   j. Redundant suppression circuits.
   k. Redundant replaceable modules.
   l. Arrangement with copper bus bars and for bolted connections to phase buses, neutral bus, and ground bus.

      OR

      Arrangement with wire connections to phase buses, neutral bus, and ground bus.
   m. LED indicator lights for power and protection status.
   n. Audible alarm, with silencing switch, to indicate when protection has failed.
   o. Form-C contacts rated at 5 A and 250-V ac, one normally open and one normally closed, for remote monitoring of protection status. Contacts shall reverse on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.
   p. Four **OR** Six, **as directed**,-digit transient-event counter set to totalize transient surges.
2. Peak Single-Impulse Surge Current Rating: 320 kA per mode/640 kA **OR** 240 kA per mode/480 kA **OR** 160 kA per mode/320 kA, **as directed**, per phase.
3. Minimum single impulse current ratings, using 8-by-20-mic.sec waveform described in IEEE C62.41.2
   a. Line to Neutral: 70,000 A.
   b. Line to Ground: 70,000 A.
   c. Neutral to Ground: 50,000 A.
4. Protection modes and UL 1449 SVR for grounded wye circuits with 480Y/277 V **OR** 208Y/120 V **OR** 600Y/347 V, **as directed**, 3-phase, 4-wire circuits shall be as follows:
   a. Line to Neutral: 800 V for 480Y/277 V **OR** 400 V for 208Y/120 V **OR** 1200 V for 600Y/347 V, **as directed**.
   b. Line to Ground: 800 V for 480Y/277 V **OR** 400 V for 208Y/120 V **OR** 1200 V for 600Y/347 V, **as directed**.
   c. Neutral to Ground: 800 V for 480Y/277 V **OR** 400 V for 208Y/120 V **OR** 1200 V for 600Y/347 V, **as directed**.

   OR

   Protection modes and UL 1449 SVR for 240/120 V, single-phase, 3-wire circuits shall be as follows:

a. Line to Neutral: 400 V.
b. Line to Ground: 400 V.
c. Neutral to Ground: 400 V.

OR

Protection modes and UL 1449 SVR for 240/120-V, 3-phase, 4-wire circuits with high leg shall be as follows:

a. Line to Neutral: 400 V, 800 V from high leg.
b. Line to Ground: 400 V.
c. Neutral to Ground: 400 V.

OR

Protection modes and UL 1449 SVR for 240 V, 480 V, or 600 V, 3-phase, 3-wire, delta circuits shall be as follows:

a. Line to Line: 2000 V for 480 V **OR** 1000 V for 240 V **OR** 2500 V for 600 V, **as directed**.
b. Line to Ground: 2000 V for 480 V **OR** 1000 V for 240 V **OR** 2500 V for 600 V, **as directed**.

B. Panelboard Suppressors

1. Surge Protection Devices:
   a. Non-modular.
   b. LED indicator lights for power and protection status.
   c. Audible alarm, with silencing switch, to indicate when protection has failed.
   d. Form-C contacts rated at 5 A and 250-V ac, one normally open and one normally closed, for remote monitoring of protection status. Contacts shall reverse on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.

   OR

   Surge Protection Devices:
   a. Comply with UL 1449.
   b. Modular design (with field-replaceable modules) **OR** Non-modular design, **as directed**.
   c. Short-circuit current rating complying with UL 1449, and matching or exceeding the panelboard short-circuit rating and redundant suppression circuits; with individually fused metal-oxide varistors.
   d. Fuses, rated at 200-kA interrupting capacity.
   e. Fabrication using bolted compression lugs for internal wiring.
   f. Integral disconnect switch (if a fused switch or circuit breaker is not provided for the TVSS in the panelboard and the TVSS will not have a direct bus bar connection).
   g. Redundant suppression circuits.
   h. Redundant replaceable modules.
   i. Arrangement with wire connections to phase buses, neutral bus, and ground bus.
   j. LED indicator lights for power and protection status.
   k. Audible alarm, with silencing switch, to indicate when protection has failed.
   l. Form-C contacts rated at 5 A and 250-V ac, one normally open and one normally closed, for remote monitoring of protection status. Contacts shall reverse on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.
   m. Four **OR** Six, **as directed**,-digit transient-event counter set to totalize transient surges.
2. Peak Single-Impulse Surge Current Rating: 160 kA per mode/320 kA **OR** 120 kA per mode/240 kA **OR** 80 kA per mode/160 kA, **as directed**, per phase.
3. Minimum single impulse current ratings, using 8-by-20-mic.sec waveform described in IEEE C62.41.2:
   a. Line to Neutral: 70,000 A.
   b. Line to Ground: 70,000 A.
   c. Neutral to Ground: 50,000 A.
4. Protection modes and UL 1449 SVR for grounded wye circuits with 480Y/277 V **OR** 208Y/120 V **OR** 600Y/347 V, **as directed**, 3-phase, 4-wire circuits shall be as follows:
   a. Line to Neutral: 800 V for 480Y/277 V **OR** 400 V for 208Y/120 V **OR** 1200 V for 600Y/347 V, **as directed**.

b. Line to Ground: 800 V for 480Y/277 V **OR** 400 V for 208Y/120 V **OR** 1200 V for 600Y/347 V, **as directed**.
c. Neutral to Ground: 800 V for 480Y/277 V **OR** 400 V for 208Y/120 V **OR** 1200 V for 600Y/347 V, **as directed**.

OR

Protection modes and UL 1449 SVR for 240/120-V, single-phase, 3-wire circuits shall be as follows:
a. Line to Neutral: 400 V.
b. Line to Ground: 400 V.
c. Neutral to Ground: 400 V.

OR

Protection modes and UL 1449 SVR for 240/120-V, 3-phase, 4-wire circuits with high leg shall be as follows:
a. Line to Neutral: 400 V, 800 V from high leg.
b. Line to Ground: 400 V.
c. Neutral to Ground: 400 V.

OR

Protection modes and UL 1449 SVR for 240 V, 480 V, or 600 V, 3-phase, 3-wire, delta circuits shall be as follows:
a. Line to Line: 2000 V for 480 V **OR** 1000 V for 240 V **OR** 2500 V for 600 V, **as directed**.
b. Line to Ground: 1500 V for 480 V **OR** 800 V for 240 V **OR** 2500 V for 600 V, **as directed**.

C. Enclosures
1. Indoor Enclosures: NEMA 250 Type 1 **OR** Type 12, **as directed**.
2. Outdoor Enclosures: NEMA 250 Type 3R **OR** Type 4 **OR** Type 4X, **as directed**.

1.3 EXECUTION

A. Installation
1. Install TVSS devices at service entrance on load side, with ground lead bonded to service entrance ground.
2. Install TVSS devices for panelboards and auxiliary panels with conductors or buses between suppressor and points of attachment as short and straight as possible. Do not exceed manufacturer's recommended lead length. Do not bond neutral and ground.
   a. Provide multiple, 30 **OR** 60 **OR** 100, **as directed**,-A circuit breaker as a dedicated disconnecting means for TVSS unless otherwise indicated.

B. Field Quality Control
1. Perform tests and inspections.
   a. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
2. Tests and Inspections:
   a. Perform each visual and mechanical inspection and electrical test stated in NETA ATS, "Surge Arresters, Low-Voltage Surge Protection Devices" Section. Certify compliance with test parameters.
   b. After installing TVSS devices but before electrical circuitry has been energized, test for compliance with requirements.
   c. Complete startup checks according to manufacturer's written instructions.
3. TVSS device will be considered defective if it does not pass tests and inspections.
4. Prepare test and inspection reports.

C. Startup Service

a. Do not energize or connect service entrance equipment **OR** panelboards **OR** control terminals **OR** data terminals, **as directed**, to their sources until TVSS devices are installed and connected.

b. Do not perform insulation resistance tests of the distribution wiring equipment with the TVSS installed. Disconnect before conducting insulation resistance tests, and reconnect immediately after the testing is over.

D. Demonstration

a. Train Owner's maintenance personnel to maintain TVSS devices.

END OF SECTION 26 43 13 00

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Task	Specification	Specification Description
26 51 13 00	01 22 16 00	No Specification Required
26 51 13 00	02 84 16 00	Removal of Fluorescent Light Ballasts/Capacitors and Fluorescent Light Tubes
26 51 13 00	02 84 16 00a	Interior Lighting
26 51 13 00	02 84 16 00b	Exterior Lighting
26 53 00 00	02 84 16 00a	Interior Lighting

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SECTION 26 55 61 00 - STAGE LIGHTING

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for stage lighting. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section Includes:
a. Dimmer racks.
b. Control console and control devices.
c. Lighting fixtures and accessories.
d. Distribution components.

C. Performance Requirements
1. Seismic Performance: Dimmer racks shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event," **as directed**.

D. Submittals
1. Product Data: For each type of product indicated.
2. Seismic Qualification Certificates: For <**Insert equipment,**> accessories, and components, from manufacturer.
3. Field quality-control reports.
4. Operation and maintenance data.
5. Software and Firmware Operational Documentation.

E. Quality Assurance
1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. Comply with NECA 1.
3. Comply with NFPA 70.

F. Software Service Agreement (if allowed)
1. Technical Support: Beginning with Final Completion, provide software support for two years.
2. Upgrade Service: Update software to latest version at Project completion. Install and program software upgrades that become available within two years from date of Final Completion. Upgrading software shall include operating system. Upgrade shall include new or revised licenses for use of software.
a. Provide 30 days' notice to the Owner to allow scheduling and access to system and to allow the Owner to upgrade computer equipment if necessary.

1.2 PRODUCTS

A. Plug Connectors
1. Pin Type: USITT S3, two-pole, three-wire, 20-A.
2. Twist-Locking Type: NEMA WD 6, two-pole, three-wire, 20-A.

B. Lighting Fixtures And Accessories
1. General:
   a. Comply with UL 1573 and listed and labeled by an NRTL.
   b. Fixtures: Equipped with pigtail, yoke with pipe clamp, safety cable for batten mounting, and filter holder.
   c. Metal Parts: Free of burrs, sharp corners, and edges.
   d. Sheet Metal Components: Steel unless otherwise indicated. Form and support to prevent warping and sagging.
   e. Fixture Doors and Their Internal Access: Smooth operating, free of light leakage under operating conditions, and arranged to permit relamping without use of tools. Doors, lenses, diffusers, and other pieces arranged to prevent accidental falling during relamping and when secured in operating position.
   f. Pigtail: Factory wired, 36-inch- (900-mm-) long, three-wire cord and plug connector assembly with cord encased in woven fiberglass or silicone tubing.
   g. Lamp Sockets: Relampable without disturbing alignment or focus adjustment.
   h. Fixture Ventilation Openings: Baffled against light leaks.
   i. Fixture Operating Controls and Handles: Thermally insulated.
   j. Lenses: Borosilicate glass in silicone mountings.
   k. Framing Shutters: Stainless steel, four way; with each blade in a separate plane under adjustable tension mounting. Blades adjust plus or minus 30 degrees of rotation in gate, for 120-degree-minimum total angular rotation between adjacent blades.
   l. Color Filter Frame Holder: Attached to front of fixture.
   m. Fixture Yoke: Rigid metal, arranged for vertical aiming of unit and equipped with T-bolt or hand screw to lock alignment.
2. Ellipsoidal Spotlights: Fixtures with an elliptical reflector mounted in a fixed relationship to the lamp. Light shall be projected through a gate where the beam is shaped by using shutters, a gobo, or an iris. The shaped beam shall then be focused by a system of lenses.
   a. Tag: ES-1:
      1) Lamp: 1000 W Q1000/4CL, ANSI FEL.
      2) Pattern Holders: Three for each fixture, with framing shutters.
      3) Color Frame: Black, metal.
      4) Minimum Cosine Illumination Performance Ratings When Operated with ANSI C78 Series, FEL Lamp:
         a) 171,000 beam candlepower at 20-degree field angle.
         b) 48,000 beam candlepower at 40-degree field angle.
3. Zoom Ellipsoidal Spotlights: Fixtures with an elliptical reflector mounted in an adjustable relationship to the lamp. Light shall be projected through a gate where the beam is shaped by using shutters, a gobo, or an iris. The shaped beam shall then be focused by a system of lenses.
   a. Tag: ZES-1:
      1) Lamp: 1000 W Q1000/4CL, ANSI FEL.
      2) Pattern Holders: Three for each fixture, with framing shutters.
      3) Operator adjustable from 25- to 50-degree field angle.
      4) Field-angle adjustment scale label on instrument housing for field reference.
      5) Minimum Cosine Illumination Performance Rating When Operated with ANSI C78 Series, FEL Lamp: 82,000 beam candlepower at 35-degree field angle.
4. Fresnel Lens Spotlights:
   a. Die-cast extruded-aluminum housing, with hinged front for relamping.
   b. Tag: FLS-1.
      1) Lamp: 1000 W Q1000T7/4CL, ANSI EGT.
      2) Lens: 6 inches (152 mm).
      3) Illumination Performance Rating When Operated with ANSI C78 Series, EGT Lamp:
         a) 175,000 beam candlepower at 12.5-degree field angle in spot focus.
         b) 12,000 beam candlepower at 74.6-degree field angle in flood focus.
      4) Barn Doors: Two 4-leaf rotatable metal flaps for every three fixtures.
5. Follow Spotlights:

a. Tag: FS-1:
   1) Lamp: Metal halide, G22 medium bi-post, CRI: 90, color: 6000 K, life: 750 hours, HMI 575 W/GS 95 V.
   2) Adjustable lenses in metal housing.
   3) Lamp: Quartz-projector type, Adjustable, underslung base stand mounted on 3-inch (75-mm), locking-type, rubber-tired, ball-bearing casters.
   4) Adjustable lamp holder and socket assembly with precision tuning adjustment; relampable without tools.
   5) Three-leaf, full-range mechanical dimmer.
   6) Adjustable iris and framing shutters.
   7) Automatic color boom.
   8) Removable power cable, 25 feet (8 m) long.
   9) Iris Open, Spot-Focus Performance: 800,000, **as directed**, beam candlepower at 7.2, **as directed**,-degree field angle.
   10) Iris Open, Flood-Focus Performance: 330,000, **as directed**, beam candlepower at 12.2, **as directed**,-degree field angle.

6. PAR Lamp Holders:
   a. Tag: PLH-1:
      1) Lamp: 300 W PAR 38.
      2) Housing: Steel or aluminum, flat black color, **as directed**, with porcelain-plated shell socket.
      3) Barn Doors: Two 4-leaf rotatable metal flaps for every three fixtures.
   b. Tag: <**Insert drawing designation**>.
      1) Lamp: 575 W tungsten halogen, 90 GLA 575 W, 230 V, color: 3200 K, ANSI GKV.
      2) Housing: Steel or aluminum, with porcelain-plated shell socket and color frame, **as directed**.
      3) Barn Doors: Two 4-leaf rotatable metal flaps for every three fixtures.
      4) With Lens Holder and Replaceable Lenses:
         a) <Insert drawing designation>: Very narrow spot.
         b) <Insert drawing designation>: Narrow spot.
         c) <Insert drawing designation>: Medium flood.
         d) <Insert drawing designation>: Wide flood.
         e) <Insert drawing designation>: Very wide.
      5) Motorized **OR** Manual, **as directed**, color wheel.
7. Borderlight Units: Compartmented, three-circuit striplight with nine 150-W, PAR 38/SP **OR** 150-W, PAR 38/FL **OR** 250-W, PAR 38/SP **OR** 150-W, R40/FL, **as directed**, lamps in porcelain sockets and steel sheet housing, 90 inches (2286 mm) long. Compartments shall be in line and wired on two **OR** three **OR** four, **as directed**, alternate circuits, each producing a different color.
   a. Front Door: Spring loaded; designed to hold either filter frames or color roundels.
   b. Color Roundels: One for each lamp; alternating red, blue, and clear, **as directed**.
      1) Additional Roundels: <**Insert number**> amber and <**Insert number**> green.
   c. Hanger: Adjustable, steel-strap type equipped at each end with pipe clamp and safety cable for suspension from a batten.
8. Cyclorama Lights: Suitable for lighting cycloramas from above.
   a. Tag: CL-1:
      1) Lamp: 1000 W Q1000T3/1CL, ANSI FFT.
      2) Housing: Aluminum or steel, **as directed**, flat black color, **as directed**, with color frame, **as directed**.
9. Black Lights: Portable, producing a wash of UV light for special effects.
   a. Tag: BL-1:
      1) Lamp: 250 W blacklight flood, H37KB-250, with integral filter to eliminate far-UV effect while maximizing the near-UV effect.
      2) Housing: Steel or aluminum, **as directed**, flat black color, **as directed**, with carry handle.
      3) C-clamp for using on light pipe.
10. Moving Lights:

a. Tag: ML-1:
   1) General: 700-W, 120-V, metal halide, motorized remote-controlled lighting instrument; NRTL listed.
   2) Lamp: Short-arc metal halide, 14,500 lumens; color temperature of 5600 K, CRI of 80.
   3) Color System: Three-filter CYM (cyan, yellow, magenta) cross-fading mechanism, and 11 standard colors on a fixed wheel.
   4) Optics: Zoom optics with continuously variable field angle from 18.5 to 42 degrees, programmable over a timed range of 2 seconds to 20 minutes; with a mechanical iris for beam-size control. Variable beam focus to soften the edges of gobos and light beams. Zoom combined with iris can project a beam with a field angle of 8 degrees.
   5) Dimming: Coated glass dimmer wheel, with controls to provide smooth timed fades.
   6) Strobe for strobe lighting effects.
   7) Gobo: One rotating wheel with five rotatable wheel positions and one open position. One fixed gobo wheel with 11 pattern positions and one open position.
   8) Beam Orientation Control: Smooth pan and tilt using a three-phase stepper motor system. Pan, 540 degrees; tilt, 270 degrees at 0.3-degree repeatability on either axis.
   9) Control: ANSI E1.11 (USITT DMX512-A) protocol using five pin connectors.

C. Distribution Components
1. Connector Strip: Listed and labeled by an NRTL; factory-wired wireway and receptacle assembly.
   a. Wireway: Steel or extruded aluminum, with removable cover and nominal cross-section dimensions of 3 by 4-1/2 inches (75 by 115 mm).
   b. Accessories: Cable clamps, support cradles, and cable strain relief grips for each cable.
   c. Receptacles: Pigtail mounted, 18 inches (450 mm) long, with strain relief at wireway wall penetration.
      OR
      Receptacles: Flush mounted in wireway cover.
   d. Receptacle Wiring: For connecting to terminal blocks; with 125 deg C, crosslinked, PE-insulated, identification-labeled wire.
   e. Terminal Blocks: Molded-barrier type with screw lugs to suit supply conductors.
   f. Mounting Hardware: Furnished with each unit; permits surface, single-pipe-bracket, or double-pipe-bracket mounting.
   g. Finish: Semigloss or matte black.
2. Plug-in Boxes: Listed and labeled by an NRTL; factory-wired wireway and receptacle assembly, 24 inches (600 mm) long unless otherwise indicated; with the following features:
   a. Wireway: Steel or extruded aluminum, with removable cover and nominal cross-section dimensions of 3 by 4-1/2 inches (75 by 115 mm).
   b. Accessories: Cable clamps, support cradles, and cable strain relief grips for each cable.
   c. Receptacles: Pigtail mounted, 18 inches (450 mm) long, with strain relief at wireway wall penetration.
      OR
      Receptacles: Flush mounted in wireway cover.
   d. Receptacle Wiring: For connecting to terminal blocks; with 125 deg C, crosslinked, PE-insulated, identification-labeled wire.
   e. Terminal Blocks: Molded-barrier type with screw lugs to suit supply conductors.
   f. Surface or Grid Mounting: With accessories for surface mounting or with pipe-mounting accessory bracket.
   g. Recessed Mounting: With flanged cover suitable for recessed mounting in wall.
   h. Finish: Semigloss or matte black.
3. Gridiron Junction Boxes: Listed and labeled by an NRTL; factory wired with terminal strips and concentric knockouts on all sides.
   a. Terminal Blocks: Molded-barrier type with screw lugs to suit supply conductors.

b. Accessories: Cable clamps, support cradles, and cable strain relief grips for each cable, and brackets for surface or pipe mounting.
c. Finish: Semigloss or matte black.

4. Floor Pockets: Listed and labeled by an NRTL; flush-mounted, receptacle outlet assembly.
   a. Box: 0.0598-inch (1.5-mm) steel sheet, 10 inches (250 mm) deep.
   b. Cover Plate: Steel, cast iron, or cast aluminum with nonskid safety tread surface and self-closing, hinged door with cable notches.
   c. Barrier for allowing installation of low-voltage control receptacle for console input or handheld remotes.

D. Wire And Cable
1. Building Wire in Raceways: Comply with requirements specified in Division 26 Section "Low-voltage Electrical Power Conductors And Cables".
2. Portable Power Cable: Listed and labeled by an NRTL; flexible stage and lighting power cable; Type SC, SCE, or SCT; 600 V; multiconductor; 60 deg C temperature rating.
3. Ethernet Cabling: Comply with requirements specified in Division 26 Section "Control-voltage Electrical Power Cables".
   a. For 10/100BaseT, comply with provisions for UTP cable and hardware.
   b. For 10Base-FL, comply with provisions for 50/125 **OR** 62.5/125, **as directed**,-micrometer, multimode, optical-fiber cable and hardware.
4. ANSI E1.11 (USITT DMX512-A) Control Cabling: Comply with requirements specified in Division 26 Section "Control-voltage Electrical Power Cables".
   a. Standard Cable: NFPA 70, Type CM **OR** Type CMG, **as directed**.
      1) Paired, low-capacitance computer cable for ANSI E1.11 (USITT DMX512-A) applications. Two pairs, twisted, No. 22 AWG **OR** No. 24 AWG, **as directed**, stranded, tinned-copper conductors.
      2) PE insulation.
      3) Inner Shield: 100 percent coverage, aluminum foil-polyester tape.
      4) Outer Shield: 90 percent coverage, tinned-copper braid.
      5) Outer Shield Drain Wire: Stranded, tinned copper.
      6) PVC jacket.
      7) Flame Resistance: Comply with UL 1581.
   b. Plenum-Rated Cable: NFPA 70, Type CMP.
      1) Paired, low-capacitance computer cable for ANSI E1.11 (USITT DMX512-A) applications. Two pairs, twisted, No. 22 AWG **OR** No. 24 AWG, **as directed**, stranded, tinned-copper conductors.
      2) Insulation: Foam fluoridated ethylene propylene.
      3) Inner Shield: 100 percent coverage, aluminum foil-polyester tape.
      4) Outer Shield: 90 percent coverage, tinned-copper braid.
      5) Outer Shield Drain Wire: Stranded, tinned copper.
      6) Low-smoke PVC jacket.
      7) Flame Resistance: Comply with NFPA 262.
5. Low-Voltage Control Cabling:
   a. Control-Cable Conductors:
      1) Class 1 Control Circuits: Stranded copper, Type THHN-THWN, in raceway; complying with UL 83.
         OR
         Class 1 Control Circuits: Stranded copper, Type THHN, in raceway; complying with UL 44.
      2) Class 2 Control Circuits: Stranded copper, Type THHN-THWN, in raceway **OR** power-limited cable, concealed in building finishes **OR** power-limited tray cable, in cable tray, **as directed**; complying with UL 83.
         OR
         Class 2 Control Circuits: Stranded copper, Type THHN, in raceway **OR** power-limited cable, concealed in building finishes **OR** power-limited tray cable, in cable tray, **as directed**; complying with UL 44.

3) Class 3 Remote-Control and Signal Circuits: Stranded copper, Type TW or Type TF; complying with UL 83.

b. Paired Cable: NFPA 70, Type CMG.
   1) One pair, twisted, No. 16 AWG, stranded, tinned-copper conductors.
   2) PVC insulation.
   3) Unshielded.
   4) PVC jacket.
   5) Flame Resistance: Comply with UL 1581.

c. Plenum-Rated, Paired Cable: NFPA 70, Type CMP.
   1) One pair, twisted, No. 16 AWG, stranded (19x29), tinned-copper conductors.
   2) PVC insulation.
   3) Unshielded.
   4) PVC jacket.
   5) Flame Resistance: Comply with NFPA 262.

d. Paired Cable: NFPA 70, Type CMG.
   1) One pair, twisted, No. 18 AWG, stranded (19x30), tinned-copper conductors.
   2) PVC insulation.
   3) Unshielded.
   4) PVC jacket.
   5) Flame Resistance: Comply with UL 1581.

e. Plenum-Rated, Paired Cable: NFPA 70, Type CMP.
   1) One pair, twisted, No. 18 AWG, stranded (19x30), tinned-copper conductors.
   2) Fluorinated ethylene propylene insulation.
   3) Unshielded.
   4) Plastic jacket.
   5) Flame Resistance: Comply with NFPA 262.

E. Lighting Control System

1. Description: Microprocessor-based modular system consisting of dimmer and control modules operated from remote-control stations and a control console.
   a. Comply with UL 508.
   b. Comply with USITT AMX192 **OR** ANSI E1.11 (USITT DMX512-A), **as directed**, for data transmission.

2. Dimmer Racks: Listed and labeled by an NRTL; dead-front, front-access, wall-mounted **OR** freestanding, **as directed**, rack for mounting modular dimmers; formed-steel or extruded-aluminum structural members; completely enclosed with steel or aluminum panels. Painted with manufacturer's standard corrosion-resistant primer and finish coats, and having the following features:
   a. Primary Circuit Breaker: Fault-current withstand rating of the rack; not less than 10,000 **OR** 50,000, **as directed**, A, symmetrical.
   b. Hinged, locking front door, with openings to allow air intake across the face of all dimmer modules.
   c. Individual rack sections shall not exceed 84 inches high by 25 inches deep by 30 inches wide (2134 mm high by 635 mm deep by 762 mm wide). Multisection racks shall be interconnected with busbars.
   d. For each module position, provide support rails and control-pin configurations, constructed for precise alignment of dimmer modules into power and signal connector sockets.
   e. Forced-air cooling of each rack for maintaining operating temperature at each dimmer, assuming full load, in ambient temperature not to exceed 40 deg C. Exhaust rates shall be variable, using temperature sensors and fan-speed control electronics. Individual control of multiple fans is acceptable in lieu of fan-speed control. Fan(s) shall start and stop automatically. Fan noise at full load shall be less than 3.1 sones.
   f. Each rack shall have an automatic air-temperature sensor to shut off all dimmers in the rack should the internal temperature rise above maximum safe operating limits. In an

overheat condition, the fan shall continue operating. When a safe operating temperature is restored, the system shall automatically reset to allow normal user control.

g. Fabricate and test dimmer racks to withstand seismic forces defined in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".

3. Dimmers: Modular solid-state units that operate smoothly over their operating ranges without audible lamp noise or radio-frequency interference at any setting. Modules shall be dead-front, draw-out type with floating line, load, and control sockets for smooth insertion and withdrawal; with load-side thermal-magnetic circuit breaker, speed-controlled cooling fan, and overtemperature sensor.
   a. Non-Dim Units: On-off relay control only. Capable of serving inductive loads such as motors or high-intensity-discharge fixtures.
   b. Surge Protection: Modules shall withstand power-line surges of 6000 V/3000 A according to IEEE C62.41.1 and IEEE C62.41.2.
   c. Filter each dimmed circuit to provide a minimum 350-mic.sec., current-rise time at a 90-degree conduction angle at 50 percent of rated dimmer capacity. At any load within rating, rate of current rise shall not exceed 30 mA/mic.sec., measured from 10 to 90 percent of load current waveform.
4. Control System: Microprocessor-based control system, ANSI E1.11 (USITT DMX512-A) protocol, with a nonvolatile system memory to adjust dimmer channel settings for different scenes, to patch dimmers to channels, and to manually or automatically change dimmer settings from one preset scene to another.
   a. Control shall support Ethernet-based LAN at every control device.
   b. Provide means to create and monitor show data on a PC using software by console manufacturer. Software shall be capable of the following:
      1) Creating show and providing for use of USITT show files.
      2) Playing back show in a console-simulation mode.
      3) Accessing all remote-control stations associated with the console and control system.
      4) Providing standard Ethernet connection between the console control system and the PC.
   c. Display the following system status information on a color, 17-inch (430-mm) LCD monitor associated with the control console:
      1) Current channel intensities.
      2) Cue information.
      3) Monitor.
   d. Moving Lights: Include a standard control library, a program patch specific to fixture(s) provided, and selective programming with ANSI E1-11 (USITT DMX512-A) addressing of fade, focus points, beam, image, color, <**Insert attributes**> and position.
5. Control Console: Tabletop unit with manual and computer-based programming controls, memory units, indicating devices, and the following features:
   a. Servicing access through hinged top panel.
   b. Grand-master level control.
   c. Blackout switch.
   d. 12 submaster level controls with overlapping pile-on performance.
      OR
      24 submaster level controls with overlapping pile-on performance.
   e. Bump buttons for momentary control of channels or submasters, one for each submaster level control.
   f. Two cross-fade controls for split dipless fade between scenes, each with its own fade progress indicator.
   g. One set of scene level controls for each scene when used in two-scene preset mode. Second set of scene level controls to allow setting levels into memory for expanded single scenes when used in multiple single-channel scene mode. Each set shall have same quantity of scene level controls as is used for submaster level controls.
   h. Multibutton keypad for programming in multiscene memory mode.

i. Fade time control for assigning fade time to cues, with individual cue adjustment from one second to five minutes, minimum.
j. Light-emitting diode **OR** LCD **OR** Computer monitor cathode-ray tube, **as directed**, with associated display controls, for displaying operating menus and memory readout.
k. Controls for setting levels into memory.
l. Cord and connector for connecting console to outlets for console power and control.

6. System Operation: Selectable between multichannel two-scene preset and four-channel single-scene memory. Console features include electronic patching of control signals for up to 512 dimmers and off-line data storage using internal, 3-1/2-inch (90-mm) disk-drive unit. Operational capability includes the following:
   a. Live and blind programming.
   b. Special effects programmability for automatic operation of lights in pulsating, sequential dimming and brightening, and other special operating modes. Special effects menu displays operator guidance for programming and individual step levels.
   c. Signal from fire-alarm control panel that automatically brings selected circuits to fully on or fully bright condition, overriding normal dimming and on-off controls.
   d. Inserting cues between designated cues without renumbering.
   e. Out-of-sequence playback of cues.
   f. Controlling houselights and stage lights from console by assigning their dimmers or non-dim on-off controls to a channel.
   g. Retaining programmed cues in memory for minimum of one year after power outage.
   h. Automatic sequential execution of programmed cues.
   i. Printing cues using parallel or serial printer port, cable, and printer. Cable and printer are not included with this system.
7. PC: Standard, unmodified, with accessories and peripherals that are configured to install and run control-console manufacturer's written requirements, but not less than the following:
   a. CPU operating speed shall be at least 1.6 GHz.
   b. Memory: 1024 MB.
   c. Serial Ports: Provide two for general use.
   d. Parallel Port: Enhanced.
   e. LAN Adapter: 10/100/1000 Mbps, internal network interface card.
   f. Three USB 2.0 ports.
   g. Sound Card: For playback and recording of digital WAV sound files that are associated with audible warning and alarm functions.
   h. Color Monitor: Not less than 17 inches (430 mm), with a minimum resolution of 1280 by 1024 pixels, noninterlaced, and a maximum dot pitch of 0.28 mm. Video card shall support at least 256 colors at a resolution of 1280 by 1024 pixels at a minimum refresh rate of 70 Hz.
   i. Keyboard: With a minimum of 64 characters; standard ASCII character set based on ANSI INCITS 154 (formerly ANSI X3.154).
   j. Mouse: Standard, compatible with installed software.
   k. Disk storage shall include the following, each with appropriate controller:
      1) Minimum 60 GB hard disk, 5400 rpm.
      2) Floppy Disk Drive: High density, 3-1/2-inch (90-mm) size.
      3) <**Insert disk drives**>.
   l. CD-ROM Drive: 24x/10x/24x CD-RW/8x DVD combination.
8. Console Power and Control Outlets: Multiple receptacles matched to connector on console connector cord.
9. House Lighting Control Station: Architectural-type, multichannel, remote-dimmer-control station with the following features:
   a. System controls designated houselights, stage lights, and other lights.
   b. Stage lighting controls compatible with dimming and control system.
   c. Flush mounting.
   d. Brushed-aluminum wall plate.
   e. Five **OR** Six, **as directed**, channels, each with slider potentiometer control.

f. Master-slider potentiometer that controls lights on all channels proportionally from completely dimmed to degree of brightness that corresponds to individual slider positions.
g. Fully on switch that turns all channels on at full brightness regardless of slider position.
h. Take-control/off switch that places station in control of channels and sets lighting to levels dictated by channel and master-slider controls.
i. Legend on face of wall plate that identifies items as "House Lighting Control Station" and identifies functions of each slider and switch position, with slider positions individually graduated from zero to 10.
j. Illuminated push buttons for activating preset scenes of house lighting and labeled "Entry" **OR** "Panic" **OR** "Entry" and "Panic," **as directed**.
k. Flush wall mounted unless otherwise indicated.

10. Entry Station: Push button activates or deactivates indicating light and presets scene of house lighting control system.
    a. Light-emitting-diode indicating light illuminates when preset command is executed.
    b. Labeled "Entry."
    c. Flush wall mounted unless otherwise indicated.
11. Key-Entry Station: Key-operated switch controls station to activate or deactivate indicating light and presets scene of lighting control system.
    a. Light-emitting-diode indicating light illuminates when preset command is executed.
    b. Labeled "Entry."
    c. Flush wall mounted unless otherwise indicated.
12. Emergency Lighting Control Station: Key-operated, **as directed**, push button activates indicating light and brings selected dimmers to fully bright condition, i.e., the "Panic" preset. Operating push button a second time returns dimmers to previous setting.
    a. Emergency mode indicating light.
    b. Labeled "Emergency Lights."
    c. Flush wall mounted unless otherwise indicated.

F. Rigging Components
1. Pipe Clamps: Malleable iron, suitable for clamping fixtures or items to pipe from 3/4 to 2 inches (20 to 51 mm) in OD. Arranged for horizontal rotation of yoke for aiming; equipped with T-bolt to lock alignment.
2. Safety Cables: Heavy-duty, flexible steel; 30-inch (762-mm) nominal length, with spring clip at one end and steel ring at the other end.
3. Cable Grips: Stainless **OR** Galvanized, **as directed**, steel; basket-weave type for supporting stage cables.

1.3 EXECUTION

A. Installation
1. Set permanently mounted items level, plumb, and square with ceilings and walls.
2. Indicated mounting heights are to bottom of unit for suspended items and to center of unit for wall-mounted items.
3. Mount and connect fixtures, and install and connect distribution devices.
    a. If arrangement is not indicated, install so each fixture, dimmer, house lighting circuit, control channel, and outlet circuit can be operated, and complete system demonstrated, in all operating modes.
    b. Install safety cables secured to stage rigging or gridiron for all pipe-mounted electrical fixtures and equipment.
4. Dimmer Rack Mounting: Install and anchor dimmer racks level on 4-inch- (100-mm-) high concrete base. Comply with requirements for concrete base specified in Division 03 Section "Cast-in-place Concrete".
    a. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch (450-mm) centers around full perimeter of base.

b. For dimmer racks, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
c. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
d. Install anchor bolts to elevations required for proper attachment to dimmer racks.

5. Comply with mounting and anchoring requirements specified in Division 26 Section "Vibration And Seismic Controls For Electrical Systems".

B. Wiring

1. Power Wiring:
   a. Install wiring as specified in Division 26 Section "Low-voltage Electrical Power Conductors And Cables" for hardwired connections. Install wiring in raceways except cable and plug connections.
   b. Install power wiring with a separate neutral for each output circuit from main dimmer and for each house and stage lighting circuit.
2. Signaling, Remote-Control, and Power-Limited Circuits:
   a. Comply with requirements specified in Division 26 Section "Control-voltage Electrical Power Cables" for installation of wiring. Install wiring in raceways except cable and plug connections.
   b. Comply with the following unless otherwise indicated:
      1) Size conductors according to lighting control device manufacturer's written instructions.
      2) Select cable insulation, shielding, drain wire, and jacket complying with lighting control device manufacturer's written instructions.
      3) Install circuits to eliminate radio-frequency interference and electromagnetic interference.
   c. Remote-control circuits associated with emergency lighting control shall be installed complying with Class 1 Circuit standards in NFPA 70.
3. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points.
4. Splices, Taps, and Terminations: Make connections only on numbered terminal strips in junction, pull, and outlet boxes and in terminal cabinets and equipment enclosures.
5. Remove wall plates and protect devices and assemblies during painting.
6. Support lighting fixtures, distribution components, and accessories as specified in Division 26 Section "Hangers And Supports For Electrical Systems". Equip all pipe-mounted equipment with safety cables that are secured to supporting pipe.
7. Ground equipment according to Division 26 Section "Grounding And Bonding For Electrical Systems".

C. Identification

1. Identify components, power, and control wiring according to Division 26 Section "Identification For Electrical Systems".
2. Label each fixture, lighting outlet, distribution device, and dimmer module with unique designation. Labels on elevated components shall be readable from the floor.

D. Field Quality Control

1. Perform tests and inspections.
2. Tests and Inspections:
   a. Schedule visual and mechanical inspections and electrical tests with at least seven days' advance notice.
   b. Visual and Mechanical Tests and Inspections:
      1) Inspect each fixture, outlet, module, control, and device for defects, finish failure, corrosion, physical damage, labeling by an NRTL, and nameplate.
      2) Exercise and perform operational tests on mechanical parts and operable devices according to manufacturer's written instructions.
      3) Check tightness of electrical connections with torque wrench.

4) Verify proper protective device settings, fuse types, and ratings.
5) Record results of tests and inspections.

c. Electrical Tests: Perform tests according to manufacturer's written instructions.
1) Continuity tests of circuits.
2) Operational Tests: Connect each outlet to a fixture and a dimmer output circuit so each dimmer module, dimmer control and output circuit, outlet, and fixture in a typical operating mode will be sequentially tested. Set and operate controls to demonstrate fixtures, outlets, dimmers, and controls in a sequence that cues and reproduces actual operating functions for a typical system of the size and scope installed. Include operation and control of houselights and stage lights from each control location and station including optional plug-in, control-console outlet locations. Record fixture and outlet assignments, control settings, operations, cues, and observations of performance.

d. Test Labeling: After satisfactory completion of tests and inspections, apply a label to tested components indicating test results, date, and responsible organization and individual.

3. Stage lighting will be considered defective if it does not pass tests and inspections.

4. Prepare test and inspection reports.

a. Prepare a schedule of lighting outlets by number; indicate circuits, dimmers, connected fixtures, and control-channel assignments. Prepare a schedule of control settings and circuit assignments for house control channels. Prepare written reports of tests and observations. Report defective materials, workmanship, and unsatisfactory test results. Include records of repairs and adjustments made.

E. Adjusting

1. Occupancy Adjustments: When requested within 12 months of date of Final Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.

END OF SECTION 26 55 61 00

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Task	Specification	Specification Description
26 56 13 00	01 22 16 00	No Specification Required
26 56 13 00	26 05 26 00b	Overhead Electrical Distribution
26 56 13 00	02 84 16 00b	Exterior Lighting
26 56 19 00	02 84 16 00b	Exterior Lighting
26 56 23 00	01 22 16 00	No Specification Required
26 56 23 00	26 05 26 00b	Overhead Electrical Distribution
26 56 23 00	02 84 16 00a	Interior Lighting
26 56 23 00	02 84 16 00b	Exterior Lighting
26 56 26 00	01 22 16 00	No Specification Required
26 56 26 00	02 84 16 00b	Exterior Lighting
26 56 33 00	02 84 16 00a	Interior Lighting
26 56 33 00	02 84 16 00b	Exterior Lighting
26 56 36 00	02 84 16 00b	Exterior Lighting

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SECTION 26 56 68 00 - SPORTS LIGHTING

1.1 GENERAL

A. Description Of Work
1. This specification covers the furnishing and installation of materials for exterior athletic lighting. Products shall be as follows or as directed by the Owner. Installation procedures shall be in accordance with the product manufacturer's recommendations. Demolition and removal of materials shall be as required to support the work.

B. Summary
1. Section includes lighting for the following outdoor sports venues:
   a. Baseball fields.
   b. Softball fields.
   c. Football fields.
   d. Soccer fields.
   e. Outdoor tennis courts.

C. Definitions
1. CV: Coefficient of variation; a statistical measure of the weighted average of all relevant illumination values for the playing area, expressed as the ratio of the standard deviation for all illuminance values to the mean illuminance value.
2. Delegated-Design Submittals: Documents, including drawings, calculations, and material and product specifications prepared as a responsibility of Contractor to obtain acceptance by the Owner and authorities having jurisdiction.
3. Illuminance: The metric most commonly used to evaluate lighting systems. It is the density of luminous flux, or flow of light, reaching a surface divided by the area of that surface.
   a. Horizontal Illuminance: Measurement in foot-candles (lux), on a horizontal surface 36 inches (914 mm) above ground unless otherwise indicated.
   b. Target Illuminance: Average maintained illuminance level, calculated by multiplying initial illuminance by LLF.
   c. Vertical Illuminance: Measurement in foot-candles (lux), in two **OR** four, **as directed**, directions on a vertical surface, at an elevation coinciding with plane height of horizontal measurements.
4. LC: Lighting Certified.
5. Light Trespass: Light spill into areas and properties outside the playing areas, which is either annoying or unwanted.
6. LLD: Lamp lumen depreciation, which is the decrease in lamp output as the lamp ages.
7. LLF: Light loss factor, which is the product of all factors that contribute to light loss in the system.
8. Luminaire: Complete lighting fixture, including ballast housing if integral.
9. UG: Uniformity gradient; the rate of change of illuminance on the playing field, expressed as a ratio between the illuminances of adjacent measuring points on a uniform grid.

D. Performance Requirements
1. Facility Type: Professional **OR** College **OR** Semiprofessional **OR** Sports club **OR** Amateur league **OR** High school **OR** Training facility **OR** Elementary school **OR** Recreational or social facility, **as directed**.
2. Illumination Criteria:
   a. Minimum average target illuminance level for each lighted area for each sports venue and for the indicated class of play according to IESNA RP-6.
   b. CV and maximum-to-minimum uniformity ratios for each lighted area equal to or less than those listed in IESNA RP-6 for the indicated class of play.
   c. UG levels within each lighted area equal to or less than those listed in IESNA RP-6 for the indicated speed of sport.

3. Illumination Criteria:
   a. Minimum Average Target Illumination: <**Insert value**>.
   b. CV: <**Insert value**>.
   c. Maximum-to-Minimum Uniformity Ratio: <**Insert value**>.
   d. UG Level: <**Insert value**>.
4. Illumination Calculations: Computer-analyzed point method complying with IESNA RP-6 to optimize selection, location, and aiming of luminaires.
   a. Grid Pattern Dimensions: For playing areas of each sport and areas of concern for spill-light control, correlate and reference calculated parameters to the grid areas. Each grid point represents the center of the grid area defined by the length and width of the grid spacing.
   b. Spill-Light Control: Minimize spill light for each playing area on adjacent and nearby areas.
      1) Prevent light trespass on properties near Project as defined by <**Insert name(s) of authorities having jurisdiction**>.
      2) For areas indicated on Drawings as "spill-light critical," limit the level of illuminance directed into the area from any luminaire or group of luminaires, and measured 36 inches (914 mm) above grade to the following:
         a) Maximum Horizontal Illuminance: 0.25 fc (2.7 lux) **OR** 0.5 fc (5.4 lux) **OR** 0.75 fc (8.1 lux), **as directed**.
         b) Maximum Vertical Illuminance from the Direction of the Greatest Contribution of Light: 1.0 fc (10.8 lux) **OR** 2.0 fc (21.5 lux) **OR** 3.0 fc (32.3 lux), **as directed**.
      3) Calculate the horizontal and vertical illuminance due to spill light for points spaced 20 feet (6 m) apart in areas indicated on Drawings as "spill-light critical," to ensure that design meets the above limits.
   c. Glare Control: Design illumination for each playing area to minimize direct glare in adjacent and nearby areas.
      1) Design source intensity of luminaires that may be observed at an elevation of 60 inches (1524 mm) above finished grade from nearby properties to be less than 12,000 **OR** 20,000 **OR** 30,000, **as directed**, candela when so observed.
      2) Design source intensity of luminaires that may be observed at an elevation of 60 inches (1524 mm) above finished grade from designated "spill-light critical" areas to be less than 12,000 **OR** 20,000 **OR** 30,000, **as directed**, candela when so observed.
   d. Determine LLF according to IESNA RP-6 and manufacturer's test data.
      1) Use LLD at 100 percent of rated lamp life. LLF shall be applied to initial illumination to ensure that target illumination is achieved at 100 percent of lamp life and shall include consideration of field factor.
      2) LLF shall not be higher than 70 percent, and may be lower when determined by manufacturer after application of the ballast output and optical system output according to IESNA RP-6.
   e. Luminaire Mounting Height: Comply with IESNA RP-6, with consideration for requirements to minimize spill light and glare.
   f. Luminaire Placement: Luminaire clusters shall be outside the glare zones defined by IESNA RP-6.
5. Baseball Fields:
   a. IESNA RP-6, Class of Play: I **OR** II **OR** III **OR** IV, **as directed**.
   b. Speed of Sport: Fast **OR** Moderate **OR** Slow, **as directed**.
   c. Grid Pattern Dimensions: 30 by 30 feet (9 by 9 m).
6. Softball Fields:
   a. IESNA RP-6, Class of Play: I **OR** II **OR** III **OR** IV, **as directed**.
   b. Speed of Sport: Fast **OR** Moderate **OR** Slow, **as directed**.
   c. Grid Pattern Dimensions: 20 by 20 feet (6 by 6 m).
7. Football Fields:
   a. IESNA RP-6, Class of Play: I **OR** II **OR** III **OR** IV, **as directed**.

b. Speed of Sport: Fast **OR** Moderate **OR** Slow, **as directed**.
c. Grid Pattern Dimensions: 30 by 30 feet (9 by 9 m).

8. Soccer Fields:
   a. IESNA RP-6, Class of Play: I **OR** II **OR** III **OR** IV, **as directed**.
   b. Speed of Sport: Fast **OR** Moderate **OR** Slow, **as directed**.
   c. Grid Pattern Dimensions: 30 by 30 feet (9 by 9 m).
9. Outdoor Tennis Courts:
   a. IESNA RP-6, Class of Play: I **OR** II **OR** III **OR** IV, **as directed**.
   b. Speed of Sport: Fast **OR** Moderate **OR** Slow, **as directed**.
   c. Grid Pattern Dimensions: 10 by 10 feet (3 by 3 m).
10. Egress Lighting: In case of power failure, provide a minimum of 1.0-fc (10.8-lux) illumination, within 30 seconds, measured at grade in spectator and spectator egress areas.
   a. Duration of emergency illumination shall be not less than 15 minutes.
   b. Momentary Power Interruptions: Provide emergency illumination immediately following restoration of power to the lighting circuits. Emergency illumination shall automatically extinguish after 15 minutes.
11. Lighting Control: Manual, low voltage, or digital; providing the following functions, integrated into a single control station, with multiple subcontrol stations as indicated:
   a. Control Station: Key-operated master switch, manual push-button controls, and system status indicator lights. Test switch of egress lighting system, **as directed**.
   b. Light Levels: Two levels of control - 100/50 percent of minimum target illumination.
12. Electric Power Distribution Requirements:
   a. Electric Power: 208 **OR** 230 **OR** 480, **as directed**, V; three phase.
      1) Include roughing-in of service indicated for nonsports improvements on Project site.
      2) Balance load between phases. Install wiring to balance three phases at each support structure.
      3) Include required overcurrent protective devices and individual lighting control for each sports field or venue.
      4) Include indicated feeder capacity and panelboard provisions for future lighted sports field construction.
13. Maximum Total Load: <**Insert number**> A.
   a. Maximum Total Voltage Drop from Source to Load: 5 percent, including voltage drops in branch circuit, subfeeder, and feeder.
14. Seismic Performance: Luminaires, ballasts, and support structures shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
   a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
15. Life-Cycle Cost Criteria:
   a. Estimated life-cycle cost of lighting system for period of <**Insert number**> years based on the parameters below:
      1) Energy Cost: <**Insert value**> {Calculate energy costs by multiplying (number of luminaires) x (kilowatt demand per luminaire) x (power cost at $/kilowatts) x (number of annual usage hours) x (number of years)}.
      2) Lamp Replacement Cost: <**Insert value**> (Calculate replacement costs by multiplying (cost to replace a lamp) x (number of luminaires) x (number of relamps over the period of years used in calculating the energy cost)).
      3) General Maintenance: <**Insert value**> (Calculate maintenance costs by multiplying (number of repairs) x (cost per repair) over the life cycle).

      OR

      Life-Cycle Cost Criteria: <**Insert value**> (Calculate according to Federal Energy Management Program's "Building Life-Cycle Cost").

E. Submittals
   1. Product Data: For each type of lighting product indicated. Include the following:

a. Lamp life, output, and energy-efficiency data. Lamp data certified by NVLAP or NRTL; comply with IESNA LM-47.
b. Photometric data based on laboratory tests of each luminaire type, complete with lamps, ballasts, and accessories; comply with IESNA LM-5.
1) Photometric data shall be certified by a qualified independent testing agency.
OR
Photometric data shall be certified by manufacturer's laboratory with a current accreditation under the NVLAP for Energy Efficient Lighting Products.

2. Delegated-Design Submittal: For exterior athletic lighting indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
a. Drawings and specifications for construction of lighting system.
b. Manufacturer's determination of LLF used in design calculations.
c. Lighting system design calculations for the following:
1) Target illuminance.
2) Point calculations of horizontal and vertical illuminance, CV, and UG at minimum grid size and area.
3) Point calculations of horizontal and vertical illuminance in indicated areas of concern for spill light.
4) Calculations of source intensity of luminaires observed at eye level from indicated properties near the playing fields.
d. Electrical system design calculations for the following:
1) Short-circuit current calculations for rating of panelboards.
2) Total connected and estimated peak-demand electrical load, in kilowatts, of lighting system.
3) Capacity of feeder **OR** service, **as directed**, required to supply lighting system.
e. Wiring requirements, including required conductors and cables and wiring methods.
f. Structural analysis data and calculations used for pole selection.
1) Manufacturer Wind-Load Strength Certification: Submit certification that selected total support system, including poles, complies with AASHTO LTS-4-M for location of Project.

3. Qualification Data: For qualified Installer, manufacturer, professional engineer, luminaire photometric data testing laboratory and field testing agency.
4. Seismic Qualification Certificates: For luminaires, accessories, and components, from manufacturer.
a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
b. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
c. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
5. Manufacturer Certificates: For support structures, including brackets, arms, appurtenances, bases, anchorages, and foundations, from manufacturer.
6. Welding certificates.
7. Field quality-control reports.
8. Operation and Maintenance Data: For sports lighting system components to include in emergency, operation, and maintenance manuals.
9. Warranty: Sample of special warranty.

F. Quality Assurance
1. Installer Qualifications: Manufacturer's authorized representative who is trained and approved for installation of units required for this Project.
2. Manufacturer Qualifications: Manufacturer's responsibilities include fabricating sports lighting and providing professional engineering services needed to assume engineering responsibility.

a. Engineering Responsibility: Preparation of delegated-design submittals and comprehensive engineering analysis by a qualified professional engineer who is additionally LC by the National Council on Qualifications for the Lighting Professions, **as directed**.

3. Luminaire Photometric Data Testing Laboratory: By manufacturers' laboratories that are accredited under the National Volunteer Laboratory Accreditation Program for Energy Efficient Lighting Products.
4. Luminaire Photometric Data Testing Laboratory: By an independent agency, with the experience and capability to conduct the testing indicated, that is an NRTL.
5. Field Testing Agency Qualifications: An independent testing agency that is accredited under the National Volunteer Laboratory Accreditation Program for Energy Efficient Lighting Products, or an NRTL as defined in 29 CFR 1910, with the experience and capability to conduct field testing according to IESNA LM-5.

   OR

   Field Testing Agency Qualifications: A qualified independent professional engineer not associated with Contractor or lighting equipment manufacturer, who is additionally LC by the National Council on Qualifications for the Lighting Professions, **as directed**.
6. Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel" and AWS D1.2/D1.2M, "Structural Welding Code - Aluminum."
7. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

G. Warranty

1. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of luminaires, lamps, and luminaire alignment products and to correct misalignment that occurs subsequent to successful acceptance tests. Manufacturer may exclude lightning damage, hail damage, vandalism, abuse, and unauthorized repairs and alterations from special warranty coverage.
   a. Luminaire Warranty: Luminaire and luminaire assembly (excluding fuses and lamps) shall be free from defects in materials and workmanship for a period of five years from date of Final Completion.
   b. Lamp Warranty:
      1) Replace lamps and fuses that fail within 12 months from date of Final Completion.
      2) Provide replacement lamps for lamps that fail within the second 12 months from date of Final Completion.
   c. Alignment Warranty: Accuracy of alignment of luminaires shall remain within specified illuminance uniformity ratios for a period of five years from date of successful completion of acceptance tests.
      1) Realign luminaires that become misaligned during the warranty period.
      2) Replace alignment products that fail within the warranty period.
      3) Verify successful realignment of luminaires by retesting as specified in "Field Quality Control" Article.

1.2 PRODUCTS

A. Luminaires, Lamps, And Ballasts

1. Luminaires: Listed and labeled, by an NRTL acceptable to authorities having jurisdiction, for compliance with UL 1598 for installation in wet locations.
   a. Doors, Frames, and Other Internal Access: Smooth operating, free from light leakage under operating conditions, and arranged to permit relamping without using tools. Arrange doors, frames, lenses, diffusers, and other pieces to prevent their accidental falling during relamping and when secured in operating position. Doors shall be removable for cleaning or replacing lens.
   b. Exposed Hardware: Stainless-steel latches, fasteners, and hinges.

c. Spill-Light Control Devices: Internal louvers and external baffles furnished by manufacturer and designed for secure attachment to specific luminaire.
d. Luminaires for tennis courts shall be bracket-mounted, full-cutoff type with integral ballasts.
e. Lamps for Tennis Court Luminaires: Metal halide, rated 1000 W.

2. Ballast Mounting: Grouped in cabinets, remote from **OR** At, **as directed**, location of associated luminaires unless otherwise indicated.

B. Support Structures

1. Support-Structure Wind-Load Strength: Poles and other support structures, brackets, arms, appurtenances, bases, anchorages, and foundations shall comply with AASHTO LTS-4-M and shall be certified by manufacturers to withstand winds up to 100 mph (160 km/h) without permanent deflection or whipping.
2. Support-Structure Seismic Strength: Poles or other support structures, brackets, arms, appurtenances, bases, anchorages, and foundations shall be designed to prevent separation of components or fracture of poles, luminaire supports, or pole foundations during a seismic event.
3. Mountings, Fasteners, and Appurtenances:
   a. Corrosion resistant, compatible with support components, and which shall not cause galvanic action at contact points.
      1) Steel Components: Hot-dip galvanized after fabrication, complying with ASTM A 123/A 123M.
      2) Mounting Hardware Fasteners: Hot-dip galvanized, complying with ASTM A 153/A 153M, or minimum 18-8 grade stainless steel.
   b. Accommodate attachments and wiring of other indicated systems.
4. Concrete for Pole Foundations: 3000-psi (20.7-MPa), 28-day minimum compressive strength. Concrete, reinforcement, and formwork are specified in Division 03 Section "Cast-in-place Concrete".
5. Direct-buried steel structures or poles shall not be used.

C. Power Distribution And Control

1. Wiring Method for Feeders, Subfeeders, Branch Circuits, and Control Wiring: Underground nonmetallic raceway; No. 10 AWG minimum conductor size for power wiring.
2. Overhead-, pole-, or structure-supported wiring and transformers are **OR** are not, **as directed**, permitted.
3. Electrical Enclosures Exposed to Weather: NEMA 250, Type 3R enclosure constructed from stainless steel **OR** corrosion-resistant material, **as directed**, with hinged doors fitted with padlock hasps or lockable latches.

D. Surge Protection

1. Surge Protection: Comply with requirements in Division 26 Section "Transient-voltage Suppression For Low-voltage Electrical Power Circuits" and include surge suppressors with the following requirements:
   a. Panelboard type.
   b. Nonmodular, with digital indicator lights and one set of dry contacts, **as directed**.
   c. Peak Single-Impulse Surge Current Rating: <**Insert number**> kA per phase.

E. Pole And Base Protection

1. Pole Pads: Wraparound pad, with 4 inches (100 mm) of extra-firm polyfoam, 360-degree coverage of ground-mounted poles and supports, continuous hook-and-loop fastening, and not less than 72 inches (1820 mm) high.

1.3 EXECUTION

A. Installation

1. Use web fabric slings (not chain or cable) to raise and set structural members. Protect equipment during installation to prevent corrosion.
2. Install poles and other structural units level, plumb, and square.
3. Except for embedded structural members, grout void between pole base and foundation. Use nonshrinking or expanding concrete grout firmly packed in entire void space. Use a short piece of 1/2-inch- (13-mm-) diameter pipe to make a drain hole through grout. Arrange to drain condensation from interior of pole. Nonshrink grout is specified in Division 05 Section "Metal Fabrications".
4. Install pole pads at all poles inside playing field boundaries and when located within 20 feet (6 m) of the field boundary.
5. Extend cast-in-place bolted base foundations 36 inches (914 mm) above grade, minimum.
6. Install protective pipe bollards on two **OR** three, **as directed**, sides of each embedded pole installed in paved areas. See Division 05 Section "Metal Fabrications" for pipe bollards.
7. Install controls and ballast housings in cabinets mounted on support structure at least 10 feet (3 m) above finished grade.

B. Field Quality Control
1. Perform tests, inspections, and analysis according to IESNA RP-6 and IESNA LM-5 where applicable.
2. Tests and Inspections:
   a. After installing sports lighting system and after electrical circuits have been energized, perform proof-of-performance field measurements and analysis for compliance with requirements.
   b. Playing and Other Designated Areas: Make field measurements at intersections of grids, dimensioned and located as specified in "Performance Requirements" Article and as described below:
      1) Baseball Fields: Measure at least 25 points of the infield and 87 points of the outfield. Extend the grid 15 feet (5 m) outside the foul lines, extending to outfield boundary or fence.
      2) Softball Fields: Measure at least 16 points of the infield and 48 points of the outfield. Extend the grid 15 feet (5 m) outside the foul lines, extending to outfield boundary.
      3) Football Fields: Lighted area is 180 by 360 feet (55 by 110 m). Measure at least 91 points.
      4) Soccer Fields: Lighted area is 210 by 370 feet (64 by 113 m). Measure at least 91 points.
      5) Tennis Courts: Measure at least 30 points for a double court.
   c. Make field measurements at established test points in areas of concern for spill light and glare.
   d. Perform analysis to demonstrate correlation of field measurements with specified illumination quality and quantity values and corresponding computer-generated values that were submitted with engineered design documents. Submit a report of the analysis. For computer-generated values, use manufacturer's lamp lumens that are adjusted to lamp age at time of field testing.
3. Correction of Illumination Deficiencies for Playing Areas: Make corrections to illumination quality or quantity, measured in field quality-control tests, that varies from specified illumination criteria by plus or minus 10 percent.
   a. Add or replace luminaires, or change mounting height, revise aiming, or install louvers, shields, or baffles.
   b. If luminaires are added or mounting height is changed, revise aiming and recalculate and modify or replace support structures if indicated.
   c. Do not replace luminaires with units of higher or lower wattage without the Owner's approval.
   d. Retest as specified above after repairs, adjustments, or replacements are made.
   e. Report results in writing.

4. Correction of Excessive Illumination in Spill-Light-Critical Areas: If measurements indicate that specified limits for spill light are exceeded, make corrections to illumination quantity, measured in field quality-control tests, that reduce levels to within specified maximum values.
   a. Replace luminaires, or change mounting heights, revise aiming, or install louvers, shields, or baffles.
   b. Obtain the Owner's approval to replace luminaires with units of higher or lower wattage.
   c. If mounting height is changed, revise aiming and recalculate and modify or replace support structures if indicated.
   d. Retest as specified above after repairs, adjustments, or replacements are made.
   e. Report results in writing.
5. Sports lighting will be considered defective if it does not pass tests and inspections.
6. Prepare test and inspection reports.

C. Demonstration
   1. Train the Owner's maintenance personnel to adjust, operate, and maintain exterior athletic lighting.

END OF SECTION 26 56 68 00

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01 22 16 00	01 22 16 00
01 22 20 00	01 22 16 00
01 22 23 00	01 22 16 00
01 32 33 00	01 32 33 00, 01 32 33 00a, 01 32 33 00b, 01 32 33 00c, 01 32 33 00d
01 52 13 00	01 52 13 00, 01 22 16 00
01 52 19 00	01 22 16 00, 01 52 13 00
01 54 23 00	01 22 16 00
01 54 26 00	01 22 16 00
01 54 29 00	01 22 16 00
01 55 23 00	01 22 16 00
01 55 26 00	01 22 16 00
01 56 16 00	01 22 16 00
01 56 26 00	01 56 26 00, 01 56 26 00a, 01 22 16 00
01 56 29 00	01 22 16 00
01 56 33 00	01 22 16 00
01 56 39 00	01 22 16 00
01 58 13 00	01 58 13 00, 01 22 16 00
01 66 19 00	01 22 16 00
01 71 13 00	01 22 16 00
01 71 23 16	01 71 23 16
01 74 16 00	01 22 16 00
01 74 19 00	01 74 19 00
02 41 13 13	02 41 13 13
02 41 16 13	02 41 16 13, 02 41 16 13a, 02 41 13 13
02 41 19 13	01 71 23 16, 02 41 16 13, 02 41 16 13a, 02 41 13 13
02 41 19 16	02 41 16 13, 02 41 16 13a, 02 41 13 13
02 58 13 00	02 58 13 00, 02 58 13 00a
02 61 00 00	02 61 00 00
02 61 13 00	02 61 13 00, 02 61 13 00a, 02 61 13 00b, 02 41 16 13, 02 61 00 00
02 65 00 00	02 41 16 13, 02 61 00 00, 02 61 13 00, 02 61 13 00a, 02 61 13 00b
02 81 00 00	02 81 00 00, 02 61 00 00
02 82 16 00	02 82 16 00
02 82 33 00	02 82 33 00, 02 82 33 00a, 01 22 16 00, 02 81 00 00, 02 82 16 00
02 83 19 13	02 83 19 13, 02 83 19 13a, 02 83 19 13b, 02 83 19 13c
02 83 33 13	02 83 19 13, 02 83 19 13a, 02 83 19 13b, 02 83 19 13c
02 84 16 00	02 84 16 00, 02 84 16 00a, 02 84 16 00b
02 85 33 00	02 85 33 00
02 86 00 00	02 41 16 13, 02 61 00 00, 02 61 13 00, 02 61 13 00a, 02 61 13 00b, 02 81 00 00
02 87 00 00	02 87 00 00
02 89 00 00	01 22 16 00, 02 83 19 13, 02 83 19 13a, 02 83 19 13b, 02 83 19 13c
03 01 30 71	03 01 30 71, 03 01 30 71a, 01 22 16 00
03 05 00 00	03 05 00 00
03 11 13 00	01 22 16 00, 03 05 00 00
03 11 16 00	03 11 16 00, 03 05 00 00
03 11 23 00	01 22 16 00, 03 05 00 00
03 15 13 13	03 05 00 00
03 15 13 16	03 05 00 00
03 15 16 00	03 05 00 00
03 15 19 00	05 50 00 00
03 21 11 00	03 05 00 00
03 21 16 00	03 05 00 00
03 31 13 00	03 31 13 00, 03 31 13 00a, 03 31 13 00b, 03 31 13 00c, 03 31 13 00d, 03 05 00 00, 03 11 16 00
03 35 16 00	03 05 00 00
03 35 23 00	03 35 23 00, 03 05 00 00

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03 35 26 00	03 05 00 00
03 35 33 00	03 05 00 00
03 35 39 00	03 35 39 00
03 35 63 00	03 05 00 00
03 35 66 00	03 05 00 00
03 35 83 00	03 05 00 00
03 37 13 00	03 37 13 00, 03 37 13 00a
03 39 13 00	03 05 00 00
03 39 23 23	03 05 00 00
03 39 33 00	03 05 00 00
03 48 29 00	03 48 29 00
03 48 49 00	03 48 29 00
03 51 13 00	03 51 13 00
03 51 16 00	03 51 16 00, 03 51 16 00a, 03 51 16 00b
03 52 16 00	03 52 16 00
03 53 00 00	03 53 00 00
03 54 16 00	03 54 16 00
03 61 16 00	01 22 16 00
03 62 13 00	03 48 29 00
03 62 16 00	03 48 29 00
03 64 23 00	03 48 29 00
03 64 26 00	01 22 16 00
04 01 20 52	04 01 20 52
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04 01 40 52	04 01 40 52, 04 01 20 52
04 01 40 91	04 01 40 91, 04 01 20 52, 04 01 40 52
04 01 50 52	04 01 20 52
04 05 13 26	04 01 20 91
04 05 16 26	04 01 20 91
04 05 19 13	04 01 20 91
04 05 19 16	04 01 20 91
04 05 23 13	04 01 20 91
04 05 23 16	01 22 16 00, 07 62 00 00
04 05 26 00	04 05 26 00, 04 01 20 91
04 21 13 00	04 01 20 91
04 21 19 00	04 01 20 91
04 21 26 00	04 01 20 91
04 21 29 00	04 01 20 91
04 22 23 13	04 01 20 91
04 22 23 23	04 01 20 91
04 22 23 26	04 01 20 91
04 22 23 29	04 01 20 91
04 22 23 31	04 01 20 91
04 23 13 00	04 23 13 00, 04 01 20 91
04 26 13 00	04 01 20 91
04 41 00 00	04 41 00 00, 04 41 00 00a
04 42 43 00	04 41 00 00, 04 01 40 91, 04 41 00 00a
04 43 00 00	01 22 16 00, 04 41 00 00, 04 01 40 91, 04 41 00 00a
04 72 00 00	04 72 00 00, 04 72 00 00a, 03 48 29 00, 04 01 20 91
05 05 19 00	05 50 00 00
05 05 23 00	05 05 23 00, 01 22 16 00, 05 50 00 00
05 12 23 00	05 12 23 00, 05 05 23 00, 05 50 00 00
05 13 00 00	05 50 00 00

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05 41 00 00	05 12 23 00
05 43 00 00	01 22 16 00, 05 12 23 00, 05 50 00 00
05 50 00 00	05 50 00 00
05 51 13 00	05 51 13 00, 05 51 13 00a, 05 50 00 00
05 51 19 00	05 50 00 00, 05 51 13 00, 05 51 13 00a
05 51 33 13	05 50 00 00, 05 52 13 00
05 51 33 16	05 50 00 00
05 51 33 23	05 50 00 00, 05 52 13 00
05 52 13 00	05 52 13 00, 05 50 00 00
05 53 13 00	05 53 13 00, 01 22 16 00, 05 50 00 00
05 54 00 00	05 50 00 00
05 55 13 00	05 50 00 00, 05 51 13 00, 05 51 13 00a
05 55 16 00	05 50 00 00, 05 51 13 00, 05 51 13 00a
05 56 00 00	05 50 00 00
05 58 16 00	05 58 16 00, 05 58 16 00a
05 58 23 00	05 50 00 00
05 59 65 00	01 22 16 00
05 73 00 00	05 73 00 00, 05 73 00 00a, 05 58 16 00
05 75 00 00	05 58 16 00, 05 58 16 00a
06 05 23 00	06 05 23 00, 06 05 23 00a, 06 05 23 00b, 06 10 00 00
06 10 00 00	06 10 00 00
06 11 13 00	06 10 00 00, 06 05 23 00a
06 11 16 00	06 11 16 00, 01 22 16 00, 06 10 00 00, 06 05 23 00a
06 15 13 00	06 15 13 00, 06 15 13 00a, 06 10 00 00, 06 05 23 00a, 06 11 16 00
06 16 23 00	06 16 23 00, 06 10 00 00, 06 05 23 00a
06 16 33 00	06 10 00 00, 06 05 23 00a, 06 16 23 00
06 16 43 00	06 10 00 00, 06 05 23 00a, 06 16 23 00, 06 11 16 00
06 17 13 00	06 17 13 00, 06 05 23 00, 06 10 00 00
06 17 23 00	06 10 00 00, 06 05 23 00a, 06 11 16 00
06 17 43 00	06 05 23 00, 06 10 00 00, 06 17 13 00
06 18 13 00	06 15 13 00a, 06 17 13 00
06 18 16 00	06 05 23 00, 06 10 00 00, 06 17 13 00
06 22 13 00	06 22 13 00, 06 22 13 00a, 06 05 23 00a
06 25 16 00	06 25 16 00
06 41 13 00	06 41 13 00, 06 41 13 00a
06 41 93 00	08 71 21 00
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06 46 19 00	01 22 16 00, 06 05 23 00a, 06 22 13 00, 06 22 13 00a, 06 41 13 00
06 46 23 00	06 41 13 00
06 46 26 00	06 41 13 00
06 46 29 00	06 46 29 00, 06 41 13 00
06 46 36 00	06 41 13 00
06 48 13 00	06 48 13 00
06 48 16 00	06 48 13 00
06 65 00 00	06 05 23 00a
06 74 13 00	05 53 13 00
07 05 13 00	07 05 13 00, 07 05 13 00a, 07 05 13 00b, 07 05 13 00c, 07 05 13 00d, 07 53 16 00
07 11 13 00	07 11 13 00, 07 11 13 00a

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07 13 53 00	07 13 53 00, 03 01 30 71a
07 14 13 00	07 14 13 00
07 16 13 00	07 16 13 00
07 16 16 00	07 16 16 00
07 16 19 00	07 16 19 00
07 17 13 00	07 17 13 00
07 19 13 00	07 19 13 00
07 19 16 00	07 19 13 00
07 21 13 13	07 21 13 13, 07 21 13 13a, 07 51 13 00, 07 05 13 00, 07 53 16 00, 07 05 13 00a, 07 05 13 00b, 07 05 13 00c
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07 21 13 19	07 21 13 13, 07 51 13 00, 07 05 13 00, 07 53 16 00, 07 05 13 00a, 07 05 13 00b, 07 05 13 00c
07 21 16 00	07 21 13 13
07 21 23 00	07 21 13 13
07 21 26 00	07 21 13 13
07 22 16 00	07 22 16 00, 07 51 13 00, 07 05 13 00, 07 53 16 00, 07 05 13 00a, 07 05 13 00b, 07 05 13 00c
07 24 13 00	07 24 13 00, 07 24 13 00a
07 26 13 00	06 10 00 00
07 31 13 00	07 31 13 00
07 31 16 00	07 31 16 00
07 31 26 00	07 31 26 00
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07 31 33 00	07 31 33 00, 01 22 16 00
07 32 13 00	07 32 13 00
07 32 16 00	07 32 16 00
07 34 00 00	07 31 13 00, 07 31 16 00, 07 31 26 00, 07 31 29 13, 07 32 13 00
07 41 13 00	07 41 13 00, 07 41 13 00a
07 41 33 00	07 41 13 00
07 46 16 00	07 46 16 00, 07 46 16 00a, 07 46 16 00b
07 46 19 00	07 46 16 00, 07 46 16 00a, 07 46 16 00b
07 46 23 00	06 10 00 00, 06 05 23 00a, 06 16 23 00
07 46 29 00	06 10 00 00, 06 05 23 00a, 06 16 23 00
07 46 33 00	07 46 16 00b
07 46 46 00	01 22 16 00, 06 46 29 00, 06 41 13 00, 07 46 16 00b
07 46 63 00	07 46 63 00, 07 46 16 00
07 51 13 00	07 51 13 00, 06 05 23 00a, 07 05 13 00, 07 53 16 00, 07 05 13 00b, 07 05 13 00c, 07 05 13 00d
07 52 13 00	07 05 13 00b, 07 05 13 00d
07 52 16 00	07 05 13 00c, 07 05 13 00d
07 53 16 00	07 53 16 00, 07 51 13 00, 07 05 13 00, 07 05 13 00a, 07 05 13 00d
07 53 23 00	07 51 13 00, 07 05 13 00, 07 53 16 00, 07 05 13 00d
07 53 29 00	07 51 13 00, 07 05 13 00, 07 53 16 00, 07 05 13 00d
07 54 19 00	07 54 19 00, 07 05 13 00d
07 54 23 00	07 54 23 00, 07 05 13 00d
07 56 00 00	07 56 00 00, 07 51 13 00, 07 05 13 00, 07 53 16 00
07 58 00 00	07 51 13 00
07 62 00 00	07 62 00 00
07 63 00 00	07 63 00 00, 07 63 00 00a, 07 63 00 00b, 07 62 00 00
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07 71 13 00	07 62 00 00
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07 72 13 00	07 72 13 00, 07 72 13 00a
07 72 23 00	07 72 23 00
07 72 26 00	07 72 23 00
07 72 33 00	07 72 23 00
07 72 36 00	07 72 23 00
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07 76 16 00	01 22 16 00
07 81 16 00	07 81 16 00
07 81 23 00	07 81 16 00
07 81 33 00	07 81 16 00
07 82 00 00	07 82 00 00, 07 81 16 00
07 84 13 16	07 84 13 16, 07 84 13 16a, 07 84 13 16b
07 84 13 19	07 84 13 16, 07 84 13 16a, 07 84 13 16b
07 84 16 00	03 05 00 00
07 84 43 00	07 84 13 16, 07 84 13 16a, 07 84 13 16b
07 84 56 13	07 81 16 00, 07 82 00 00
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08 13 13 13	08 01 11 00, 08 12 13 13
08 14 16 00	08 14 16 00, 06 48 13 00, 08 05 13 00
08 14 66 00	01 22 16 00
08 14 73 00	06 48 13 00, 08 05 13 00
08 16 13 00	08 16 13 00, 08 16 13 00a, 08 01 11 00, 08 12 13 13
08 17 23 00	06 48 13 00, 08 05 13 00
08 31 13 00	08 31 13 00
08 32 13 00	08 32 13 00
08 32 19 00	08 32 19 00
08 33 13 00	08 33 13 00
08 33 23 00	08 33 13 00
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08 34 63 13	08 34 63 13, 08 34 63 13a, 08 34 53 00
08 34 73 00	08 34 73 00, 08 01 11 00, 08 16 13 00, 08 12 13 13
08 35 13 13	08 35 13 13
08 36 13 00	08 36 13 00, 08 33 13 00
08 38 13 00	08 38 13 00
08 38 16 00	08 01 11 00, 08 16 13 00, 08 12 13 13
08 38 19 00	08 01 11 00, 08 16 13 00, 08 12 13 13
08 42 29 23	08 32 13 00, 08 71 13 00

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08 42 36 00	08 01 11 00, 08 16 13 00, 08 12 13 13
08 44 13 00	08 44 13 00, 08 44 13 00a, 08 44 13 00b
08 45 23 00	08 45 23 00, 08 45 23 00a, 08 45 23 00b, 08 45 23 00c
08 51 13 00	08 51 13 00, 08 51 13 00a
08 51 19 00	01 22 16 00
08 51 23 00	08 51 23 00
08 52 16 00	08 01 52 61
08 52 19 00	08 01 52 61
08 52 66 00	08 01 52 61
08 53 13 00	08 53 13 00
08 53 66 00	08 53 13 00
08 56 19 00	08 56 19 00
08 56 56 00	08 11 63 13a, 08 34 53 00a
08 56 59 00	01 22 16 00
08 65 00 00	08 45 23 00
08 71 13 00	08 71 13 00
08 71 16 00	01 22 16 00, 08 71 21 00, 08 34 63 13
08 71 19 00	06 48 13 00, 08 05 13 00, 08 71 21 00
08 71 21 00	08 71 21 00
08 74 16 00	08 74 16 00
08 75 00 00	08 71 21 00, 08 71 13 00
08 79 00 00	08 34 63 13
08 81 23 00	08 01 81 00
08 81 26 00	08 01 81 00
08 83 13 00	08 83 13 00, 08 01 81 00
08 84 00 00	08 84 00 00
08 85 00 00	08 01 81 00, 08 44 13 00, 08 44 13 00a, 08 44 13 00b
08 87 13 00	08 01 81 00
08 87 23 16	08 87 23 16
08 88 53 00	08 88 53 00, 08 01 81 00
08 90 00 00	08 90 00 00
08 91 16 00	08 90 00 00
08 95 13 00	01 22 16 00
08 95 16 00	01 22 16 00, 05 50 00 00, 05 73 00 00
09 01 30 91	09 31 00 00
09 01 60 00	09 01 60 00, 09 01 60 00a, 07 91 23 00, 09 68 13 00
09 05 71 00	09 31 00 00
09 22 13 00	09 22 13 00, 09 22 13 00a, 09 22 13 00b
09 22 16 13	09 22 16 13
09 22 36 13	09 22 13 00, 09 22 13 00a, 09 22 13 00b
09 22 36 23	09 22 36 23, 09 22 13 00, 09 22 13 00a, 09 22 13 00b
09 22 36 33	09 22 13 00, 09 22 13 00a, 09 22 13 00b, 09 22 36 23
09 23 13 00	09 23 13 00, 09 22 13 00, 09 22 13 00a, 09 22 13 00b, 09 22 36 23
09 24 33 00	01 22 16 00
09 28 13 00	09 28 13 00, 09 28 13 00a, 09 22 13 00a, 09 31 00 00
09 29 00 00	01 22 16 00, 09 28 13 00, 09 23 13 00, 09 28 13 00a
09 30 13 00	09 31 00 00
09 30 16 00	09 31 00 00
09 31 00 00	09 31 00 00
09 32 00 00	09 31 00 00
09 34 00 00	09 31 00 00
09 35 00 00	09 31 00 00
09 39 00 00	09 31 00 00

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09 51 13 00	09 51 13 00
09 51 23 00	09 51 23 00
09 51 33 13	09 51 33 13
09 53 23 00	09 51 13 00
09 54 23 00	09 54 23 00, 09 51 33 13
09 64 66 00	09 64 66 00
09 65 13 13	09 65 13 13, 09 65 13 13a
09 65 13 23	09 65 13 13
09 65 13 33	09 65 13 33, 09 65 13 33a, 01 22 16 00, 09 65 13 13, 09 65 23 00, 09 65 13 13a
09 65 13 36	09 65 13 13, 09 65 13 13a
09 65 16 23	09 65 13 13, 09 65 23 00
09 65 19 19	09 65 13 13, 09 65 13 33
09 65 19 23	09 65 13 13, 09 65 13 33
09 65 19 33	09 65 13 13, 09 65 13 33
09 65 19 43	09 65 13 13, 09 65 13 33
09 65 23 00	09 65 23 00, 09 65 13 13
09 65 43 00	09 65 13 13, 09 65 23 00
09 65 66 00	09 65 13 33
09 66 13 00	09 01 60 00
09 66 16 00	09 01 60 00
09 66 33 13	09 66 33 13
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09 69 13 00	09 69 13 00
09 69 53 00	09 69 13 00
09 72 13 00	09 72 13 00
09 72 16 00	09 72 13 00
09 72 19 00	09 72 13 00
09 72 23 00	09 72 13 00
09 73 00 00	09 01 60 00a
09 81 16 00	09 84 13 00
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09 85 00 00	09 28 13 00, 09 23 13 00, 09 28 13 00a
09 91 13 00	09 91 13 00, 09 91 13 00a, 09 91 13 00b, 01 22 16 00
09 91 23 00	09 91 23 00, 09 91 23 00a, 09 91 13 00
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09 96 00 00	09 96 00 00
09 96 53 00	09 91 13 00
09 97 35 00	09 91 23 00
10 11 13 13	10 11 13 13
10 11 13 33	10 11 13 13
10 11 16 13	10 11 13 13
10 11 16 33	10 11 13 13
10 11 23 13	10 11 13 13
10 13 16 00	10 11 13 13
10 14 00 00	10 14 00 00
10 14 19 00	01 22 16 00, 10 14 00 00, 01 58 13 00
10 14 23 00	10 14 00 00, 01 58 13 00
10 14 53 00	10 14 53 00, 10 14 00 00
10 21 13 13	10 21 13 13, 01 22 16 00

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10 21 13 19	10 21 13 19, 10 21 13 13
10 21 13 43	01 22 16 00, 10 21 13 13
10 21 16 00	10 21 16 00, 10 21 16 00a, 10 21 13 13
10 26 13 00	10 26 13 00, 05 50 00 00
10 26 23 00	10 26 13 00
10 28 13 13	10 28 13 13, 10 28 13 13a, 01 22 16 00
10 28 13 63	10 28 13 13, 10 28 13 13a
10 28 19 16	10 28 19 16
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10 44 16 13	10 44 16 13, 01 22 16 00, 10 44 13 00
10 51 13 00	10 51 13 00, 10 51 13 00a, 01 22 16 00
10 51 26 00	10 51 26 00
10 51 53 00	01 22 16 00
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10 55 26 00	10 55 23 26
10 56 16 00	06 05 23 00a
10 73 13 00	10 73 13 00
10 73 26 00	10 73 26 00, 01 22 16 00
10 75 16 00	10 75 16 00
10 75 23 00	10 75 16 00
10 81 13 00	10 81 13 00
11 12 16 00	11 12 16 00, 11 12 16 00a
11 12 23 00	11 12 16 00, 11 12 16 00a
11 12 26 00	11 12 16 00, 11 12 16 00a
11 13 13 00	11 13 13 00
11 13 16 13	11 13 13 00
11 13 16 23	11 13 13 00
11 13 19 13	11 13 13 00
11 13 19 26	11 13 13 00
11 13 19 33	11 13 13 00
11 13 23 23	11 13 13 00
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11 14 13 19	11 14 13 16
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11 44 16 00	11 21 63 00
11 44 19 00	11 44 19 00, 11 21 63 00
11 46 13 00	11 21 63 00
11 46 16 00	11 21 63 00
11 46 19 00	11 21 63 00
11 46 83 00	11 21 63 00
11 48 13 00	11 21 63 00
11 48 16 00	11 21 63 00
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11 52 19 00	11 52 13 13
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11 82 26 00	11 21 63 00
11 98 16 00	08 34 63 13a
12 01 60 00	12 01 60 00, 01 22 16 00
12 21 13 13	12 21 13 13, 12 21 13 13a
12 21 13 33	12 21 13 13, 12 21 13 13a
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12 21 16 33	12 21 13 13, 12 21 13 13a
12 22 13 00	12 22 13 00
12 22 16 00	12 22 13 00
12 24 13 00	12 24 13 00, 12 24 13 00a, 12 21 13 13, 12 21 13 13a
12 31 13 00	12 31 13 00, 01 22 16 00
12 36 23 13	12 36 23 13, 06 41 13 00
12 36 61 16	12 36 61 16, 06 41 13 00
12 48 13 13	12 48 13 13, 12 48 13 13a
12 48 13 16	12 48 13 13, 12 48 13 13a
12 61 13 00	12 01 60 00
12 61 16 00	12 01 60 00
12 61 19 00	12 01 60 00
12 62 23 00	12 62 23 00, 01 22 16 00
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13 34 23 13	13 34 23 13
14 01 20 00	14 01 20 00, 14 01 20 00a, 01 22 16 00
14 01 30 00	14 01 20 00, 14 01 20 00a, 14 31 00 00
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14 31 00 00	14 31 00 00
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22 07 19 00	22 07 19 00, 21 07 00 00
22 11 16 00	22 11 16 00, 22 11 16 00a, 22 11 16 00b, 22 11 16 00c, 22 11 16 00d, 22 11 16 00e, 22 11 16 00f, 22 11 16 00g, 22 11 16 00h, 22 11 16 00i, 07 63 00 00, 07 63 00 00a, 07 63 00 00b
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22 13 16 00	22 05 23 00, 22 11 23 39, 22 05 76 00, 07 63 00 00, 07 63 00 00a, 07 63 00 00b, 22 11 16 00a, 22 11 16 00b
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22 13 19 26	22 13 19 26, 22 13 19 00
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22 13 19 36	22 13 19 00
22 13 23 00	22 13 19 26
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22 13 29 16	22 13 29 13b
22 13 29 33	01 22 16 00
22 14 29 13	22 14 29 13, 22 05 23 00
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