SECTION 230993.11 - SEQUENCE OF OPERATIONS FOR HVAC DDC

Revise this Section by deleting and inserting text to meet Project-specific requirements.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

1. GENERAL
   * + 1. RELATED DOCUMENTS

Retain or delete this article in all Sections of Project Manual.

* + - * 1. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.
      1. SUMMARY
         1. Section includes control sequences for DDC for HVAC systems, subsystems, and equipment.
         2. Related Requirements:

Retain subparagraph below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections.

Section 230923 "DDC Systems for HVAC" for control equipment.

* + - 1. DEFINITIONS

Retain terms that remain after this Section has been edited for a project.

* + - * 1. Analog Output: Proportional output signal (zero- to 10-V dc, 4 to 20 mA).
        2. Binary Output: On/off output signal or contact closure.
        3. DDC: Direct digital control.
        4. Digital Output: Data output that must be interpreted digitally.
      1. SUBMITTALS
         1. Submittals for this section are subject to the re-evaluation fee identified in Article 4 of the General Conditions.
         2. Manufacturer’s installation instructions shall be provided along with product data.
         3. Submittals shall be provided in the order in which they are specified and tabbed (for combined submittals).
         4. Product Data:

An instrumentation list for each controlled system. Label each element of the controlled system in table format. Show, in the table element name, type of device, manufacturer, model number, and control device product data sheet number.

A complete description of the operation of the control system, including sequences of operation. Include and reference a schematic diagram of the controlled system.

* + - * 1. Shop Drawings:

Riser diagrams showing control network layout, communication protocol, and wire types.

Schematic diagram of each controlled system. Include all control points labeled with point names shown or listed. Show the location of control elements in the system.

Wiring diagram for each controlled system. Show all control elements labels. Where a control element is the same as that shown on the control system schematic, label with the same name. Label all terminals.

Remaining articles below are examples of operation sequences, which are presented in the following order: central plant equipment, distribution systems and subsystems, terminal heating-and-cooling units, and ventilation. The sequences are written in the form of performance requirements, without specifying the devices needed to accomplish the performance. Revise the operation sequences and add others if necessary to suit Project.

If applying for LEED certification, or intending to comply with ASHRAE standards, review the applicable requirements and revise the operation sequences accordingly.

* + - 1. HEATING CONTROL SEQUENCES

In "Control Circulating Pump(s)" paragraph below, sequence is for control of pumps in a hydronic heating system.

* + - * 1. Control Circulating Pump(s):

Input Device:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter] <Insert device>**.

Location: **[Outdoor-air] [Room] <Insert location>**.

Transference: DDC controller.

Output Device:

Device: Command to electric relay.

Location: Motor controller.

Transference: Starter relay.

Action:

Retain one of first two subparagraphs below.

Energize pump(s) at outdoor-air temperatures below **[65 deg F] <Insert temperature>**.

Energize pump(s) at room temperatures below **[72 deg F] <Insert temperature>**.

Enable **[additional circulating pump(s)] [, alternate pump(s)] [, heating-water supply temperature control] [and] [, heating-water supply temperature reset]** control sequences.

Retain "Additional Circulating Pump(s)" paragraph below to activate additional pumps in a parallel pumping arrangement or to start a standby pump if the primary pump fails.

* + - * 1. Additional Circulating Pump(s):

Input Device:

Device: Liquid pressure differential **[switch] [transmitter]**.

Location: Between the primary supply and return piping.

Transference: DDC controller.

Output Device:

Device: Binary output.

Location: Motor controller.

Transference: Starter relay.

Action:

Retain one of two subparagraphs below. Retain first subparagraph to specify a pressure differential by a percentage; retain second to specify a specific pressure.

Energize pump(s) and maintain operation when differential pressure drops below [30] <Insert number> percent of specified pump head.

Energize pump(s) and maintain operation when differential pressure drops below <Insert pressure differential in psig> of specified pump head.

Retain "Circulating Pump(s) Failure Alarm" paragraph below to signal pump start failure.

* + - * 1. Circulating Pump(s) Failure Alarm:

Input Device:

Device: Liquid pressure differential **[switch] [transmitter]**.

Location: Between the primary supply and return piping.

Transference: DDC controller.

Output Device:

Device: DDC controller.

Transference: Operator's workstation.

Action:

Signal alarm condition, no pressure differential between supply and return piping.

"Alternate Pump(s)" paragraph below provides for alternate start of multiple pumps. This sequence can also be applied to any other system with more than one pump.

* + - * 1. Alternate Pump(s):

Input:

Device: DDC controller.

Location: Software, <Insert software definition>.

Transference: Software.

Output Device:

Device: DDC controller.

Location: Motor controller.

Transference: Motor-controller relay.

Retain one of two "Action" subparagraphs below.

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

Action: Operate pump(s) on lead-lag, alternating on <Insert value> run hours.

In "Control Circulating Pump(s) Speed" paragraph below, sequence is for control of pump speed in a hydronic heating system.

* + - * 1. Control Circulating Pump(s) Speed:

Input Device:

Device: Liquid pressure differential transmitter.

Location: Heating supply and return piping.

Transference: DDC controller.

Output Device:

Device: Analog command.

Location: Motor controller.

Transference: Variable-frequency motor controller.

Action:

Control pump speed to maintain pressure differential of **<Insert psig>**.

In "Heating-Water Supply Temperature Control" paragraph below, sequence is for temperature reset control of a hydronic heating system with a heat exchanger.

* + - * 1. Heating-Water Supply Temperature Control:

Input:

Device: **[Liquid temperature sensor] [or] [liquid temperature sensor with liquid temperature transmitter]**.

Location: Heating-water supply.

Transference: DDC controller.

Output:

Device: Control-valve actuator.

Location: Heating-water supply.

Transference: Control-valve actuator.

Action:

Modulate control valve to maintain heating-water supply temperature.

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

**[195 deg F] <Insert highest heating temperature> heating water when outdoor-air temperature is [minus 30 deg F] <Insert lowest outdoor-air temperature>**.

**[130 deg F] <Insert lowest heating temperature>** heating water when outdoor-air temperature is 75 deg F.

In "Heating-Water Supply Temperature Reset" paragraph below, sequence is for temperature reset control of a hydronic heating system from DDC system.

* + - * 1. Heating-Water Supply Temperature Reset:

Input:

Device: **[Liquid temperature sensor] [Liquid temperature sensor with liquid temperature transmitter]**.

Location: Outdoor-air and heating-water supply.

Transference: DDC controller.

Output:

Device: DDC controller to boiler controls.

Location: Local panel.

Transference: Boiler control panel.

Action:

Retain one of two subparagraphs below.

Reset heating-water supply temperature in response to greatest heating demand to maintain at least one cooling control valve 90 percent open.

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

**[195 deg F] <Insert highest heating temperature>** heating water when outdoor-air temperature is **[minus 30 deg F] <Insert lowest outdoor-air temperature>**.

**[130 deg F] <Insert lowest heating temperature>** heating water when outdoor-air temperature is **[75 deg F] <Insert highest outdoor-air temperature>**.

**[150 deg F] <Insert temperature>** minimum heating-water temperature.

* + - * 1. Indicate the following on the operator's workstation display terminal:

subparagraphs below are examples only. Retain subparagraphs to suit specific Project requirements.

DDC system graphic.

DDC system status, on-off.

Outdoor-air temperature.

Room temperature.

Circulating pump(s) on-off status (enabled or disabled).

Circulating pump(s) on-off indication (operating or not operating).

Additional circulating pump(s) pressure differential.

Additional circulating pump(s) pressure differential set point.

Additional circulating pump(s) on-off indication (operating or not operating).

Circulating pump(s) alarm pressure differential.

Circulating pump(s) alarm pressure differential set point.

Alarm (circulating pump(s) failure).

Circulating pump(s) speed pressure differential.

Circulating pump(s) speed pressure differential set point.

Circulating pump(s) speed.

Heating-water supply temperature.

Heating-water return temperature.

Heating-water control-valve position.

Heating-water supply temperature set point.

Heating-water control-point output valve.

* + - 1. CENTRAL CHILLED-WATER SYSTEM SEQUENCES

In this article, sequence is for water-cooled chiller system with one or more water chillers, one or more cooling towers, one or more chilled-water pumps, and one or more condenser-water pumps.

Sequence assumes that the condenser-water pump system is energized first, followed by the chilled-water system, then the cooling tower, and finally the chiller. If all the startups are through the DDC system and its software, then the sequence is not required and all system components can be initiated at the same time.

* + - * 1. Central Chilled-Water System Time Schedule:

"Occupied Time Schedule" subparagraph below allows system to start when the time is appropriate.

Occupied Time Schedule:

Input:

Device: DDC controller.

Location: Time schedule.

Transference: DDC controller.

Output:

Device: DDC controller.

Action:

Enable startup, initiation, and control.

Energize condenser-water pumps on occupied/unoccupied cycle.

Energize condenser-water pumps on day/night cycle.

After chilled-water system shutdown, operate pump(s) for an additional **[3 minutes] <Insert time>**.

Display:

Time and time schedule.

The first steps in allowing the condenser-water pump(s) to start are to ensure that water is in the cooling tower sump, that the outdoor temperature is above an appropriate temperature, that the system being served requires cooling, and that the time schedule allows a start.

* + - * 1. Start and Stop Condenser-Water Pump(s):

Allow pump to start when water is in cooling tower.

The sequence below is for hard-wired electric control.

Enable:

Input:

Device: **[Level] [Liquid pressure]** switch.

Location: **[Cooling tower sump] [Pump suction]**.

Output:

Device: Hard wired.

Location: Motor controller.

Transference: Motor-controller relay.

Action: Confirm adequate water level **[in cooling-tower sump] [at pump suction]** and energize pump(s).

The sequence below is for DDC system control.

Enable:

Input:

Device: **[Level transmitter] [or] [liquid pressure transmitter]**.

Location: **[Cooling tower sump] [Pump suction]**.

Transference: DDC controller.

Output:

Device: Binary output.

Location: Motor controller.

Transference: Motor-controller relay.

Action: Confirm adequate water level **[in cooling-tower sump] [at pump suction]** at pressures above **<Insert** psig**>** and energize pump(s).

Retain first "Enable" subparagraph below if pump is allowed to start when outdoor-air temperature conditions are met.

Enable:

Input:

Device: DDC controller outdoor-air temperature.

Location: Outdoors.

Transference: Binary output.

Output:

Device: Hard wired.

Location: Motor controller.

Transference: Starter relay.

Action: Confirm outdoor-air temperature is above **[50 deg F] <Insert temperature>** and energize pump(s).

Retain "Enable" subparagraph below if pump is allowed to start when there is a demand.

Enable:

Input:

Device: DDC controller.

Location: Software demand.

Transference: Binary output.

Output:

Device: Hard wired.

Location: Motor controller.

Transference: Starter relay.

Action: Confirm cooling demand from ventilation system(s) and energize pump(s).

Display:

Low-level cooling-tower sump alarm.

Outdoor-air temperature.

Cooling (software) demand indication.

Time and time schedule.

Condenser-water pump(s) on-off status (enabled or disabled).

Condenser-water pump(s) on-off indication (operating or not operating).

The chilled-water pumps are allowed to start when the condenser-water pump(s) and system start.

* + - * 1. Start and Stop Chilled-Water Pump(s):

Input:

Device: **[Flow] [Pressure differential]** switch.

Location: Chilled-water piping.

Transference: **[Control voltage relay] [DDC controller]**.

Output:

Device: **[Hard wired] [Binary output]**.

Location: Motor controller.

Transference: Starter relay.

Action: Energize pump(s) when the condenser-water pump(s) and system start.

Display:

Chilled-water flow indication.

Chilled-water pump(s) on-off status (enabled or disabled).

Chilled-water pump(s) on-off indication (operating or not operating).

The cooling-tower fans are allowed to start when the condenser-water pump(s) and system start.

* + - * 1. Start and Stop Cooling-Tower Fan(s):

Input:

Device: **[Flow] [Pressure differential]** switch.

Location: Condenser-water piping.

Transference: **[Control relay] [DDC controller]**.

Output:

Device: **[Hard wired] [Binary output]**.

Location: Motor controller.

Transference: Starter relay.

Action: Energize fan(s) when the condenser-water pump(s) and system start.

Display:

Condenser-water flow indication.

Cooling-tower fan(s) on-off indication (operating or not operating).

Retain "Start and Stop Chillers" paragraph below when Project includes chillers.

* + - * 1. Start and Stop Chillers:

Input:

Device: **[Flow] [or] [pressure differential]** switch.

Location: Chilled-**[ and condenser-]**water piping.

Transference: **[Chiller controls] [DDC controller]**.

Output:

Device: **[Hard wired] [Binary output]**.

Location: Chiller control panel.

Transference: Chiller controls.

Action: Energize chiller(s) internal control circuit when the condenser-water and chilled-water pump(s), and system start.

Display:

Condenser-water flow indication.

Chilled-water flow indication.

Chiller on-off indication (operating or not operating).

Chilled-water supply and return temperature.

Chilled-water temperature control-point adjustment.

Retain "Start and Stop Chiller(s)" paragraph below when Project includes water chillers.

* + - * 1. Start and Stop Chiller(s):

Input:

Device: Flow switches.

Location: Condenser-water and chilled-water circuit.

Transference: **[Chiller terminal strip] [DDC system]**.

Output:

Device: **[Hard wired] [Binary output]**.

Location: Chiller control panel.

Transference: Chiller controls.

Action: Energize chiller internal control circuit when the condenser-water and chilled-water pump(s), and system start.

Display:

Condenser-water flow indication.

Chilled-water flow indication.

Chiller(s) on-off status (enabled or disabled).

Chiller(s) on-off indication (operating or not operating).

Chilled-water supply and return temperature.

Chilled-water temperature control-point adjustment.

"Alternate Chiller(s)" paragraph below provides for alternate start of multiple chillers.

* + - * 1. Alternate Chiller(s):

Input:

Device: DDC controller.

Location: DDC software, **<Insert software definition>**.

Transference: DDC software.

Output Device:

Device: DDC controller command to chiller.

Location: Chiller control panel.

Transference: Chiller controls.

Retain one of two "Action" subparagraphs below. Retain second subparagraph to insert custom sequence.

Action:

Retain one of first two subparagraphs below.

Operate chiller(s) on lead-lag, **[alternating each startup] [based on adjustable runtime hour set point]**.

Start additional chiller when load exceeds capacity of operating chillers as follows:

When common chilled-water supply temperature exceeds set point for a **[30-minute] <Insert time>** period.

When chiller power draw has reached its operator adjustable high limit for a **[30-minute] <Insert time>** period.

When combination of outdoor temperature and time schedule ensure enough run-time before time schedule shutdown.

Stop chiller when load capacity of operating chillers drops to less than **[110] <Insert number>** percent of capacity of next chiller to be shut down for a **[30-minute] <Insert time>** period.

Action: <Insert sequence and parameters>.

Display: Chiller(s) on-off indication (operating or not operating).

Retain "Alarm Chiller(s) Start Failure" paragraph below to signal alarm condition.

* + - * 1. Alarm Chiller(s) Start Failure:

Input:

Device: **[Software signal] [Hardwired] <Insert devices>**.

Location: Chiller control panel.

Transference: DDC controller.

Output:

Device: DDC controller.

Transference: Operator's workstation.

Action: Signal alarm on signal from chiller control panel.

Display:

Chiller "failure-to-start" indication.

**<Insert chiller controller alarm points>**.

Retain "Start and Stop Chiller(s)" paragraph below to report from chiller control panel.

* + - * 1. Start and Stop Chiller(s):

Input:

Device: Chiller control panel.

Location: Chiller.

Transference: DDC controller.

Output:

Device: DDC controller.

Transference: Operator's workstation.

Action: Report chiller electronic control, operating, and alarm functions.

Display:

**<See chiller Sections for listing>**.

Retain "Chilled-Water Level" paragraph below to signal alarm condition.

* + - * 1. Chilled-Water Level:

Retain one of two "Input" subparagraphs below. Retain first subparagraph for electrical devices in systems with hydropneumatic tanks; second, for DDC devices. Coordinate first subparagraph with expansion tank specifications in Section 232116 "Hydronic Piping Specialties."

Input:

Device: **[Level switch] [Liquid level sensor]**.

Location: Expansion tank.

Transference: DDC controller.

Input:

Device: Liquid gage pressure switch.

Location: Makeup-water piping downstream from pressure-reducing valve.

Transference: DDC controller.

Output:

Device: DDC controller.

Transference: Operator's workstation.

Action: Signal alarm on **[expansion tank low level] [low pressure]**.

Display: **[Expansion tank low-level] [Low-pressure]** alarm.

Retain "Chilled-Water Supply Temperature" paragraph below to control chilled-water temperature.

* + - * 1. Chilled-Water Supply Temperature:

Input:

Device: **[Liquid temperature sensor] [or] [liquid temperature sensor with liquid temperature transmitter]**.

Location: **[Common ]**chilled-water supply piping.

Transference: DDC controller.

Output:

Device: DDC controller signal.

Location: Local panel.

Transference: Chiller control panel.

Action: Maintain chilled-water supply temperature.

Retain one of first three subparagraphs below.

Reset chilled-water supply temperature in response to greatest cooling demand to maintain at least one cooling control valve 90 percent open.

Reset chilled-water supply temperature in straight-line relationship with outdoor-air temperature for the following conditions:

**[44 deg F] <Insert highest chilled-water temperature>** chilled water when outdoor-air temperature is **[80 deg F] <Insert highest outdoor-air temperature>**.

**[54 deg F] <Insert lowest chilled-water temperature>** chilled water when outdoor-air temperature is **[60 deg F] <Insert lowest operating outdoor-air temperature>**.

Reset chilled-water supply temperature based on constant return chilled-water temperature of **[54 deg F] <Insert temperature>**.

**<Insert reset strategy>**.

Display:

Chilled-water supply temperature.

Chilled-water supply temperature set point.

* + - * 1. Condenser-Water Temperature:

Input:

Device: **[Liquid temperature sensor] [Liquid temperature sensor with liquid temperature transmitter]**.

Location: **[Cooling-tower sump] [Common condenser-water supply piping]**.

Transference: DDC controller.

Two "Output" subparagraphs below assume a tower bypass valve and single- or variable-speed fans have associated motor-control circuitry.

Output:

Device: Analog output.

Location: DDC controller.

Transference: Control-valve actuator.

Coordinate temperatures in "Action" subparagraph below with chiller specification.

Action: Modulate control valve open to cooling tower and closed to bypass to maintain when condenser-water supply temperature is above **[**85 deg F**] <Insert value>** temperature set point. Modulate control valve closed to cooling tower and open to bypass when condenser-water supply temperature is below **[**55 deg F**] <Insert value>** temperature set point.

"Output" and first "Action" subparagraphs below assume a one-speed cooling tower.

Output:

Device: DDC controller control relay.

Location: DDC controller.

Transference: Fan starter relay.

Action: Cycle tower fan(s) on and off to maintain **[55 deg F] <Insert value>** temperature set point.

"Action" subparagraph below allows reset schedule to match chiller operating energy characteristics.

Action: Cycle tower fan(s) on and off to maintain condenser-water supply temperature in straight-line relationship with outdoor-air temperature for the following conditions:

**[85 deg F] <Insert highest condenser-water temperature>** condenser water when outdoor-air temperature is **[80 deg F] <Insert highest outdoor-air temperature>**.

**[55 deg F] <Insert lowest condenser-water temperature>** condenser water when outdoor-air temperature is **[55 deg F] <Insert lowest operating outdoor-air temperature>**.

"Output" and first "Action" subparagraphs below assume fans have associated variable-frequency motor-control circuitry.

Output:

Device: DDC controller digital output.

Location: DDC controller.

Transference: Fan variable-speed controller.

Action: Cycle tower fan(s) on and modulate fan speed from minimum to maximum to maintain **[55 deg F] <Insert value>** temperature set point.

"Action" subparagraph below allows reset schedule to match chiller operating energy characteristics.

Action: Cycle tower fan(s) on and off to maintain condenser-water supply temperature in straight-line relationship with outdoor-air temperature for the following conditions:

**[**85 deg F**] <Insert highest condenser-water temperature>** condenser water when outdoor-air temperature is **[**80 deg F**] <Insert highest outdoor-air temperature>**.

**[**55 deg F**] <Insert lowest condenser-water temperature>** condenser water when outdoor-air temperature is **[**55 deg F**] <Insert lowest operating outdoor-air temperature>**.

Display:

Control-valve(s) position.

Cooling-tower fan(s) on-off indication (operating or not operating).

Cooling-tower fan(s) speed.

Condenser-water supply temperature.

Condenser-water supply temperature set point.

Condenser-water return temperature.

"Cooling-Tower Sump Heater" paragraph below is for a cooling tower sump with an electric heater with electric controls.

* + - * 1. Cooling-Tower Sump Heater:

Input:

Retain option in "Device" subparagraph below if retaining control valve in sump drain piping.

Device: **[Two-stage ]**thermostat.

Location: Cooling tower sump.

Transference: Heater relay and control-valve actuator.

Output:

Device: Heater relay and control-valve actuator.

Location: Electric heater control panel and control-valve actuator in sump drain.

Transference: Electric heater contactor and control-valve actuator.

Action:

Energize sump heater if sump temperature falls below **[40 deg F] <Insert value>** temperature set point.

Open control valve in sump heater drain piping if sump temperature falls below **[35 deg F] <Insert value>** temperature set point.

Display:

Cooling-tower sump temperature.

Cooling-tower sump heater on-off indication (operating or not operating).

Cooling-tower control valve open-close indication.

"Cooling-Tower Sump Heater" paragraph below is for an electric heater with DDC.

* + - * 1. Cooling-Tower Sump Heater:

Input:

Device: **[Liquid temperature sensor] [or] [liquid temperature sensor with liquid temperature transmitter]**.

Location: Cooling tower sump.

Transference: DDC controller.

Output:

Device: Binary output.

Location: Electric heater control panel **[and solenoid valve in sump drain] [and control-valve actuator in sump drain]**.

Transference: Electric heater contactor **[and solenoid valve] [and control-valve actuator]**.

Action:

Energize sump heater if sump temperature falls below **<Insert value>** temperature set point.

Open control valve in sump heater drain piping if sump temperature falls below **<Insert value>** temperature set point.

Display:

Cooling-tower sump temperature.

Cooling-tower sump heater on-off indication (operating or not operating).

Cooling-tower control valve open-close indication.

In "Control Circulating Pump(s) Speed" paragraph below, sequence is to measure water flow through the chiller and control variable-speed pump.

* + - * 1. Control Circulating Pump(s) Speed:

Input Device:

Device: **[Liquid pressure differential transmitter] [Liquid flow meter] [Liquid flow sensor]**.

Location: Chilled-water supply and return piping**[ and condenser-water supply and return piping]** to chiller.

Transference: DDC controller.

Output Device:

Device: DDC controller.

Location: Motor controller.

Transference: Pump variable-speed controller.

Action:

Control pump speed to maintain flow through chiller.

Report pressure drop and flow.

In "Circulation through Chiller" paragraph below, sequence is to measure and report water flow through the chiller.

* + - * 1. Circulation through Chiller:

Input Device:

Device: **[Liquid pressure differential transmitter] [Liquid flow meter] [Liquid flow sensor]**.

Location: Chilled-water supply and return piping**[ and condenser-water supply and return piping]** to chiller.

Transference: DDC controller.

Output Device:

Device: DDC controller.

Action:

Report pressure drop and flow through chiller.

* + - * 1. Indicate the following on the operator's workstation display terminal:

Retain subparagraphs below to suit Project.

DDC system graphic.

DDC system status, on-off.

Low-level cooling-tower sump alarm.

Outdoor temperature.

Cooling (software) demand indication.

Time and time schedule.

Condenser-water pump(s) on-off status (enabled or disabled).

Condenser-water pump(s) on-off indication (operating or not operating).

Condenser-water flow indication.

Chilled-water pump(s) on-off status (enabled or disabled).

Chilled-water pump(s) on-off indication (operating or not operating).

Cooling-tower fan(s) on-off indication (operating or not operating).

Chilled-water flow indication.

Refrigeration machine on-off indication (operating or not operating).

Chilled-water supply temperature.

Chilled-water return temperature.

Chilled-water temperature control-point adjustment.

Chiller(s) on-off status (enabled or disabled).

Chiller(s) on-off indication (operating or not operating).

Chiller "failure-to-start" indication.

Expansion tank low-level alarm.

Condenser-water sump (return) control-point temperature.

Condenser-water sump (return) temperature.

Condenser-water control-valve position.

Cooling-tower fan(s) on-off indication (operating or not operating).

Condenser-water supply temperature.

Cooling-tower sump temperature.

Cooling-tower sump heater on-off indication (operating or not operating).

Cooling-tower sump drain indication.

Chiller(s) power input (instantaneous).

Chilled-water pressure drop through chiller.

Chilled-water flow through chiller.

Condenser-water pressure drop through chiller.

Condenser-water flow through chiller.

Chiller condenser-water supply and return temperature.

Chiller chilled-water supply and return temperature.

System capacity in tons.

**<Insert requirement>**.

* + - 1. AIR-HANDLING-UNIT CONTROL SEQUENCES

Retain applicable paragraphs below for Project's air-handling unit. If a project has more than one type of air-handling-unit control sequence of operation, copy and revise this article accordingly.

Paragraphs below allow the air-handling unit to start if temperature is above or below a safe limit, if there is no smoke in the duct, and if the unit is scheduled to operate.

* + - * 1. Air-Handling Unit Time Schedule:

"Occupied Time Schedule" subparagraph below allows unit to start when the time is appropriate.

Occupied Time Schedule:

Input:

Device: DDC controller.

Location: Time schedule.

Transference: DDC controller.

Output:

Device: DDC controller.

Action:

Enable startup, initiation, and control.

Energize unit on occupied/unoccupied cycle.

Energize unit on day/night cycle.

Energize unit on duty cycle.

Energize return-air fans **[30 seconds] <Insert time>** after supply fans are energized.

Do not enable mixed-air control during morning warm-up period.

Unoccupied: Position outdoor-air**[ and relief-air]** dampers closed and return-air dampers open.

Do not enable humidifier control during morning warm-up period.

Enable control of heating coil(s) during morning warm-up period.

Energize coil circulating pump(s).

Return heating control valves to normal position when unit is cycled on.

Do not enable cooling-coil control during morning warm-up period.

* + - * 1. Start and Stop Supply Fan(s):

First "Enable" subparagraph below allows the fan to start when temperature is above potential freezing condition.

Enable:

Input:

Device: Low limit temperature switch with **[manual] [automatic]** reset.

Location: Upstream of cooling coil.

Transference: Starter relay.

Output:

Device: Hard wired to motor controller**[ and DDC controller].**

Location: Motor controller.

Transference: Starter relay.

Action:

Allow start if temperature is above **[37 deg F] <Insert temperature>**.

Signal alarm if fan fails to start as commanded.

First "Enable" subparagraph below allows the fan to start when temperature is below a high-temperature threshold.

Enable:

Input:

Device: Low limit temperature switch with **[manual] [automatic]** reset.

Location: **[Supply airstream] <Insert location>**.

Transference: Starter relay.

Output:

Device: Hard wired to motor controller**[ and DDC controller]**.

Location: Motor controller.

Input Transference: Starter relay.

Action:

Allow start if temperature is below **[120 deg F] <Insert temperature>**.

Signal alarm if fan fails to start as commanded.

"Enable" subparagraph below allows the fan to start when the duct is clear of smoke.

Enable:

Input:

Device: Smoke detector with auxiliary contact **[manual] [automatic]** reset.

Retain one of two "Location" subparagraphs below.

Location: Duct mounted **[before] [and] [after] [supply fan] [air-handling unit]**.

Location: Mounted in air-handling unit.

Transference: Starter relay.

Output:

Device: Hard wired.

Location: Motor controller.

Transference: Starter relay.

Output Device: Hard wired through motor controller; DDC controller alarm.

Action:

Allow start if airstream is free of products of combustion.

Signal alarm if fan fails to start as commanded.

"Supply Fan(s) Variable-Volume Control" paragraph below is for systems where the supply fans are installed in a variable-volume system.

* + - * 1. Supply Fan(s) Variable-Volume Control:

Fan Speed Control:

Input:

Device: Air pressure transmitter.

Location: Supply-duct static pressure referenced to ambient-space static pressure.

Transference: DDC controller.

Output:

Device: Analog output.

Transference: Variable-frequency motor controller.

Action:

Maintain constant supply-duct static-pressure set point of **<Insert value>**.

Set-Point Reset (for Systems with DDC of Individual Zone Terminals): Reset static-pressure set point based on the zone requiring the most pressure; reset set point lower until one zone damper is nearly wide open.

Set variable-frequency drive to minimum speed when fan is stopped.

Fan Airflow:

Input:

Device: Airflow **[sensor] [transmitter]**.

Location: Supply duct.

Transference: DDC controller.

Output:

Device: DDC controller.

Action: Report supply-duct airflow.

High Pressure:

Input:

Device: Air pressure switch.

Location: Supply duct referenced to outside the duct.

Transference: DDC controller.

Output:

Device: Binary output; DDC controller.

Transference: Starter relay; operator's workstation.

Action: When static pressure rises above excessive-static-pressure set point of **<Insert value>**:

Stop fan.

Signal alarm.

"Return Fan(s) Variable-Volume Control" paragraph below is for systems where the return fans are installed in a variable-volume system.

* + - * 1. Return Fan(s) Variable-Volume Control:

Retain first "Fan Speed Control" subparagraph below for systems equipped with flow measuring devices.

Fan Speed Control:

Input:

Device: Airflow **[sensor] [transmitter]**.

Location: Supply airstream and return airstream.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Variable-frequency drive.

Transference: Variable-frequency drive controller.

Action:

Maintain constant airflow offset between supply- and return-air fans.

Set variable-frequency drive to minimum speed when fan is stopped.

Retain "Fan Speed Control" subparagraph below for fans equipped with variable-speed drives.

Fan Speed Control:

Input:

Device: Air pressure **[sensor] [differential transmitter]**.

Location: Indoor space static pressure referenced to outdoor static pressure.

Transference: DDC controller.

Output:

Device: Analog output.

Transference: Variable-frequency motor controller.

Action:

Maintain constant indoor static-pressure set point of **[0.02-inch wg] <Insert value>** positive for outdoors.

Set variable-frequency drive to minimum speed when fan is stopped.

Action: Maintain constant indoor static pressure.

Retain "Preheat Coil" paragraph below for air-handling units that have a hydronic preheat coil with circulating pump.

* + - * 1. Preheat Coil:

Freeze Protection:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter] [Thermostat]**.

Location: After preheat coil.

Transference: **[DDC controller] [Starter relay]**.

Output:

Device: **[Binary output] [Hard wired]**.

Location: Motor controller.

Transference: Starter relay.

Action: Allow start if duct temperature is above **[33 deg F] <Insert temperature>**.

Low-Temperature Operation:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter] <Insert device>**.

Location: Outdoor air.

Transference: DDC controller.

Output Device:

Device: Binary output.

Location: Motor controller.

Transference: Starter relay.

Action:

Energize coil circulating pump(s) at outdoor-air temperatures below **[35 deg F] <Insert temperature>**.

**[Supply] [Discharge]**-Air Temperature:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: **[Supply] [Discharge]** airstream.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Control valve.

Transference: Control-valve actuator.

Action: Maintain air-temperature set point of **[55 deg F] <Insert temperature>**.

Retain "Mixed-Air Control" paragraph below for air-handling units that have a mixing section.

* + - * 1. Mixed-Air Control:

Minimum Position:

Retain first "Input" subparagraph below for mechanically fixed minimum position.

Input:

Device: DDC controller.

Location: Time schedule.

Transference: DDC controller.

Retain "Input" subparagraph below for measured airflow.

Input:

Device: Flow measuring station.

Location: Outdoor-air intake.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Outdoor damper.

Transference: Damper actuator(s).

Action:

Retain first subparagraph below for mechanically fixed minimum position; retain second subparagraph for measured airflow.

Open **[minimum outdoor-air dampers] [outdoor-air dampers to minimum position]**.

Modulate outdoor-air dampers to maintain minimum airflow at set point of **<Insert value>**.

Retain "Heating Reset" subparagraph below when the air-handling-unit is used to heat either during unoccupied hours (close dampers) or during the occupied hours (minimum position).

Heating Reset:

Input:

Device: DDC controller.

Location: Software.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Outdoor dampers.

Transference: Damper actuator(s).

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

Carbon Dioxide Reset:

Input:

Device: Carbon dioxide transmitter.

Location: Space.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Dampers.

Transference: Damper actuator(s).

Action: Reset minimum outdoor-air damper position to maintain carbon dioxide set point of **<Insert value>**.

**[Supply] [Mixed]**-Air Temperature:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: **[Supply-airstream] [Mixed-air plenum] <Insert location>**.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Damper section.

Transference: Damper actuator(s).

Action:

Modulate outdoor-, return-, and relief-air dampers to maintain air-temperature set point of **[55 deg F] <Insert temperature>**.

Do not enable control during morning warm-up period.

Cooling Reset:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter] [and moisture sensors and transmitters]**.

Location: Outdoor- and return-air ducts.

Input Transference: DDC controller.

Output:

Device: Analog output.

Location: Outdoor- and return-air ducts.

Transference: Damper actuator(s).

Action: Set outdoor-air dampers to minimum position when outdoor-air **[temperature exceeds return-air temperature] [enthalpy exceeds return-air enthalpy]**.

Retain "Humidifier" paragraph below for air-handling units that have a humidifier.

* + - * 1. Humidifier:

Input:

Device: Moisture sensor and transmitter.

Location: **[Return airstream] [Supply airstream] [Space] <Insert location>**.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Humidifier.

Transference: **[Valve actuator] [and] [pump]**.

Action:

**[Modulate humidity control valve] [Cycle humidifier pump] [Cycle humidifier pump and modulate humidity control valve].**

Retain subparagraph below for air-handling units that have equipment for humidity control.

Maintain humidity in straight-line relationship for the following conditions:

20 percent when outdoor-air temperature is **[minus 30 deg F] <Insert temperature>**.

40 percent when outdoor-air temperature is **[75 deg F] <Insert temperature>**.

Retain "Evaporative Cooler" paragraph below for air-handling units that have an evaporative cooler for cooling.

* + - * 1. Evaporative Cooler:

Temperature:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: **[Supply] [Discharge]** airstream.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Evaporative cooler.

Transference: **[Valve actuator] [and] [pump]**.

Action:

**[Modulate evaporative cooler control valve] [and] [cycle evaporative cooler pump]**.

Maintain air-temperature set point of **[55 deg F] <Insert temperature>**.

Humidity Limit:

Input:

Device: Moisture sensor and transmitter.

Location: **[Return airstream] [Supply airstream] [Space] <Insert location>**.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Evaporative cooler.

Transference: **[Valve actuator] [and] [pump]**.

Action:

Return **[humidity control valve] [humidifier pump] [humidifier pump and humidity control valve]** to their normal position.

Signal high humidity alarm.

* + - * 1. Filters:

Differential Pressure:

Input:

Device: Pressure differential **[switch] [transmitter]**.

Location: Filter bank.

Transference: DDC controller.

Output:

Device: DDC controller.

Location: DDC controller.

Transference: Operator's workstation.

Action: Signal alarm on **[low- and ]**high-pressure conditions.

Retain "(Hydronic) (Steam) Heating Coil" paragraph for air-handling units that have a hydronic or steam heating coil. or "Hydronic Cooling Coil" paragraph below for air-handling units that have a hydronic heating-coil and a coil circulating pump.

* + - * 1. **[Hydronic] [Steam]** Heating Coil:

**[Supply] [Discharge]**-Air Temperature:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: **[Supply] [Discharge]-air [duct] <Insert location>**.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Heating-coil control valve.

Input Transference: Normally **[open] [closed]** valve actuator.

Action:

Maintain supply-air-temperature set point of **[55 deg F] <Insert temperature>** by modulating heating-coil control valve.

Retain temperature reset in first subparagraph below for constant-temperature supply-air systems.

Maintain supply-air-temperature set point in straight-line relationship for the following conditions:

**[65 deg F] <Insert temperature>** when return-air temperature is **[70 deg F] <Insert temperature>**.

**[55 deg F] <Insert temperature>** when return-air temperature is **[75 deg F] <Insert temperature>**.

Maintain supply-air-temperature set point within limits in response to space temperature reset:

Minimum **[55 deg F] <Insert temperature>**.

Maximum **[131 deg F] <Insert temperature>**.

During morning warm-up period, maintain supply-air-temperature set point of **[80 deg F] <Insert temperature>**.

Retain "Space Temperature Reset" subparagraph below for multizone or dual-duct supply-air systems.

Space Temperature Reset:

Input:

Device: Space **[air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: Indoor spaces served by system.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Heating-coil control valve.

Input Transference: Normally **[open] [closed]** valve actuator.

Action:

Reset supply-air temperature in response to greatest heating demand.

Supply-Air-Temperature Reset: Reset the supply-air temperature to outdoor temperature at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.

Low-Temperature Operation:

Input Device:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter] <Insert device>**.

Location: Outdoor air.

Transference: DDC controller.

Output Device:

Device: Binary output.

Location: Motor controller.

Transference: Starter relay.

Action:

Energize coil circulating pump(s) at outdoor-air temperatures below **[35 deg F] <Insert temperature>**.

Retain "Hydronic Cooling Coil" paragraph below for air-handling units that have a cooling coil.

* + - * 1. Hydronic Cooling Coil:

**[Supply] [Discharge]**-Air Temperature:

Input:

Device: **[Air-temperature sensor] [or] [transmitter]**.

Location: **[Supply] [Discharge]**-air **[duct] <Insert location>**.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Cooling-coil valve.

Input Transference: Valve actuator.

Action:

Maintain supply-air-temperature set point of **[55 deg F] <Insert temperature>** by modulating cooling-coil control valve.

Maintain supply-air-temperature set point within limits in response to space temperature reset:

Minimum **[55 deg F] <Insert temperature>**.

Maximum **[68 deg F] <Insert temperature>**.

Supply-Air-Temperature Reset: Reset the supply-air temperature to outdoor temperature at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.

Retain "Temperature Reset" subparagraph below for constant-temperature systems.

Temperature Reset:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: Return-air **[duct] <Insert location>**.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Cooling-coil control valve.

Transference: Valve actuator.

Action: Reset supply-air temperature in straight-line relationship for the following conditions:

**[65 deg F] <Insert temperature>** when return-air temperature is **[70 deg F] <Insert temperature>**.

**[55 deg F] <Insert temperature>** when return-air temperature is **[75 deg F] <Insert temperature>**.

Action:

Reset supply-air temperature in response to greatest cooling demand.

Supply-Air-Temperature Reset: Reset the supply-air temperature to outdoor temperature at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.

Retain "Space Temperature Reset" subparagraph below for multizone or dual-duct supply-air systems.

Space Temperature Reset:

Input:

Device: Space **[air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: Spaces served by system.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Cooling coil.

Input Transference: Valve actuator.

Action:

Reset supply-air temperature in response to greatest cooling demand.

Supply-Air-Temperature Reset: Reset the supply-air temperature to outdoor temperature at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.

Retain "Space Humidity Reset" subparagraph below for dehumidification.

Space Humidity Reset:

Input:

Device: Humidity sensor and transmitter.

Location: Return-air **[duct] <Insert location>**.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Cooling-coil control valve.

Transference: Valve actuator.

Action: Reset supply-air temperature to **[55 deg F] <Insert temperature>** to maintain space relative humidity of **[45] <Insert number>** percent.

Retain "Multizone Damper Control" paragraph below for multizone air-handling-units.

* + - * 1. Multizone Damper Control:

Spaces Temperature:

Input Device:

Device: **[Air-temperature sensors] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: Spaces served by system.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Multizone head.

Transference: Damper actuators.

Action: Maintain the following space temperature set points:

Revise temperatures below to suit Project.

Occupied Cooling Temperature: **[75 deg F] <Insert temperature>**.

Occupied Heating Temperature: **[70 deg F] <Insert temperature>**.

Unoccupied Cooling Temperature: **[85 deg F] <Insert temperature>**.

Unoccupied Heating Temperature: **[65 deg F] <Insert temperature>**.

Retain "Coordination of Air-Handling Unit Sequences" paragraph below to ensure that individual sequences of operation are not taken in isolation but are integrated. For example, the intent is that a supply-air sensor for a preheat coil, mixed-air dampers, and cooling coil can be the same sensor; individual components are not required. Design system so that components are integrated.

* + - * 1. 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.
        2. Indicate the following on the operator's workstation display terminal:

DDC system graphic.

DDC system on-off indication (operating or not operating).

DDC system occupied/unoccupied mode.

Outdoor-air-temperature indication.

Supply-fan on-off indication (operating or not operating).

Supply duct static-pressure indication.

Supply duct static-pressure set point.

Supply-fan airflow rate.

Supply-fan speed.

Return-fan on-off indication (operating or not operating).

Space static-pressure indication.

Space static-pressure set point.

Return-fan airflow rate.

Return-fan speed.

Preheat-coil air-temperature indication.

Preheat-coil air-temperature set point.

Preheat-coil pump on-off indication (operating or not operating).

Preheat-coil control-valve position.

Mixed-air-temperature indication.

Mixed-air-temperature set point.

Mixed-air damper position.

Relative humidity indication.

Relative humidity set point.

Relative humidity control-valve position.

Filter air-pressure-drop indication.

Filter low-air-pressure drop set point.

Filter high-air-pressure drop set point.

[**Supply**] [**Discharge**]-air-temperature indication.

[**Supply**] [**Discharge**]-air-temperature set point.

Heating-coil leaving-air-temperature indication.

Heating-coil leaving-air-temperature set point.

Heating-coil pump on-off indication (operating or not operating).

Heating-coil control-valve position.

Hot-deck air-temperature indication.

Hot-deck air-temperature set point.

Cooling-coil leaving-air-temperature indication.

Cooling-coil leaving-air-temperature set point.

Cooling-coil control-valve position.

Cold-deck air-temperature indication.

Cold-deck air-temperature set point.

Space temperature indication.

Space temperature set point.

Multizone damper position.

* + - 1. TERMINAL UNIT OPERATING SEQUENCE
         1. Cabinet Unit Heater, [**Hydronic**] [**Steam**]:

Retain "Space Temperature" subparagraph below for electric controls.

Space Temperature:

Input:

Device: Line-voltage thermostat.

Location: Space.

Output:

Device: Hard wired.

Location: Motor controller.

Transference: Starter relay.

Action: Cycle fan to maintain [**75 deg F**] <**Insert value**> space temperature.

Retain "Space Temperature" subparagraph below for DDC.

Space Temperature:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: Occupied space.

Transference: DDC controller.

Retain one of two "Output Device" subparagraphs below. Retain first subparagraph for fan control; retain second for control valves.

Output Device:

Device: Binary output.

Location: Motor controller.

Transference: Starter relay.

Output Device:

Device: Analog output.

Location: Control valve.

Transference: Control-valve actuator.

Retain appropriate option in "Action" subparagraph below coordinated with "Output Device" subparagraph retained above.

Action: **[Cycle fan] [Modulate valve]** to maintain **[75 deg F] <Insert value>** space temperature.

Low-Temperature Safety:

Input Device: Line-voltage, on-off thermostat; mounted.

Device: Line-voltage thermostat.

Location: **[Return heating-water] [Condensate]** pipe.

Output Device:

Device: Hard wired.

Location: Motor controller.

Input Transference: Starter relay.

Action: Stop fan when **[return heating-water] [condensate] temperature falls below [35 deg F] <Insert temperature>**.

* + - * 1. Cabinet Unit Heater, Electric:

Input:

Device: Line-voltage thermostat.

Location: Occupied space.

Output:

Device: Hard wired.

Location: Motor-controller and heater relay.

Transference: Starter relay.

Action: Cycle fan to maintain **[75 deg F] <Insert value>** space temperature.

* + - * 1. Unit Heater, **[Hydronic] [Steam]**:

Space Temperature:

Input:

Device: Line-voltage thermostat.

Location: Space.

Output:

Device: Hard wired.

Location: Motor controller.

Transference: Starter relay.

Action: Cycle fan to maintain **[75 deg F] <Insert value>** space temperature.

Space Temperature:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: Space.

Transference: DDC controller.

Retain one of two "Output Device" subparagraphs below. Retain first subparagraph for fan control; retain second for control valves.

Output Device:

Device: Binary output.

Transference: Starter relay.

Output Device:

Device: Analog output.

Location: Control valve.

Transference: Control-valve actuator.

Retain appropriate option in "Action" subparagraph below coordinated with "Output Device" subparagraph retained above.

Action: **[Cycle fan] [Modulate valve]** to maintain **[**75 deg F**] <Insert value>** space temperature.

Low-Temperature Safety:

Input Device: Line-voltage, on-off thermostat; pipe mounted.

Device: Line-voltage thermostat.

Location: **[Return heating-water] [Condensate]** pipe.

Output Device:

Device: Hard wired.

Location: Motor controller.

Input Transference: Starter relay.

Action: Stop fan when **[return heating-water] [condensate] temperature falls below [35 deg F] <Insert temperature>**.

* + - * 1. Unit Heater, Electric: Space thermostat cycles fan and sequences stages of heating.

Space Temperature:

Input:

Device: Electric multistage thermostat.

Location: Space.

Output:

Device: Hard wired.

Location: Unit control panel.

Transference: Electric multistage contactors.

Action: Sequence electric coil stages to maintain **[75 deg F] <Insert value>** space temperature.

* + - * 1. Combustion-Air Unit Heaters:

Space Temperature:

Input:

Device: Thermostat.

Location: Space.

Output:

Device: Low-voltage wiring.

Location: Control valve.

Transference: Valve actuator.

Retain "Input" and "Output" subparagraphs above for thermostat control; retain "Input" and "Output" subparagraphs below for DDC.

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: Space.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Control valve.

Transference: Valve actuator.

Action: Modulate valve to maintain **[75 deg F] <Insert value>** space temperature.

* + - * 1. Radiant Heating Cable, Electric:

Space Temperature:

Input:

Device: Electric thermostat.

Location: Space.

Output:

Device: Line-voltage wiring.

Location: Junction box.

Transference: Cable.

Action: Cycle power to maintain **[75 deg F] <Insert value>** space temperature set point.

Retain sequence in "Radiant Heating Cable, Electric" paragraph above for line-voltage, electric control; retain sequence in "Radiant Heating Panel, Electric" paragraph below for pilot duty.

* + - * 1. Radiant Heating Panel, Electric:

Space Temperature:

Input:

Device: Electronic thermostat.

Location: Space.

Output:

Device: Low-voltage wiring.

Location: Junction box.

Transference: Line-voltage relay.

Action: Cycle power to maintain the following space temperature set points:

Occupied: **[75 deg F] <Insert temperature>**.

Unoccupied: **[65 deg F] <Insert temperature>**.

Radiant Heating Panel, Hydronic:

Space Temperature:

Input:

Device: Electronic thermostat.

Location: Space.

Output:

Device: Low-voltage wiring.

Location: Control valve.

Transference: Valve actuator.

Action: Cycle valve open and closed to maintain temperature set point.

Retain "Input," "Output," and "Action" subparagraphs above for thermostat control; retain "Input," "Output," and "Action" subparagraphs below for DDC.

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: Space.

Transference: DDC controller.

Output:

Device: DDC analog output.

Location: Control valve.

Transference: Valve actuator.

Action: Modulate valve to maintain the following space temperature set points:

Occupied: **[75 deg F] <Insert temperature>**.

Unoccupied: **[65 deg F] <Insert temperature>**.

* + - * 1. Two-Pipe, Single-Coil, Fan-Coil Unit:

Manual Start:

Input:

Device: Fan switch.

Location: Integral to thermostat.

Output:

Device: Hard wired.

Location: Motor controller.

Transference: Starter relay.

Action: Start and stop fan.

Space Temperature:

Input:

Device: Electronic thermostat.

Location: Space.

Output:

Device: Low-voltage wiring.

Location: Control valve.

Transference: Valve.

Action: Modulate valve to maintain the following space temperature set points:

Revise temperatures below to suit Project.

Occupied Cooling Temperature: **[75 deg F] <Insert temperature>**.

Occupied Heating Temperature: **[70 deg F] <Insert temperature>**.

Unoccupied Cooling Temperature: **[85 deg F] <Insert temperature>**.

Unoccupied Heating Temperature: **[65 deg F] <Insert temperature>**.

Occupied Time Schedule:

Input:

Device: DDC controller.

Location: Time schedule.

Transference: DDC controller.

Output:

Device: Binary output.

Location: Motor controller.

Transference: Starter relay.

Action: Start and stop fan.

Space Temperature:

Input:

Device: Air-temperature sensor.

Location: Space.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Control valve.

Transference: Valve actuator.

Action: Modulate valve to maintain the following space temperature set points:

Occupied: **[75 deg F] <Insert temperature>**.

Unoccupied: **[65 deg F] <Insert temperature>**.

System Changeover:

Input:

Device: Liquid temperature sensor **[or] [liquid temperature sensor with liquid transmitter]**.

Location: Supply-water piping.

Transference: DDC controller.

Output:

Device: Binary output.

Location: Control valve.

Transference: Valve actuator.

Action: Reverse control-valve action to switch from heating to cooling.

Fan-coil units in "Four-Pipe, Hydronic Fan-Coil Unit" paragraph below have a split coil, or two separate coils, where hot water or steam can be used for heating and chilled water for cooling.

* + - * 1. Four-Pipe, Hydronic Fan-Coil Unit:

Occupied Time Schedule:

Input:

Device: DDC controller.

Location: Time schedule.

Transference: DDC controller.

Output:

Device: Binary output.

Location: Motor controller.

Transference: Starter relay.

Action: Start and stop fan, and enable control.

Space Temperature:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: Space.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Control valve.

Transference: Valve actuators.

Action: Modulate control valves to maintain the following space temperature set points:

Revise temperatures below to suit Project.

Occupied Cooling Temperature: **[75 deg F] <Insert temperature>**.

Occupied Heating Temperature: **[70 deg F] <Insert temperature>**.

Unoccupied Cooling Temperature: **[85 deg F] <Insert temperature>**.

Unoccupied Heating Temperature: **[65 deg F] <Insert temperature>**.

Unit ventilator controls are usually packaged with units; if so, revise or delete "Unit Ventilator" paragraph below.

* + - * 1. Unit Ventilator:

Occupied Time Schedule:

Input:

Device: DDC controller.

Location: Time schedule.

Transference: DDC controller.

Output:

Device: Binary output.

Location: Fan motor controller and damper.

Transference: Starter relay and damper actuators.

Action: Start and stop fan, move outdoor- and return-air dampers to **[minimum] [maximum]** outdoor-air position, and enable control.

Space Temperature - Valves:

Input:

Device: **[Air-temperature sensor] [or] [transmitter]**.

Location: Space.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Control valve.

Transference: Valve actuator.

Action: Modulate heating-water control valve and chilled-water control valve in sequence to maintain the following space temperature set points:

Revise temperatures below to suit Project.

Occupied Cooling Temperature: **[75 deg F] <Insert temperature>**.

Occupied Heating Temperature: **[70 deg F] <Insert temperature>**.

Unoccupied Cooling Temperature: **[85 deg F] <Insert temperature>**.

Unoccupied Heating Temperature: **[65 deg F] <Insert temperature>**.

Space Temperature - Dampers:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature RTD transmitter]**.

Location: Mixed-air plenum.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Dampers.

Transference: Damper actuators.

Action: Modulate outdoor- and return-air dampers to maintain the following space temperature set points:

Revise temperatures below to suit Project.

Occupied Cooling Temperature: **[75 deg F] <Insert temperature>**.

Occupied Heating Temperature: **[70 deg F] <Insert temperature>**.

Unoccupied Cooling Temperature: **[85 deg F] <Insert temperature>**.

Unoccupied Heating Temperature: **[65 deg F] <Insert temperature>**.

Supply-Air-Temperature Limit:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: Discharge air.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Control valve and dampers.

Transference: Valve and damper actuators.

Action: Override space temperature set point to control valves and dampers to prevent discharge air from dropping below a minimum set point of **<Insert value>**.

Warm-up Cycle:

Input:

Device: DDC controller.

Location: Time schedule.

Input Transference: DDC controller.

Output:

Device: Analog output.

Location: Control valve and damper.

Transference: Valve and damper actuators.

Action: Open heating-water control valve, close outdoor-air damper, and open return-air damper.

In "Heating Coils, (Hydronic) (Steam)" paragraph below, both coil types are controlled in the same way.

* + - * 1. Heating Coils, **[Hydronic] [Steam]**:

Space Temperature:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: Space.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Control valve.

Transference: Valve actuator.

Action: Modulate valve to maintain the following space temperature set points:

Revise temperatures below to suit Project.

Occupied Cooling Temperature: **[75 deg F] <Insert temperature>**.

Occupied Heating Temperature: **[70 deg F] <Insert temperature>**.

Unoccupied Cooling Temperature: **[85 deg F] <Insert temperature>**.

Unoccupied Heating Temperature: **[65 deg F] <Insert temperature>**.

* + - * 1. Heating Coils, Electric:

Space Temperature:

Input:

Device: Electric thermostat.

Location: Space.

Transference: Low-voltage control.

Output:

Device: Pilot relays.

Location: Heating-coil electrical cabinet.

Transference: Line-voltage relays.

Action: Sequence stages of heating to maintain **[**75 deg F**] <Insert value>** space temperature.

* + - * 1. Radiators and Convectors, **[Hydronic] [Steam]**:

Occupancy:

Input:

Device: Occupancy sensor.

Location: Space.

Transference: DDC controller.

Output:

Device: DDC controller.

Action: Report occupancy and enable occupied temperature set point.

Space Temperature:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: Space.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Control valve.

Transference: Valve actuator.

Action: Modulate valve to maintain **[**75 deg F**] <Insert value>** space temperature set point.

Retain "Occupied Temperature" and "Unoccupied Temperature" subparagraphs below for DDC system control. Revise temperatures to suit Project.

Occupied Temperature: **[75 deg F] <Insert temperature>**.

Unoccupied Temperature: **[65 deg F] <Insert temperature>**.

* + - * 1. Radiators and Convectors, Electric:

Space Temperature:

Input:

Device: Electric thermostat.

Location: Space.

Transference: Low-voltage control.

Output:

Device: Pilot relays.

Location: Radiator electrical cabinet.

Transference: Line-voltage relays.

Action: Sequence stages of heating to maintain **[75 deg F] <Insert value>** space temperature set point.

* + - * 1. Constant-Volume, Terminal Air Units, **[Hydronic] [Steam]**:

Occupancy:

Input:

Device: Occupancy sensor.

Location: Space.

Transference: DDC controller.

Output:

Device: DDC controller.

Action: Report occupancy and enable occupied temperature set point.

Space Temperature:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: Space.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Control valve.

Transference: Valve actuator.

Action: Modulate valve to maintain the following space temperature set points:

Revise temperatures below to suit Project.

Occupied Cooling Temperature: **[75 deg F] <Insert temperature>**.

Occupied Heating Temperature: **[70 deg F] <Insert temperature>**.

Unoccupied Cooling Temperature: **[85 deg F] <Insert temperature>**.

Unoccupied Heating Temperature: **[65 deg F] <Insert temperature>**.

* + - * 1. Variable-Air-Volume Terminal Air Units with **[Hydronic] [Steam]** Coils:

Occupancy:

Input:

Device: Occupancy sensor.

Location: Space.

Transference: DDC controller.

Device: DDC controller.

Action: Report occupancy and enable occupied temperature set point.

Revise temperatures blow to suit Project.

Occupied Cooling Temperature: **[75 deg F] <Insert temperature>**.

Occupied Heating Temperature: **[70 deg F] <Insert temperature>**.

Unoccupied Cooling Temperature: **[85 deg F] <Insert temperature>**.

Unoccupied Heating Temperature: **[65 deg F] <Insert temperature>**.

Space Temperature:

Input:

Device: **[Air-temperature sensor] [or] [transmitter]**.

Location: Space.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Control damper and valve actuators.

Input Transference: Control damper and valves.

Action: Modulate damper and valve to maintain the following space temperature set points:

Revise temperatures below to suit Project.

Occupied Cooling Temperature: **[75 deg F] <Insert temperature>**.

Occupied Heating Temperature: **[70 deg F] <Insert temperature>**.

Unoccupied Cooling Temperature: **[85 deg F] <Insert temperature>**.

Unoccupied Heating Temperature: **[65 deg F] <Insert temperature>**.

Modulate damper actuator from full open to minimum position.

When damper is at minimum position, modulate reheat coil valve from closed to open.

If occupied space temperature is not maintained with valve open, modulate damper actuator from minimum position to **[100] <Insert number>** percent open.

Reverse the sequence for full heating to full cooling.

* + - * 1. Dual-Duct, Variable-Air-Volume Terminal Air Units:

Occupancy:

Input:

Device: Occupancy sensor.

Location: Space.

Transference: DDC controller.

Output:

Device: DDC controller.

Action: Report occupancy and enable occupied temperature set point.

Revise temperatures below to suit Project.

Occupied Temperature: **[75 deg F] <Insert temperature>**.

Unoccupied Temperature: **[65 deg F] <Insert temperature>**.

Space Temperature:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: Space.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Damper actuator(s).

Transference: Dampers.

Action: Modulate dampers to maintain the following space temperature set points:

Revise temperatures below to suit Project.

Occupied Cooling Temperature: **[75 deg F] <Insert temperature>**.

Occupied Heating Temperature: **[70 deg F] <Insert temperature>**.

Unoccupied Cooling Temperature: **[85 deg F] <Insert temperature>**.

Unoccupied Heating Temperature: **[65 deg F] <Insert temperature>**.

When occupied space temperature is below set point, close cold-deck damper to minimum position and open hot-deck damper.

When occupied space temperature is above set point, close hot-deck damper to minimum position and open cold-deck damper.

* + - * 1. Sequence Control:

Retain "Space Temperature" subparagraph below where several devices are sequenced from one control device. This example includes a reheat coil, occupied space finned-tube radiation, and a variable-air-volume cooling terminal, all of which are controlled from a unitary controller.

Space Temperature:

Input:

Device: **[Air-temperature sensor] [or] [air-temperature sensor with air-temperature RTD transmitter]**.

Location: Space.

Transference: DDC controller.

Output:

Device: Analog output.

Location: Control damper and valve actuators.

Input Transference: Control dampers and valves.

Action: Modulate valves and dampers to maintain the following space temperature set points:

Revise temperatures below to suit Project.

Occupied Cooling Temperature: **[75 deg F] <Insert temperature>**.

Occupied Heating Temperature: **[70 deg F] <Insert temperature>**.

Unoccupied Cooling Temperature: **[85 deg F] <Insert temperature>**.

Unoccupied Heating Temperature: **[65 deg F] <Insert temperature>**.

Modulate damper actuator from open to minimum position.

When damper is at minimum position, modulate finned-tube radiation valve from closed to fully open.

When finned-tube radiation valve is fully open, modulate reheat coil valve from closed to fully open.

If occupied space temperature is not maintained with both valves open, modulate damper actuator from minimum position to **[100] <Insert number>** percent open.

Reverse the sequence for full heating to full cooling.

* + - * 1. Indicate the following on the operator's workstation display terminal:

DDC system graphic.

DDC system on-off indication (operating or not operating).

DDC system occupied/unoccupied mode.

Outdoor-air-temperature indication.

Cabinet Unit Heater, Hydronic:

Space temperature indication.

Space temperature set point.

Fan on.

Unit Heater, Hydronic:

Space temperature indication.

Space temperature set point.

Fan on.

Combustion-Air Unit Heaters:

Space temperature indication.

Space temperature set point.

Control-valve position.

Radiant Heating Panel, Hydronic:

Space temperature indication.

Space temperature set point.

Control-valve position.

Two-Pipe, Single-Coil, Fan-Coil Unit:

Space temperature indication.

Space temperature set point.

Control-valve position.

Supply-water temperature indication.

Four-Pipe, Hydronic Fan-Coil Unit:

Space temperature indication.

Space temperature set point.

Control-valve position.

Unit Ventilator:

DDC system on-off indication (operating or not operating).

Space temperature indication.

Space temperature set point.

Control-valve position.

Damper position.

Heating Coils, Hydronic:

Space temperature indication.

Space temperature set point.

Control-valve position.

Radiators and Convectors, Hydronic:

Space/area served.

Space temperature indication.

Space temperature set point.

Space temperature set point, occupied.

Space temperature set point, occupied standby.

Space temperature set point, unoccupied.

Control-valve position as percentage open.

Constant-Volume, Terminal Air Units, Hydronic:

Space/area served.

Space occupied/unoccupied.

Space temperature indication.

Space temperature set point, occupied.

Space temperature set point, unoccupied.

Control-valve position as percentage open.

Variable-Air-Volume Terminal Air Units with Hydronic Coils:

Space/area served.

Space occupied/unoccupied.

Space temperature indication.

Space temperature set point.

Space cooling and heating temperature set point, occupied.

Space cooling and heating temperature set point, unoccupied.

Air-damper position as percentage open.

Control-valve position as percentage open.

Dual-Duct, Variable-Air-Volume Terminal Air Units:

Space/area served.

Space occupied/unoccupied.

Occupied space temperature indication.

Occupied space temperature set point, occupied.

Occupied space temperature set point, unoccupied.

Hot-deck damper position as percentage open.

Cold-deck damper position as percentage open.

Sequence Control:

Space/area served.

Space occupied/unoccupied.

Space temperature indication.

Space temperature set point, occupied.

Space temperature set point, unoccupied.

Damper position as percentage open.

Control-valve positions as percentage open.

* + - 1. VENTILATION SEQUENCES
         1. Combustion-Air, Makeup Unit Control, Electric:

Initiation:

Input:

Device: Auxiliary contact.

Location: Served appliance.

Output:

Device: Hard wired.

Location: Served appliance.

Transference: Starter relay and electric solenoid.

Action: Start fan when appliance burner starts.

Space Temperature:

Input:

Device: Electronic multistage thermostat.

Location: Space.

Output:

Device: Hard wired.

Location: Unit control panel.

Transference: Electric multistage contactors.

Action: Sequence electric coil stages to maintain **[75 deg F] <Insert value>** space temperature.

* + - * 1. Combustion-Air, Makeup Unit Control, **[Hydronic] [Steam]**:

Initiation:

Input:

Device: Auxiliary contact.

Location: Served appliance.

Output:

Device: Hard wired.

Location: Motor controller.

Transference: Starter relay and electric solenoid.

Action: Start fan when appliance burner starts.

Space Temperature:

Input:

Device: Electronic thermostat.

Location: Space.

Output:

Device: Hard wired.

Location: Control valve.

Transference: Valve actuator.

Action: Modulate control valve to maintain **[75 deg F] <Insert value>** space temperature set point.

* + - * 1. Gravity Roof Ventilator:

Input:

Device: **[Occupancy sensor] [Electric thermostat]**.

Location: Space.

Output:

Device: Hard wired.

Location: Control damper.

Transference: Damper actuator.

Action: Open control damper when space [**is occupied**] [**temperature rises above set point**].

* + - * 1. Exhaust Fan: **[Occupancy sensor] [Light switch] [Room thermostat]**.

Input:

Device: **[Occupancy sensor] [Light switch] [Electric thermostat]**.

Location: Space.

Output:

Device: Hard wired.

Location: Motor controller.

Transference: Starter relay.

Action: Cycle fan on when **[space is occupied] [lights are turned on] [space temperature rises above set point]**.

* + - * 1. Kitchen Exhaust Fan: Occupancy sensor.

Input:

Device: Occupancy sensor.

Location: Space.

Output:

Device: Hard wired.

Location: Motor controller.

Transference: Starter relay.

Action: Start fan and energize makeup air unit when space is occupied.

1. PRODUCTS (Not Applicable)
2. EXECUTION (Not Applicable)

END OF SECTION 230993.11