SECTION 23 09 93
SEQUENCE OF OPERATIONS FOR HVAC CONTROLS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes control sequences for HVAC systems, subsystems, and equipment.

B. Related Sections include the following:

1. Division 23 Section "Instrumentation and Control for HVAC" for control equipment and devices and for submittal requirements.

1.3 DEFINITIONS

A. DDC: Direct digital control.

B. VAV: Variable air volume.

1.4 HEATING CONTROL SEQUENCES

A. Heating-Water Supply Temperature Control:

1. Input Device: [Thermostat], [Thermistor temperature sensor], [Resistance temperature sensor], [Temperature Sensor],

2. Output Device: Control valve.

3. Action: Modulate control valve to maintain heating-water supply temperature.

4. Display:

   a. Heating-water supply temperature.

   b. Heating-water supply temperature set point.

   c. Control-valve position.

B. Heating-Water Supply Temperature Reset:

1. Input Device: [Electric, outdoor-air-reset controller], [Outdoor-air sensor],
2. **Output Device:** [Unitary controller], [DDC system software].

3.2. **Action:** Reset heating-water supply temperature in straight-line relationship with outdoor-air temperature for the following conditions:

a. \[195 \text{ deg F (90 deg C)}\] \(<\) \[305 \text{ deg F (152 deg C)}\] \(<\) heating water when outdoor-air temperature is \[140 \text{ deg F (60 deg C)}\] \(<\) \[115 \text{ deg F (46 deg C)}\] \(<\) or above (adjustable).

b. \[130 \text{ deg F (54 deg C)}\] \(<\) heating water when outdoor-air temperature is 75 deg F (24 deg C).

c. \[150 \text{ deg F (65 deg C)}\] \(<\) \[160 \text{ deg F minimum}, heating-water temperature.\]

4.3. **Display:**

a. Outdoor-air temperature.

b. Heating-water supply temperature.

c. Heating-water supply temperature set point.

4. **Alarms:** Send signal to BMS if Boiler Room flammable gas levels exceed 400ppm.

C. **Control Primary Circulating Pump(s):**

1. **Input Device:** [Thermostat], [DDC system].

2. **Output Device:** [Starter], [DDC system command to starter relay].

3.2. **Action:** Energize pump(s) at outdoor-air temperatures below \[65 \text{ deg F (18 deg C)}\] \(<\) or when fan coil units call for heating.

4.3. **Display:**

a. Outdoor-air temperature.

b. Operating status of primary circulating pump(s).

4.5 **CENTRAL REFRIGERATION EQUIPMENT SEQUENCES**

A. **Start and Stop Condenser-Water Pump(s):**

1. **Enable:** Allow pump to start when water is in cooling tower:

   a. **Input Device:** Water pressure transducer.

   b. **Output Device:** Hard wired through motor starter, [DDC system binary output].

   c. **Action:** Confirm water in cooling-tower sump.

2. **Enable:** When outdoor-air temperature conditions are met:
a. Input Device: [Space thermostat] [DDC system outdoor air temperature].

b. Output Device: Hard wired through motor starter; [DDC system binary output].

c. Action: Confirm outdoor air temperature is above 50 deg F (10 deg C).

3. Enable: When demand conditions are met:

a. Input Device: DDC system software demand.

b. Action: Confirm cooling demand from ventilation system(s).

4. Initiate:

a. Input Device: [Time clock] [DDC system time schedule].

b. Output Device: [Time clock] [Binary output].

c. Action: Energize pump(s).

5. Display:

a. Low-level cooling tower sump alarm.

b. Outdoor air temperature.

c. Cooling (software) demand indication.

d. Time and time schedule.

e. Condenser water pump(s) on-off status.

f. Condenser water pump(s) on-off indication.

B. Start and Stop Chilled-Water Pump(s):

1. Input Device: Flow switch in condenser-water circuit.

2. Output Device: [Starter] [DDC system command to starter] relay.

3. Action: Energize pump(s).

4. Display:

a. Chilled-water flow indication.

b. Chilled-water pump(s) on-off status.

c. Chilled-water pump(s) on-off indication.

C. Start and Stop Cooling-Tower Fans(s):

1. Input Device: Flow switch in condenser-water circuit.

2. Output Device: [Starter] [DDC system command to starter] relay.
3. Action: Energize fan(s).

4. Display:
   a. Condenser-water flow indication.
   b. Cooling-tower fan(s) on-off indication.

D. Start and Stop Refrigeration Machine(s):

1. Input Device: Flow switch in condenser-water circuit. [Flow switch in chilled-water circuit.]

2. Output Device: [Refrigeration] [DDC system command to refrigeration] machine terminal strip.

3. Action: Energize refrigeration machine(s) internal control circuit.

4. Display:
   a. Condenser-water flow indication.
   b. Chilled-water flow indication.
   c. Refrigeration machine on-off indication.
   d. Chilled-water supply and return temperature.
   e. Chilled-water temperature control-point adjustment.

E. Start and Stop Chiller(s):

1. Input Device: Flow switches in condenser-water and chilled-water circuit.

2. Output Device: [Chiller] [DDC system command to chiller] terminal strip.

3. Action: Energize chiller internal control circuit.

4. Display:
   a. Condenser-water flow indication.
   b. Chilled-water flow indication.
   c. Chiller(s) on-off status.
   d. Chiller(s) on-off indication.
   e. Chilled-water supply and return temperature.
   f. Chilled-water temperature control-point adjustment.

F. Alternate Chiller(s):

1. Input Device: [Electric alternator] [DDC system software].
2. Output Device: [Chiller] [DDC system command to chiller] terminal strip.

3. Action: Operate chiller(s) on lead-lag, alternating each startup.

4. Action: Adding and dropping chiller(s) as follows: <Insert sequence and parameters.>

5. Display: Chiller(s) on-off indication.

G. Alarm Chiller(s) Start Failure:

1. Input Device: Chiller [control panel terminal strip contact] [software signal].

2. Output Device: [Analog control panel] [DDC system alarm].

3. Action: Signal alarm.


H. Chilled-Water Level:

1. Input Device: Expansion tank [level switch] [liquid sensor].

2. Output Device: [Electric relay signal to alarm panel] [DDC system alarm].

3. Action: Signal alarm.


I. Chilled-Water Supply Temperature:

1. Input Device: Temperature [sensor] [transmitter] in common chilled-water supply piping.

2. Output Device: [Integral chiller controls] [DDC system signal to chiller control panel].

3. Action: Maintain constant leaving chilled-water temperature [reset according to highest cooling demand].

   a. Display: Chilled-water supply temperature.

J. Condenser-Water Temperature:

1. Input Device: Temperature [sensor] [transmitter] in cooling-tower sump.

2. Output Device: [Bypass control valve] [Cooling-tower fan starter relay] [DDC system command to cooling-tower fan starter relay].

3. Action: Modulate control valve open to cooling tower and closed to bypass and cycle tower fan(s) [on and off] and to low speed and then to high speed to maintain [65 deg F (18 deg C)] [70 deg F (21 deg C)] sump temperature. [Close valve when unoccupied.]

4. Display:
a. Condenser-water sump (return) control-point temperature.
b. Condenser-water sump (return) temperature.
c. Control-valve position.
d. Cooling-tower fan(s) on-off indication.
e. Condenser-water supply temperature.

K. Cooling-Tower Sump Heater:

1. Input Device: Sump temperature [sensor] [transmitter].
2. Output Device: [Electric relay], [DDC system command to electric relay] [and solenoid valve].
3. Action: Energize sump heater; drain sump on low temperature.
4. Display:
   a. Cooling-tower sump temperature.
   b. Cooling-tower sump heater on-off indication.
   c. Cooling-tower dump indication.

L. Operator Station Display: Indicate the following on operator workstation display terminal:

1. DDC system graphic.
2. DDC system status, on-off.
3. Low-level cooling-tower sump alarm.
4. Outdoor-air temperature.
5. Cooling (software) demand indication.
6. Time and time schedule.
7. Condenser-water pump(s) on-off status.
8. Condenser-water pump(s) on-off indication.
9. Condenser-water flow indication.
10. Chilled-water pump(s) on-off status.
11. Chilled-water pump(s) on-off indication.
12. Cooling-tower fan(s) on-off indication.
13. Chilled-water flow indication.
15. Chilled-water supply temperature.
17. Chilled-water temperature control-point adjustment.
18. Chiller(s) on-off status.
19. Chiller(s) on-off indication.
22. Condenser-water sump (return) control-point temperature.
23. Condenser-water sump (return) temperature.
24. Condenser-water control-valve position.
25. Cooling-tower fan(s) on-off indication.
26. Condenser-water supply temperature.
27. Cooling-tower sump temperature.
29. Cooling-tower dump indication.
30. Chilled-water pressure drop through chiller.
31. Entering condenser-water temperature.
32. Leaving condenser-water temperature.
33. Condenser-water pressure drop through chiller.
34. Chiller condenser-water supply and return temperature.
35. Chiller chilled-water supply and return temperature.
36. System capacity in tons.

1.6 AIR-HANDLING-UNIT CONTROL SEQUENCES

A. Start and Stop Supply Fan(s):

1. Enable: Freeze Protection:
   a. Input Device: Duct-mounted averaging element thermostat, located before supply fan.
b. Output Device: Hard wired through motor starter; [analog alarm panel] [DDC system alarm].

c. Action: Allow start if duct temperature is above 37 deg F (3 deg C); signal alarm if fan fails to start as commanded.

2. Enable: High-Temperature Protection:

   a. Input Device: Duct-mounted thermostat, located in return air.

   b. Output Device: Hard wired through motor starter; [analog alarm panel] [DDC system alarm].

   c. Action: Allow start if duct temperature is below 300 deg F (150 deg C).

3. Enable: Smoke Control:

   a. Input Device: Duct-mounted smoke detector, located in [return] [supply] air.

   b. Output Device: Hard wired through motor starter; [analog alarm panel] [DDC system alarm].

   c. Action: Allow start if duct is free of products of combustion.

4. Initiate: Occupied Time Schedule:

   a. Input Device: [Time clock] [DDC system time schedule].

   b. Output Device: [Time clock] [Binary output] to motor starter.

   c. Action: Energize fan(s).

5. Initiate: Unoccupied Time Schedule:

   a. Input Device: [Room thermostat] [DDC system demand].

   b. Output Device: [Room thermostat] [Binary output] to motor starter.

   c. Action: Energize fan(s).

6. Unoccupied Ventilation:

   a. Input Device: [Time clock and room thermostat] [DDC system time schedule and output].

   b. Output Device: [Room thermostat] [DDC system binary output] to motor starter.

   c. Action: Cycle fan(s) during unoccupied periods.


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

1. Occupied Time Schedule:
a. Input Device: [Time clock] [DDC system time schedule].

b. Output Device: [Time clock] [Binary output].

c. Action: Enable control.

2. Volume Control:

a. Input Device: [Static-pressure transmitter] [Differential-pressure switch] sensing supply-duct static pressure referenced to conditioned-space static pressure.

b. Output Device: [Receiver controller] [DDC system analog output] to [DDC system analog output to digital-to-pneumatic transducer] to modulating damper actuator. Set inlet guide vanes to [minimum] [closed] position when fan is stopped.

c. Action: Maintain constant supply-duct static pressure.

3. Volume Control:

a. Input Device: [Static-pressure transmitter] [Differential-pressure switch] sensing supply-duct static pressure referenced to conditioned-space static pressure.

b. Output Device: [Receiver controller] [DDC system analog output] to motor speed controller. Set variable-speed drive to minimum speed when fan is stopped.

c. Action: Maintain constant supply-duct static pressure.

4. High Pressure:

a. Input Device: Static-pressure transmitter sensing supply-duct static pressure referenced to static pressure outside the duct.

b. Output Device: [Receiver controller] [DDC system binary output] to [alarm panel] [motor starter].

c. Action: Stop fan and signal alarm when static pressure rises above excessive static-pressure set point.

5. Display:

a. Supply-fan-discharge static-pressure indication.

b. Supply-fan-discharge static-pressure set point.

c. Supply-fan airflow rate.

d. Supply-fan [Inlet vane position] [speed].

C. Start and Stop Return Fan(s):

1. Initiate: Occupied Time Schedule:
a. Input Device: [Time clock] [DDC system time schedule].

b. Output Device: [Time clock] [Binary output] to motor starter.

c. Action: Energize fans when supply fans are energized.

2. Initiate: Unoccupied Time Schedule:

a. Input Device: [Room thermostat] [DDC system demand].

b. Output Device: [Room thermostat] [Binary output] to motor starter.

c. Action: Energize fans when supply fans are energized.

3. Unoccupied Ventilation:

a. Input Device: [Time clock and room thermostat] [DDC system time schedule and output].

b. Output Device: [Room thermostat] [DDC system binary output] to motor starter.

c. Action: Cycle fan(s) during unoccupied periods.


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

1. Occupied Time Schedule:

a. Input Device: [Time clock] [DDC system time schedule].

b. Output Device: [Time clock] [Binary output].

c. Action: Enable control.

2. Volume Control:

a. Input Device: [Static-pressure transmitter] [Differential-pressure switch] sensing building static pressure referenced to outdoor static pressure.

b. Output Device: [Receiver controller] [DDC system analog output] [DDC system analog output to digital-to-pneumatic transducer] to modulating damper actuator. Set inlet guide vanes to [minimum] [closed] position when fan is stopped.

Action: Maintain constant building static pressure.

3. Volume Control:

a. Input Device: [Static-pressure transmitter] [Differential-pressure switch] sensing building static pressure referenced to outdoor static pressure.

b. Output Device: [Receiver controller] [DDC system analog output] to motor speed controller. Set variable-speed drive to minimum speed when fan is stopped.
c. Action: Maintain constant building static pressure.

4. Display:
   a. Return-air-static-pressure indication.
   b. Return-air-static-pressure set point.
   c. Return-fan airflow rate.
   d. Return-fan [inlet vane position] [speed].
   e. Building static-pressure indication.
   f. Building static-pressure set point.

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

   1. Occupied Time Schedule:
      a. Input Device: [Time clock] [DDC system time schedule].
      b. Output Device: [Time clock] [Binary output].
      c. Action: Enable control.

   2. Volume Control:
      a. Input Device: [Static-pressure transmitter] [Differential-pressure switch]
         sensing building static pressure referenced to outdoor static pressure.
      b. Output Device: [Receiver controller] [DDC system analog output] [DDC system analog output to digital-to-pneumatic transducer] to modulating damper actuator. Set inlet guide vanes to [minimum] [closed] position when fan is stopped.
      c. Action: Maintain constant building static pressure.

   3. Volume Control:
      a. Input Device: [Static-pressure transmitter] [Differential-pressure switch]
         sensing building static pressure referenced to outdoor static pressure.
      b. Output Device: [Receiver controller] [DDC system analog output] to motor speed controller. Set variable-speed drive to minimum speed when fan is stopped.
      c. Action: Maintain constant building static pressure.

4. Display:
   a. Return-fan-discharge-static-pressure indication.
   b. Return-fan-discharge-static-pressure set point.
   c. Return-fan airflow rate.
d. Return-fan [inlet vane position] [speed].

**F. Preheat Coil:**

1. **Freeze Protection:**
   a. Input Device: Duct-mounted averaging element thermostat, located after preheat coil.
   b. Output Device: Hard wired through motor starter; [analog alarm panel] [DDC system alarm].
   c. Action: Allow start if duct temperature is above 33 deg F (1 deg C).

2. **Occupied Time Schedule:**
   a. Input Device: [Time clock] [DDC system time schedule].
   b. Output Device: [Time clock] [Binary output] to motor starter.
   c. Action: Energize coil circulating pump(s).

3. **Supply/Discharge Air Temperature:**
   a. Input Device: [Time clock and duct-mounted thermostat] [DDC system time schedule and electronic temperature sensor].
   b. Output Device: Modulating control valve.
   c. Action: Maintain air temperature set point of 55 deg F (13 deg C).

4. **Unoccupied Time Schedule:**
   a. Input Device: [Time clock and duct-mounted thermostat mounted in outdoor air] [DDC system time schedule and outdoor-air temperature].
   b. Output Device: [Time clock] [Binary output] to motor starter.
   c. Action: Energize coil circulating pump(s) when outdoor-air temperature falls below 35 deg F (2 deg C).

5. **Display:**
   a. Preheat-coil air-temperature indication.
   b. Preheat-coil air-temperature set point.
   c. Preheat-coil pump operation indication.
   d. Preheat-coil control-valve position.

**G. Mixed-Air Control:**

1. **Occupied Time Schedule:**
a. Input Device: [Time clock] [DDC system time schedule].

b. Output Device: [Pneumatic relay] [DDC system output].

c. Action: Enable control.

2. Minimum Position:

a. Input Device: [Time clock] [DDC system time schedule].

b. Output Device: [Receiver controller] [DDC system analog output] [DDC system analog output to digital-to-pneumatic transducer] to modulating damper actuator(s).

c. Action: Open [minimum outdoor-air dampers] [outdoor-air dampers to minimum position].

3. Heating Reset:

a. Input Device: [Room thermostat] [DDC system software].

b. Output Device: [Receiver controller] [DDC system analog output] [DDC system analog output to digital-to-pneumatic transducer] to modulating damper actuator(s).

c. Action: Close minimum outdoor-air dampers [Set outdoor-air dampers to minimum position].

4. [Supply] [Mixed]-Air Temperature:

a. Input Device: [Duct-mounted thermostat] [Electronic temperature sensor].

b. Output Device: [Receiver controller] [DDC system analog output] [DDC system analog output to digital-to-pneumatic transducer] to modulating damper actuator(s).

c. Action: Modulate outdoor-, return-, and relief-air dampers to maintain air temperature set point of 55 deg F (13 deg C).

5. Cooling Reset:

a. Input Device: [Outdoor- and return-air, duct-mounted] [thermostats] [electronic temperature sensors].

b. Output Device: [Receiver controller] [DDC system analog output] [DDC system analog output to digital-to-pneumatic transducer] to damper actuator(s).

c. Action: Set outdoor-air dampers to minimum position when outdoor-air temperature exceeds return-air temperature or enthalpy exceeds return-air enthalpy.

6. Unoccupied Time Schedule:

a. Input Device: [Time clock] [DDC system time schedule].
b. Output Device: [Receiver controller] [DDC system analog output] [DDC system analog output to digital-to-pneumatic transducer] to modulating damper actuator(s).

c. Action: Position outdoor- and relief-air dampers closed and return-air dampers open.

7. Display:


b. Mixed-air-temperature set point.

c. Mixed-air damper position.

H. Humidifier:

1. Occupied Time Schedule:

a. Input Device: [Time clock] [DDC system time schedule] and airflow switch

b. Output Device: [Pneumatic relay] [DDC system output].

c. Action: Enable control.

2. Humidity:

a. Input Device: [Room humidistat] [Return-air, duct-mounted humidistat] [DDC system].

b. Output Device: [Receiver controller] [DDC system analog output] [DDC system analog output to digital-to-pneumatic transducer] [enables humidifier] [modulates control valve to maintain humidity] [cycles pump to maintain humidity] [cycles pump and modulates control valve to maintain humidity] in straight-line relationship for the following conditions:

1) 20 percent when outdoor-air temperature is [minus 30 deg F (minus 35 deg C)] <Insert temperature>.

2) 40 percent when outdoor-air temperature is [75 deg F (24 deg C)] <Insert temperature>.

c. Action: Modulate outdoor-, return-, and relief-air dampers to maintain air temperature set point of [55 deg F (13 deg C)] <Insert temperature>.

3. Display:

a. Relative humidity indication.

b. Relative humidity set point.

c. Relative humidity control-valve position.

I. Filters: During occupied periods, when fan is running, differential air-pressure transmitters exist.
1. Occupied Time Schedule:
   a. Input Device: [Time clock] [DDC system time schedule].
   b. Output Device: [Electric relay] [DDC system output].
   c. Action: Enable control.

2. Differential Pressure:
   a. Input Device: [Differential-pressure switches] [Pressure transmitter].
   b. Output Device: [Analog alarm panel] [DDC system alarm].
   c. Action: Signal alarm on low- and high-pressure conditions.

3. Display:
   a. Filter air-pressure-drop indication.
   b. Filter low-air-pressure set point.
   c. Filter high-air-pressure set point.

J. [Hydronic] [Steam] Heating Coil:

1. Occupied Time Schedule:
   a. Input Device: [Time clock] [DDC system time schedule].
   b. Output Device: [Time clock] [Binary output].
   c. Action: Enable control.

2. [Supply] [Discharge]-Air Temperature:
   a. Input Device: [Duct-mounted thermostat] [Electronic temperature sensor].
   c. Action: Maintain supply-air temperature set point of 55 deg F (13 deg C).

3. Temperature Reset:
   a. Input Device: [Duct-mounted thermostat] [Electronic temperature sensor] in return air.
   b. Output Device: [Direct to receiver controller] [DDC system] in straight-line relationship for the following conditions:

   1) [65 deg F (18 deg C)] <Insert temperature> when return-air temperature is [70 deg F (21 deg C)] <Insert temperature>.

   2) [55 deg F (13 deg C)] <Insert temperature> when return-air temperature is [75 deg F (24 deg C)] <Insert temperature>. 
c. Action: Reset supply-air temperature set point of 55 deg F (13 deg C).

4. Temperature Reset:
   a. Input Device: [Load analyzer] [DDC system] with input from room [thermostats] [temperature sensors].
   b. Output Device: [Direct to receiver controller] [DDC system].
   c. Action: Reset supply-air temperature in response to greatest heating demand.

5. Unoccupied Time Schedule:
   a. Input Device: [Time clock and room thermostat] [DDC system time schedule and output].
   b. Output Device: [Room thermostat (cycling fan)] [DDC system binary output].
   c. Action: [Enable normal control] [Return valve to normal position] when fan is cycled on.

6. Display:
   a. Fan-discharge air-temperature indication.
   b. Fan-discharge air-temperature set point.
   c. Heating-coil air-temperature indication.
   d. Heating-coil air-temperature set point.
   e. Heating-coil pump operation indication.
   f. Heating-coil control-valve position.
   g. Hot-deck air-temperature indication.
   h. Hot-deck air-temperature set point.

K. Hydronic Cooling Coil:

1. Occupied Time Schedule:
   a. Input Device: [Time clock] [DDC system time schedule].
   b. Output Device: [Time clock] [Binary output].
   c. Action: Enable control.

2. [Supply] [Discharge] Air Temperature:
   a. Input Device: [Duct-mounted thermostat] [Electronic temperature sensor].
c. Action: Maintain supply-air temperature set point of 55 deg F (13 deg C).

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

4. Temperature Reset:
   a. Input Device: [Load analyzer] [DDC system] with input from room [thermostats] [temperature sensors].
   b. Output Device: [Direct to receiver controller] [DDC system].
   c. Action: Reset supply-air temperature in response to greatest heating demand.

5. Unoccupied Time Schedule:
   a. Input Device: [Time clock] [DDC system time schedule].
   b. Output Device: [Time clock] [Binary output].
   c. Action: Disable control.

6. Display:
   a. Fan-discharge air-temperature indication.
   b. Fan-discharge air-temperature set point.
   c. Cooling-coil air-temperature indication.
   d. Cooling-coil air-temperature set point.
   e. Cooling-coil control-valve position.
   f. Cold-deck air-temperature indication.
   g. Cold-deck air-temperature set point.

L. Multizone Damper Control:
   1. Occupied Time Schedule:
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SEQUENCE OF OPERATIONS FOR HVAC CONTROLS

23 09 93 - 18

2. Room Temperature:
   a. Input Device: [Room thermostat] [Electronic temperature sensor].
   b. Output Device: Damper actuator.
   c. Action: Maintain room temperature.

3. Display:
   a. Room temperature indication.
   b. Room temperature set point.
   c. Multizone damper position.

M. 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.

N. Operator Station Display: Indicate the following on operator workstation display terminal:
   1. DDC system graphic.
   2. DDC system on-off indication.
   3. DDC system occupied/unoccupied mode.
   5. Supply-fan on-off indication.
   7. Supply-fan-discharge-static-pressure set point.
   9. Supply-fan [inlet vane position] [speed].
   11. Return-air static-pressure indication.
   12. Return-air static-pressure set point.
   14. Return-fan [inlet vane position] [speed].
15. Building static-pressure indication.
16. Building static-pressure set point.
17. Preheat-coil air-temperature indication.
18. Preheat-coil air-temperature set point.
19. Preheat-coil pump operation indication.
20. Preheat-coil control-valve position.
23. Mixed-air-damper position.
25. Relative humidity set point.
27. Filter air-pressure-drop indication.
28. Filter low-air-pressure set point.
29. Filter high-air-pressure set point.
30. Fan-discharge air-temperature indication.
31. Fan-discharge air-temperature set point.
32. Heating-coil air-temperature indication.
33. Heating-coil air-temperature set point.
34. Heating-coil pump operation indication.
35. Heating-coil control-valve position.
37. Hot-deck air-temperature set point.
38. Cooling-coil air-temperature indication.
40. Cooling-coil control-valve position.
41. Cold-deck air-temperature indication.
42. Cold-deck air-temperature set point.
43. Room temperature indication.
44. Room temperature set point.
45. Multizone damper position.

4.7.1.5 TERMINAL UNIT OPERATING SEQUENCE

A. Cabinet Unit Heater, [Hydronic] [Steam]:

1. Room Temperature:
   a. Input Device: [Room thermostat] [Electronic temperature sensor].
   b. Output Device: [Room thermostat] [DDC system binary output].
   c. Action: Cycle fan to maintain temperature.

2. Low-Temperature Safety:
   c. Action: Stop fan when [return heating-water] [condensate] temperature falls below 35 deg F (2 deg C).

3. Display:
   a. Room temperature indication.
   b. Room temperature set point.

B.A. Cabinet Unit Heater, Electric: Room thermostat cycles fan and sequences stages of heating.

C. Unit Heater, [Hydronic] [Steam]:

1. Room Temperature:
   a. Input Device: [Room thermostat] [Electronic temperature sensor].
   b. Output Device: [Room thermostat] [DDC system binary output].
   c. Action: Cycle fan to maintain temperature.

2. Low-Temperature Safety:
   c. Action: Stop fan when [return heating-water] [condensate] temperature falls below 35 deg F (2 deg C).
3. Display:
   a. Room temperature indication.
   b. Room temperature set point.

D. Unit Heater, Electric: Room thermostat cycles fan and sequences stages of heating.

E. Combustion-Air Unit Heaters:
   1. Room Temperature:
      a. Input Device: [Room thermostat] [Electronic temperature sensor].
      c. Action: Modulate valve to maintain temperature.

   2. Display:
      a. Room temperature indication.
      b. Room temperature set point.
      c. Control-valve position.

F. Radiant Heating Cable, Electric: Room thermostat cycles power.

G. Radiant Heating Panel, Electric: Room thermostat cycles power.

H. Radiant Heating Panel, Hydronic:
   1. Room Temperature:
      a. Input Device: [Room thermostat] [Electronic temperature sensor].
      c. Action: Modulate valve to maintain temperature.

   2. Display:
      a. Room temperature indication.
      b. Room temperature set point.
      c. Control-valve position.

I. Two-Pipe, Single-Coil, Fan-Coil Unit:
   1. Occupied Time Schedule:
      a. Input Device: [Fan switch] [Time clock] [DDC system time schedule].
      b. Output Device: [Time clock] [Binary output].
c. Action: Start and stop fan and enable control.

2. Room Temperature:
   a. Input Device: [Room thermostat] [Electronic temperature sensor] in [room] [return air].
   c. Action: Modulate valve to maintain temperature.

3. DDC System Changeover:
   a. Input Device: [Thermostat] [Electronic temperature sensor] in supply-water [on supply-water piping] [DDC system].
   b. Output Device: [Hard-wired relay] [DDC system software].
   c. Action: Reverse control-valve action to switch from heating to cooling.

4. Display:
   a. DDC system graphic.
   b. DDC system on-off indication.
   c. DDC system occupied/unoccupied mode.
   d. Room temperature indication.
   e. Room temperature set point.
   f. Control-valve position.
   g. Supply-water temperature indication.

J.B. Four-Pipe, Hydronic Fan-Coil Unit:

1. Occupied Time Schedule:
   a. Input Device: [Fan switch] [Time clock] [DDC system time schedule].
   b. Output Device: [Time clock] [Binary output].
   c. Action: Start and stop fan, and enable control. Provide air temperature sensor over full face of coil to shut down fan, motorized dampers and water valves if the mixed air temperature falls below 40 degrees F.

2. Room Temperature:
   a. Input Device: [Room thermostat] [Electronic temperature sensor].
   c. Action: Modulate multiport control valves to maintain temperature.
3. Display:
   a. DDC system graphic.
   b. DDC system on-off indication.
   c. DDC system occupied/unoccupied mode.
   d. Room temperature indication.
   e. Room temperature set point.
   f. Control-valve position.

4. Outside Air Motorized Dampers
   a. Shall close when the associated Fan Coil Unit is not operating and shall remain closed for morning warm-up until minimum 65 degrees F space temperature is achieved (adjustable).

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

1. Occupied Time Schedule:
   a. Input Device: [Fan switch] [Time clock] [DDC system time schedule].
   b. Output Device: [Time clock] [Binary output].
   c. Action: Start and stop fan, move outdoor- and return-air dampers to [minimum] [maximum] outdoor-air position, and enable control.

2. Room Temperature - Valves:
   a. Input Device: [Room thermostat] [Electronic temperature sensor].
   c. Action: Modulate heating-water supply control valve and chilled-water supply control valve in sequence to maintain temperature.

3. Room Temperature - Dampers:
   a. Input Device: [Thermostat] [Electronic temperature sensor] in mixed air.
   c. Action: Modulate outdoor- and return-air dampers to maintain temperature.

4. Supply-Air Temperature Limit:
   a. Input Device: [Thermostat] [Electronic temperature sensor] in discharge air.
   b. Output Device: [Pneumatic] [Electronic] control-valve operators and control damper actuators.
c. Action: Override room thermostat to control valves and dampers to prevent discharge air from dropping below a minimum set point.

5. Warm-up Cycle:
   a. Input Device: [Time clock] [DDC system time schedule].
   b. Output Device: [Hard-wired relay] [DDC system binary output].
   c. Action: Open heating-water supply control valve, close outdoor-air damper, and open return-air damper.

6. Display:
   a. DDC system graphic.
   b. DDC system on-off indication.
   c. DDC system occupied/unoccupied mode.
   d. Room temperature indication.
   e. Room temperature set point.
   f. Control-valve position.
   g. Damper position.

L. Heating Coils, [Hydronic] [Steam]:
   1. Room Temperature:
      a. Input Device: [Room Exhaust Fan] Interlock with room thermostat [Electronic temperature sensor].
      b. Output Device: [Pneumatic] [Electronic] [Electric] control-valve operators.
      c. Action: [Modulate] [Cycle]-valve to maintain temperature.
   2. Display:
      a. Room temperature indication.
      b. Room temperature set point.
      c. Control-valve position.

M. Heating Coils, Electric: Room thermostat [cycles coils] [sequences stages of heating].

N. Radiators 80 degrees F (adjustable). BMS shall monitor fan status and Convectors, [Hydronic] [Steam].
   1. Occupancy:
      a. Input Device: Occupancy sensor.
b. Output Device: DDC system binary output.

c. Action: Report occupancy and enable occupied temperature set point.

2. Room Temperature:

   a. Input Device: [Room thermostat] [Electronic temperature sensor].

   b. Output Device: [Pneumatic] [Electronic] [Electric] control-valve operators.

   c. Action: [Modulate] [Cycle] valve to maintain temperature.

      1) Occupied Temperature: 75 deg F (24 deg C).

      2) Unoccupied Temperature: 65 deg F (18 deg C).

3. Display:

   a. Room/area served.

   b. Room temperature indication.

   c. Room temperature set point.

   d. Room temperature set point, occupied.

   e. Room temperature set point, occupied standby.

   f. Room temperature set point, unoccupied.

   g. Control-valve position as percent open.

O. Radiators and Convectors, Electric: Room thermostat [cycles coils] [sequences stages of heating].

P. Constant-Volume, Terminal Air Units, [Hydronic] [Steam]:

1. Occupancy:

   a. Input Device: Occupancy sensor.

   b. Output Device: DDC system binary output.

   c. Action: Report occupancy and enable occupied temperature set point.

      1) Occupied Temperature: 75 deg F (24 deg C).

      2) Unoccupied Temperature: 65 deg F (18 deg C).

2. Room Temperature:

   a. Input Device: [Room thermostat] [Electronic temperature sensor].

   b. Output Device: [Pneumatic] [Electronic] [Electric] control-valve operators.
c. Action: [Modulate] [Cycle] valve to maintain temperature.

3. Display:
   a. Room/area served.
   b. Room occupied/unoccupied.
   c. Room temperature indication.
   d. Room temperature set point.
   e. Room temperature set point, occupied.
   f. Room temperature set point, unoccupied.
   g. Control-valve position as percent open.

Q. VAV, Terminal Air Units with [Hydronic] [Steam] Coils:

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

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

3. Display:
   a. Room/area served.
   b. Room occupied/unoccupied.
   c. Room temperature indication.
   d. Room temperature set point.
   e. Room temperature set point, occupied.
f. Room temperature set point, unoccupied.
g. Air-damper position as percent open.
h. Control-valve position as percent open.

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

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

2. Room Temperature:
   a. Input Device: Room thermostat.
   b. Output Device: Pneumatic or Electronic damper actuators.
   c. Action: Modulate dampers to maintain temperature.

S.C. 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.

D. Sequence when Toilet Exhaust Fan: Shall operate on a timed schedule (i.e. Monday-Friday 7am-8pm). Coordinate with client. BMS shall monitor fan status.
   1) Split Fan Coil Unit: Shall operate 24/7 to maintain space temperature is above set point. Close VAV damper to minimum position, close hot-deck dampers. (75 degrees F adjustable.) Condensate pump shall always be energized. BMS shall monitor unit status and open cold-deck dampers, then open VAV damper.

2. Display:
   a. Room/area served.
   b. Room occupied/unoccupied.
   c. Room temperature indication.
   d. Room temperature set point.
   e. Room temperature set point, occupied.
   f. Room temperature set point, unoccupied.
   g. VAV damper position as percent open.
h. Hot-deck damper position as percent open.

i. Cold-deck damper position as percent open.

1.8 VENTILATION SEQUENCES

A. Combustion-Air, Makeup Unit Control, Electric: Start fan when served appliance burner starts; room thermostat sequences stages of heating.

B. Combustion-Air, Makeup Unit Control, [Hydronic] [Steam]: Start fan when served appliance burner starts; room thermostat [cycles] [modulates] control valve.

C. Gravity Roof Ventilator: [Occupancy sensor] [Room thermostat] opens dampers.

D. Exhaust Fan: [Occupancy sensor] [Interlock with light switch] [Room thermostat] cycles fan.

E. Kitchen Exhaust Fan: Occupancy sensor starts fan and energizes makeup air unit.

PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION (Not Applicable)

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