

# HVAC CONTROL SYSTEM PROJECT MANUAL

SCOPE OF WORK • SEQUENCES OF OPERATION • CONTROL POINTS

*For:*

## **Houston Community College HVAC System Replacement and Renovation Projects**

*Facilities:*

**HCC Spring Branch Campus**



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## **1-A. GENERAL HARDWARE NOTES**

- 1) Provide new programming, graphics, controllers, wiring, sensors, actuators, and other control devices as required to comply with the project specifications, control point lists, sequences of operation, and drawings. All equipment identified on the Equipment Control Lists in this project manual shall receive new controls.
- 2) If the facility has an existing control system, the new controllers, programming, graphics, etc. shall be fully integrated into the building's existing control system. If the facility does not have an existing control system, provide all new central infrastructure required to manage controllers and connect the new facility control system to the Owner's existing central control network. Refer to the Equipment Control List for existing control system information.
- 3) Provide proportional modulating-type actuators for all dampers/valves listed as an analog "AO" point type on the point lists (including those on VAV terminal units).
- 4) Provide pressure-independent control valves on chilled water and hot water coils. Pressure independent control valves shall automatically limit the maximum flow to within +/-5% of the design coil flow, independent of system pressure. The automatic flow control pressure regulator shall be a factory-set and field-replaceable cartridge, or an externally adjustable regulator with GPM-calibrated dial. Characterized ball valve-type or globe valve-type control valves may be used. Refer to coil connection details on the project drawings, and the specifications manual for more information.
- 5) New duct smoke detectors will be provided by the Mechanical Contractor for new equipment where required. Duct smoke detectors shall be directly interlocked with the associated system's fan motor starter/VFD or emergency stop contactor for automatic shutdown. The control system shall display an alarm indicating that an emergency shutdown has occurred (i.e. a "fan failure" alarm or discharge air temperature alarm).
- 6) Refer to the drawings for new motor starters and variable frequency drives to be provided by the Mechanical or Electrical Contractor.
- 7) Any existing control components including controllers, control valves, actuators, sensors, etc. that the Owner chooses to retain shall remain property of the Owner and shall be returned to the Owner immediately after removal for spare parts inventory. Any control components that the Owner does not wish to retain or recycle will be property of the Contractor
- 8) HVAC systems serving portable buildings and other small, remote buildings shall be provided with wireless controls, or shall access the control network through a wireless router to communicate with the nearest permanent main building controller. All remote HVAC systems shall be seamlessly controlled by the main building automation system. A separate control system shall not be allowed.
- 9) Control Wiring and Conduit:
  - A) All control wiring shall be continuous cable between connection points of new equipment, controllers, sensors, etc. Spliced wires will not be permitted. Provide a new

continuous cable if the existing is not long enough. Completely remove unused/abandoned control wiring, or cut back far enough to not be easily accessible on either end.

- B) Existing control wiring conduit (if present) may be re-used unless existing conduit is damaged or corroded, is not water-tight (exterior locations), or does not meet specification requirements.
  - C) Replace all existing flexible conduit for control wiring at connections to equipment located outdoors. If flexible conduit length exceeds 5 feet, provide new metal conduit to within 5 feet of the equipment connection.
  - D) Provide EMT or rigid metal conduit for all indoor control wiring, with the following exceptions:
    - a. Flexible conduit may be used within 5 feet of equipment connection point.
    - b. Conduit is not required for control wiring routed above ceilings or inside walls.
    - c. Control wiring in mechanical, electrical, telephone and data rooms with exposed structure may be installed without raceway where routed horizontally, tight to ceiling structure. Provide metal conduit drops down from the ceiling level to equipment or devices.
    - d. Architectural raceway may be used in occupied spaces where control wiring must be routed on a wall surface to zone sensors.
  - E) Refer to "Building Automation Systems" specification for additional control wiring installation requirements.
- 10) New controllers for packaged rooftop units may be installed inside the controls section of the rooftop unit. Controller enclosures are not required for HVAC equipment located above finished ceilings (e.g. VAV terminal units, split system AHUs).
- 11) All thermostats with push-button overrides or other occupant-adjustable controls will need to be located to comply with ADA mounting height requirements and project specifications.
- 12) Provide networking equipment where required to interface new controllers with the Owner's existing network server. New operator workstations or servers should not be required to operate the new control system.
- 13) Refer to project specification section 25 00 00 "Building Automation Systems", as well as the control point lists and control sequences of operation in this project manual for additional control system renovation requirements.

## **1-B. GENERAL SOFTWARE NOTES**

- 1) All equipment identified on the following pages is to be controlled by the new control system according to the sequence of operation specified for each.
- 2) An estimate of the required control points for each sequence of operation is provided in this project manual, but additional points and logic may be required so that the system functions as intended. The controls contractor's bid shall include all necessary control points and logic to operate equipment per the sequence of operation.
- 3) The term "User" in this document shall refer to the Building Owner/Operator, or any individual assigned with the system access permissions required to modify parameters such as setpoints, schedules, and overrides within the control system.
- 4) The User shall be able to define and assign a weekly time schedule to any equipment which is provided with enable/disable control or occupied/unoccupied mode control. The scheduling program shall also enable the User to assign temporary event or holiday schedules which are active for a defined period of calendar days, with the option to save the schedule for future use and automatically repeat the schedule for recurring events.
- 5) All control inputs, outputs, and setpoints shall be available for data-logging within User-defined parameters through the control system interface.
- 6) All setpoints, delays, alarm parameters, PID settings, etc. defined in the control system shall be adjustable by the User. The minimum required User-adjustable settings are noted as "(adj.)" in the sequence of operation for each equipment type.
- 7) All control outputs shall be provided with User-adjustable override or lockout controls.
- 8) The control system interface shall display status and setpoint values in the following default units unless otherwise noted:

Temperature: °F  
Relative Humidity: %RH  
Enthalpy: BTU/LB  
CO2 Concentration: PPM  
Static Pressure (Air): INCHES W.C.  
Water Pressure: PSI  
VFD Speed: Hz  
Valve and Damper Positions: % OPEN  
Air Flow: CFM  
Water Flow: GPM

## 2. LIST OF EQUIPMENT TO BE CONTROLLED PER EACH FACILITY

### A. SPRING BRANCH CAMPUS

#### HCC - SPRING BRANCH CAMPUS

Existing Control System: Andover Controls

Scope: Integrate all HVAC equipment listed below into the existing control system. Refer to the HVAC project drawings for equipment information and locations, and control schematic diagrams.

#### Facility Monitoring

TAG	CONTROL SEQUENCE
Outside Air Temperature and Humidity	3 : Facility Monitoring and References

- Provide new outdoor temperature and humidity sensors (replace existing sensors, if present)

#### Central Plant Equipment

TAG	SERVICE	CONTROL SEQUENCE
CHILLER-3	Chilled Water System	4 : Air-Cooled Chillers
CHILLER-4	Chilled Water System	4 : Air-Cooled Chillers
PCHWP-3	Chiller Primary Pump	5 : Variable Volume Primary CHW Pumps
PCHWP-4	Chiller Primary Pump	5 : Variable Volume Primary CHW Pumps
SCHWP-3	South Roof CHW Pump	6 : Variable Volume Secondary CHW Pumps
SCHWP-4	P.A. Bldg CHW Pump	6 : Variable Volume Secondary CHW Pumps
SCHWP-5	Science Bldg CHW Pump	6 : Variable Volume Secondary CHW Pumps
B-1	Hot Water System	7 : Natural Gas Boilers
HWP-1	Hot Water System	8 : Constant Volume Secondary HW Pumps
HWP-2	Hot Water System	8 : Constant Volume Secondary HW Pumps

#### Packaged Rooftop Units

TAG	SERVICE	CONTROL SEQUENCE	CO2 DCV	CO2 SENSOR LOC.	DEHUMIDIFICATION	RH SENSOR LOC.	ECONOMIZER	NOTES
RTU-1	Library	10 : CHW / Gas Heat Packaged SZ VAV RTU	NO	N / A	REHEAT	ZONE	YES	1
RTU-2	South Classrooms	9 : CHW / Gas Heat Packaged SZ CV RTU	NO	N / A	REHEAT	RETURN DUCT	YES	1
RTU-3	South Classrooms	9 : CHW / Gas Heat Packaged SZ CV RTU	NO	N / A	REHEAT	RETURN DUCT	YES	1
RTU-4	South Classrooms	9 : CHW / Gas Heat Packaged SZ CV RTU	NO	N / A	REHEAT	RETURN DUCT	YES	1
RTU-5	South Classrooms	11 : CHW / Gas Heat Packaged RTU w/ ERV	NO	N / A	REHEAT	RETURN DUCT	YES	1
RTU-6	South Classrooms	11 : CHW / Gas Heat Packaged RTU w/ ERV	NO	N / A	REHEAT	RETURN DUCT	YES	1
RTU-7	South Classrooms	9 : CHW / Gas Heat Packaged SZ CV RTU	NO	N / A	REHEAT	RETURN DUCT	YES	1
RTU-8	South Classrooms	11 : CHW / Gas Heat Packaged RTU w/ ERV	NO	N / A	REHEAT	RETURN DUCT	YES	--
RTU-9	Electrical / Storage	13 : DX Packaged RTU (Gas Heat)	NO	N / A	NO	N / A	YES	--
PA RTU-1	Stage	10 : CHW / Gas Heat Packaged SZ VAV RTU	NO	N / A	REHEAT	ZONE	YES	--
PA RTU-2	Auditorium Seating	11 : CHW / Gas Heat Packaged RTU w/ ERV	YES	ZONE	REHEAT	ZONE	YES	--
PA RTU-3	Stage	10 : CHW / Gas Heat Packaged SZ VAV RTU	NO	N / A	REHEAT	ZONE	YES	--
PA RTU-4	Auditorium Seating	11 : CHW / Gas Heat Packaged RTU w/ ERV	YES	ZONE	REHEAT	ZONE	YES	--
PA RTU-5	Audio/Video Production	12 : CHW / Gas Heat Packaged MZ VAV RTU	YES	RETURN DUCT	NO	N / A	YES	--
PA RTU-6	Front Lobby / Classrooms	12 : CHW / Gas Heat Packaged MZ VAV RTU	YES	RETURN DUCT	NO	N / A	YES	--
PA RTU-7	Dance / Theater CRs	12 : CHW / Gas Heat Packaged MZ VAV RTU	YES	RETURN DUCT	NO	N / A	YES	--

#### NOTES:

(1) PROVIDE MULTIPLE TEMPERATURE SENSORS FOR AVERAGING CONTROL, REFER TO "MAIN BUILDING SOUTH AREA TEMPERATURE SENSOR PLAN" DRAWING.

#### Hydronic Fan Coil Units

TAG	SERVICE	CONTROL SEQUENCE	OA DAMPER	CO2 DCV	DEHUMIDIFICATION	ECONOMIZER
SCI OAHU-1	Science - Outside Air	15 : Hydronic Outside Air Handling Unit	2-POSITION	NO	NO	NO
SCI OAHU-2	Science - Outside Air	15 : Hydronic Outside Air Handling Unit	2-POSITION	NO	NO	NO
SCI AHU-3	Science - Biology CR	14 : Hydronic Fan Coil Unit	2-POSITION	NO	HW REHEAT	NO
SCI AHU-4	Science - Classroom	14 : Hydronic Fan Coil Unit	2-POSITION	YES	HW REHEAT	NO
SCI AHU-5	Science - Biology CR	14 : Hydronic Fan Coil Unit	2-POSITION	NO	HW REHEAT	NO
SCI AHU-6	Science - Biology Prep.	14 : Hydronic Fan Coil Unit	2-POSITION	NO	HW REHEAT	NO
SCI AHU-7	Science - Chemistry CR	14 : Hydronic Fan Coil Unit	2-POSITION	NO	HW REHEAT	NO
SCI AHU-8	Science - Chemistry Prep.	14 : Hydronic Fan Coil Unit	2-POSITION	NO	HW REHEAT	NO
SCI AHU-9	Science - Corridors	14 : Hydronic Fan Coil Unit	2-POSITION	NO	HW REHEAT	YES
SCI AHU-10	Science - Biology CR	14 : Hydronic Fan Coil Unit	2-POSITION	NO	HW REHEAT	NO
SCI AHU-11	Science - Chemistry CR	14 : Hydronic Fan Coil Unit	2-POSITION	NO	HW REHEAT	NO
SCI AHU-12	Science - Classroom	14 : Hydronic Fan Coil Unit	2-POSITION	YES	HW REHEAT	NO
SCI AHU-13	Science - Classroom	14 : Hydronic Fan Coil Unit	2-POSITION	YES	HW REHEAT	NO
SCI AHU-14	Science - Classroom	14 : Hydronic Fan Coil Unit	2-POSITION	YES	HW REHEAT	NO



**DX Split Systems**

<b>TAG</b>	<b>SERVICE</b>	<b>CONTROL SEQUENCE</b>	<b>OA DAMPER</b>	<b>CO2 DCV</b>	<b>DEHUMIDIFICATION</b>	<b>ECONOMIZER</b>
CU/AHU-306	Main Bldg CR 306	16 : DX Split System Heat Pump	2-POSITION	NO	NO	NO
CU/AHU-B1	Bookstore	16 : DX Split System Heat Pump	2-POSITION	NO	NO	NO
CU/AHU-B2	Bookstore	16 : DX Split System Heat Pump	2-POSITION	NO	NO	NO
CU/AHU-1H	Honors Lounge	16 : DX Split System Heat Pump	2-POSITION	NO	NO	NO
CU/AHU-F1	Faculty Offices	16 : DX Split System Heat Pump	2-POSITION	NO	NO	NO
CU/AHU-F2	Faculty Offices	16 : DX Split System Heat Pump	2-POSITION	NO	NO	NO
CU/AHU-C1	Commons	16 : DX Split System Heat Pump	2-POSITION	NO	NO	NO
CU/AHU-C2	Commons	16 : DX Split System Heat Pump	2-POSITION	NO	NO	NO
CU/AHU-C3	Commons	16 : DX Split System Heat Pump	2-POSITION	NO	NO	NO
CU/AHU-C4	Commons	16 : DX Split System Heat Pump	2-POSITION	NO	NO	NO

### **3. FACILITY MONITORING AND REFERENCES**

- 1) Outside Air Conditions:
  - a. The control system shall monitor the outside air temperature and humidity, and calculate the outside air enthalpy. These values will be representative of the current outdoor air conditions at the building location and shall be made available to other equipment control sequences where required.
  - b. Alarms shall be generated as follows:
    - i. Outdoor Sensor Failure: Sensor reading indicates shorted or disconnected sensor. In the event of a sensor failure, an alternate outside air conditions status from the district control network shall be made available to the system without interruption to control sequences.



#### **4. AIR-COOLED CHILLERS**

- 1) Run Conditions:
  - a. The chiller plant shall be enabled to run upon receiving 1 (adj.) or more occupied zone cooling requests, or 3 (adj.) or more unoccupied zone cooling requests.
  - b. The chiller plant may also be commanded to run by a User-defined time schedule; however, the time schedule shall not prevent the chiller plant from running if the required number of cooling requests are received while the plant is scheduled off.
  - c. After being enabled by the time schedule, the chiller and chilled water pumps shall stop if no chilled water coils have requested cooling for a period of 1 hour (adj.). The chiller and chilled water pumps shall re-start if 1 (adj.) or more chilled water coils request cooling AND the chiller is still enabled by the time schedule.
  - d. The chiller plant shall have an outside ambient temperature lockout preventing it from operating while the outside temperature is less than an adjustable value, unless the pumps are called to run for freeze protection.
  - e. To prevent short cycling, the chiller shall be enabled for and be disabled for a minimum period of 10 minutes each (adj.), unless shutdown on safeties.
  - f. Each chiller shall run subject to its own internal safeties and controls.
  - g. Alarms shall be provided as follows:
    - i. Chiller Failure: The chiller status is off 2 minutes (adj.) after being commanded on.
    - ii. Chiller Running in Hand: The chiller status is on 2 minutes (adj.) after being commanded off.
    - iii. Chiller Runtime Exceeded: Status runtime exceeds a User definable limit.
- 2) Chiller Start / Stop Sequence
  - a. When the chilled water system is activated, the control system will first open the lead chiller isolation valve and start the associated primary chilled water pump. After the pump status has been 'ON' for 2 minutes (adj.) the lead chiller will be commanded to start. The chiller will operate by its own internal controls to maintain the leaving water temperature at setpoint.

- b. If the lead chiller or associated primary chilled water pump fail to start, the chiller failure or pump failure alarm will be triggered. The lead chiller and associated pump will be deactivated, and the lag chiller and associated pump will attempt to start in the same sequence as the lead chiller and pump.
  - c. Increment State - The lag chiller and pump shall be activated to meet increasing cooling demand or flow if:
    - i. The chilled water supply temperature is 2°F (adj.) above setpoint for more than 15 minutes (adj.).
    - ii. OR, the primary chilled water pump is operating at maximum speed AND the bypass differential pressure is below -2 psid (adj.) AND the chiller entering/leaving water temperature differential is greater than 6°F (adj.). Refer to the “Variable Volume Primary Chilled Water Pumps” sequence for bypass differential pressure measurement.
  - d. Decrement State – The lag chiller and pump shall be deactivated due to decreasing cooling demand or flow if:
    - i. The chiller entering/leaving water temperature differential is less than 6°F (adj.) for more than 15 minutes (adj.).
    - ii. OR, the primary chilled water pumps are operating at minimum speed AND the chiller entering/leaving water temperature differential is less than 12°F (adj.).
  - e. There shall be a delay of 15 minutes (adj.) after incrementing or decrementing states before the state is allowed to change again.
  - f. When chillers are deactivated, the control system will stop the chiller(s). After the chiller has status has been ‘OFF’ for 2 minutes (adj.) the control system will stop the primary chilled water pump(s) and close the chiller isolation valve(s).
- 3) Chiller Lead/Lag Operation: The designated lead chiller shall rotate upon one of the following conditions (User-selectable):
- i. Manually through a software switch.
  - ii. If runtime hours (adj.) are exceeded.
  - iii. Daily, weekly, or monthly.
- 4) Chiller Controller Interface: The chiller manufacturer shall provide a BACnet interface which allows the following control or monitoring points:
- a. Chiller enable / disable.

- b. Chiller supply water temperature setpoint.
  - c. Chiller status and/or percent output.
  - d. Individual compressor statuses.
  - e. Chiller alarm status.
- 5) Chilled Water Temperature Monitoring:
- a. The entering water temperature and leaving water temperature of each chiller shall be monitored.
  - b. Alarms shall be provided as follows:
    - i. Low Chiller Leaving Water Temp: The chiller leaving water temperature is less than 38°F (adj.) while the chiller is running. Disable the chiller until the alarm is manually reset. Continue to run the chilled water pump until the leaving water temperature rises above 40°F (adj.).
    - ii. High Chiller Leaving Water Temp: The chiller leaving water temperature is greater than 55°F (adj.) for 15 minutes (adj.) while the chiller is running.
- 6) Chilled Water Supply Temperature Setpoint Reset: The chilled water supply temperature setpoint shall be allowed to reset based on a correlation to the outside ambient temperature. The chilled water supply temperature setpoint shall incrementally increase from a minimum setpoint of 44°F (adj.) at 80°F (adj.) OAT, up to a maximum of 48°F (adj.) at 40°F (adj.) OAT.

## Air-Cooled Chiller Points Summary

*Typical of Each*

Point Name	Point Type				Show on Graphic
	AI	DI	AO	DO	
Chiller Leaving Water Temp.	X				X
Chiller Entering Water Temp.	X				X
CHW Supply Temp Setpoint			X		X
Chiller Iso. Valve Open/Close				X	X
Chiller Enable/Disable				X	X
Chiller % Full Load	X				X
Compressor Status (each)		X			X
Chiller Alarm		X			X
<b>Totals</b>	<b>3</b>	<b>2</b>	<b>1</b>	<b>2</b>	
	<b>8</b>				

Additional Settings and Statuses to Show on Graphic
Current Number of Cooling Requests
Current Schedule Status (Enabled or Disabled)
Active Program Overrides
Active Alarms

Alarms
High Chiller Leaving Water Temperature
Low Chiller Leaving Water Temperature
Chiller Failure
Chiller Running in Hand
Chiller Runtime Exceeded
Chiller Internal Alarm

Adjustable Control Settings (At Minimum)	Initial Setting
Occupied Zone Cooling Requests to Enable	1 or more
Unoccupied Zone Cooling Requests to Enable	3 or more
Chilled Water Supply Temperature Setpoint	44°F
CHW Supply Temperature Setpoint Reset Settings	SEE SEQUENCE
Chiller Plant Increment State Requirements	SEE SEQUENCE
Chiller Plant Decrement State Requirements	SEE SEQUENCE
Chiller Start Delay Time	2 minutes
Chiller Stop Delay Time	0 minutes
Chiller Isolation Valve Open Delay Time	0 minutes
Chiller Isolation Valve Close Delay Time	2 minutes
Minimum Chiller Run Time / Off-Time	10 minutes
If scheduled, but 0 clg requests, stop chiller plant after:	1 hour
No. of Clg Requests Req. to Restart Scheduled Operation	1
Lead Chiller Selection Settings	Daily Rotation
OAT Lockout	Not set

## **5. VARIABLE VOLUME PRIMARY CHILLED WATER PUMPS**

- 1) Run Conditions:
  - a. Each primary chilled water pump shall be controlled to run anytime the associated chiller is called to run.
  - b. Each primary chilled water pump shall run for freeze protection anytime the outside air temperature is less than 35°F (adj.). The chiller isolation valves must be commanded to open any time the pumps are commanded to run.
  - c. Alarms shall be provided as follows:
    - i. Pump Failure: The pump status is off 2 minutes (adj.) after being commanded on.
    - ii. Pump Running in Hand: The pump status is on 2 minutes (adj.) after being commanded off.
    - iii. Pump Runtime Exceeded: Status runtime exceeds a User-definable limit.
    - iv. Pump VFD Fault: Pump VFD is reporting an error.
- 2) Primary Chilled Water Pump Start / Stop Sequence
  - a. Refer to the chiller sequence of operation for pump start/stop sequencing.
  - b. Each pump shall have a User-adjustable delay on stop. The pump shall continue to run for 2 minutes (adj.) after the chiller status is proven off.
- 3) Primary Chilled Water Pump Variable Speed Control:
  - a. The primary/secondary bypass differential pressure shall be monitored. The primary pump speed shall be controlled to maintain the bypass at the differential pressure setpoint. The differential pressure setpoint shall be 0 psid (adj.), equivalent to zero flow through the bypass under normal operating conditions. Refer to the bypass control section for more information.
  - b. If the bypass differential pressure is higher on the chilled water supply side (positive differential), then the primary flow is greater than the secondary flow. Reduce the primary pump speed until the differential pressure reaches setpoint, or the pumps are operating at the minimum speed setpoint.
  - c. If the bypass differential pressure is higher on the chilled water return side (negative differential), then the primary flow is less than the secondary flow. Increase the primary pump speed until the differential pressure reaches setpoint, or the pumps are operating at the maximum speed setpoint.

- d. If both primary chilled water pumps are operating simultaneously, control both pumps to operate at the same speed.
  - e. The primary pump speed shall be controlled between a maximum frequency of 60 HZ (adj.) and a minimum of 30 HZ (adj.), unless noted otherwise. The test and balance contractor may adjust the minimum and maximum VFD frequency setpoints as necessary to achieve the design minimum and maximum flow rates required by the design documents and chiller manufacturer.
- 4) Pump Differential Pressure Monitoring:
- a. The control system shall monitor the differential pressure between the pump suction and discharge.
  - b. Alarms shall be provided as follows:
    - i. High Pump Differential Pressure: The pump differential pressure is equivalent to the pump dead-head pressure (adj.). Refer to manufacturer's pump curve and test and balance contractor measurements.
- 5) Bypass Control:
- a. The bypass isolation valve shall remain fully closed during normal operating conditions so that the primary pumps operate in series with the secondary pumps.
  - b. The bypass isolation valve shall fully open if ALL the following conditions are met:
    - i. Only one primary chilled water pump is running.
    - ii. AND, the primary chilled water pump is operating at the minimum speed setpoint.
    - iii. AND, the bypass differential pressure rises above setpoint by more than 0.5 psid (adj.), indicating that the primary flow is greater than the secondary flow.
  - c. Once open, the bypass isolation valve shall only close if the primary chilled water pump speed rises above the minimum speed setpoint by more than 1 Hz (adj.) for a period of 5 minutes (adj.).

## Variable Volume Primary CHW Pump Points Summary

*Typical of Each*

Point Name	Point Type				Show on Graphic
	AI	DI	AO	DO	
Bypass Differential Pressure	X				X
Bypass Isolation Valve				X	X
Pump Differential Pressure	X				X
Pump Start/Stop				X	X
Pump VFD Speed			X		X
Pump Amps / Run Status	X				X
Pump VFD Fault		X			X
<b>Totals</b>	<b>3</b>	<b>1</b>	<b>1</b>	<b>2</b>	
	<b>7</b>				

Additional Settings and Statuses to Show on Graphic
Current Differential Pressure Setpoint
Active Program Overrides
Active Alarms

Alarms
High Pump Differential Pressure
Pump Failure
Pump Running in Hand
Pump Runtime Exceeded
Pump VFD Fault

Adjustable Control Settings (At Minimum)	Initial Setting
Bypass Differential Pressure Setpoint	0 psid
Maximum Pump VFD Speed	60 Hz
Minimum Pump VFD Speed	30 Hz
Start Delay Time	0 minutes
Stop Delay Time	2 minutes
Minimum Run Time / Off-Time	Not set
Freeze Protection Enable	Below 35°F

## **6. VARIABLE VOLUME SECONDARY CHILLED WATER PUMPS**

- 1) Run Conditions:
  - a. The secondary chilled water pump shall be controlled to run anytime the chiller plant is enabled AND one or more chilled water coils served by the pump is requesting cooling.
  - b. The secondary chilled water pump shall stop when the chiller plant is disabled, OR all chilled water coils served by the pump are 0% open.
  - c. The secondary chilled water pump shall run for freeze protection anytime the outside air temperature is less than 35°F (adj.).
  - d. To prevent short cycling, the pumps shall be enabled for and be disabled for a minimum period of 10 minutes each (adj.).
  - e. If twin pumps are provided for redundancy:
    - i. Only one pump will be allowed to operate at a time.
    - ii. An output transfer switch shall be provided by the VFD manufacturer to allow the control system to transfer power from one pump to the other. During the transfer process, the VFD output will be fully stopped before switching from one motor to the other. After the switching operation has completed, the VFD will resume normal operation.
    - iii. Pump Lead/Lag Operation: The designated lead pump shall rotate upon one of the following conditions (User-selectable):
      - A. Manually through a software switch.
      - B. If runtime hours (adj.) are exceeded.
      - C. Daily, weekly, or monthly.
    - iv. If the designated lead pump fails to start, the pump failure alarm will be triggered, and the control system will attempt to start the lag pump.
  - f. Alarms shall be provided as follows:
    - i. Pump Failure: The pump status is off 2 minutes (adj.) after being commanded on.
    - ii. Pump Running in Hand: The pump status is on 2 minutes (adj.) after being commanded off.



- iii. Pump Runtime Exceeded: Status runtime exceeds a User-definable limit.
- iv. Pump VFD Fault: Pump VFD is reporting an error.

2) Secondary Loop Pressure Control:

- a. The chilled water supply and return differential pressure shall be monitored near the end of the main loop (refer to drawings). The secondary pump speed shall be controlled to maintain the differential pressure at setpoint.
- b. The differential pressure setpoint shall be determined by the test and balance contractor to achieve design flow through all coils simultaneously while maintaining a minimum of 5 psid across the control valves. Refer to the chilled water piping schematic drawing for dP setpoint estimates.
- c. A control sequence shall be provided to reset the differential pressure setpoint using a trim and respond algorithm based on cooling coil valve positions as follows:
  - i. If all chilled water coil valves are at a position of 80% open (adj.) or less, the differential pressure setpoint shall incrementally decrease until one or more valves reach a position of 90% open (adj.). The minimum differential pressure shall be 5 psid (adj.).
  - ii. If 2 (adj.) or more chilled water coil valves are at a position of 100%, the differential pressure setpoint shall incrementally increase until all valves are at a position of 90% open (adj.) or less, up to the default differential pressure setpoint determined by test and balance.
- d. The secondary pump speed shall be controlled between a maximum frequency of 60 Hz (adj.) and a minimum of 0 Hz (adj.). The test and balance contractor may adjust the maximum VFD frequency setpoint as necessary to achieve the design maximum flow rate required by the design documents.
- e. If all cooling coil valves are 0% open, the pump shall stop.
- f. Alarms shall be provided as follows:
  - i. High System Differential Pressure: The chilled water system differential pressure is 25% (adj.) greater than setpoint.
  - ii. Low System Differential Pressure: The chilled water system differential pressure is 25% (adj.) less than setpoint.

- 3) Pump Differential Pressure Monitoring:
  - a. The control system shall monitor the differential pressure between the pump suction and discharge.
  - b. Alarms shall be provided as follows:
    - i. High Pump Differential Pressure: The pump differential pressure is equivalent to the pump dead-head pressure (adj.). Refer to manufacturer's pump curve and test and balance contractor measurements.
  
- 4) Chilled Water Temperature Monitoring:
  - a. The secondary loop chilled water supply and return temperatures shall be monitored at the entrance to the building or near the secondary chilled water pump.
  - b. Alarms shall be provided as follows:
    - i. High Chilled Water Supply Temp: The temperature of the chilled water supply to the building is greater than 55°F (adj.) for 15 minutes (adj.) while the chiller is running.

## Variable Volume Secondary CHW Pump Points Summary

*Typical of Each*

Point Name	Point Type				Show on Graphic
	AI	DI	AO	DO	
Loop Differential Pressure	X				X
Building CHWS Temperature	X				X
Building CHWR Temperature	X				X
Pump A Differential Pressure	X				X
Pump B Differential Pressure	X				X
Pump Transfer Switch				X	X
Pump Start/Stop				X	X
Pump VFD Speed			X		X
Pump Amps / Run Status	X				X
Pump VFD Fault		X			X
<b>Totals</b>	<b>6</b>	<b>1</b>	<b>1</b>	<b>2</b>	
	<b>10</b>				

Adjustable Control Settings (At Minimum)	Initial Setting
System Differential Pressure Setpoint	SET BY T&B
Minimum Reset Differential Pressure	5 psid
Maximum Pump VFD Speed	60 Hz
Minimum Pump VFD Speed	0 Hz
Start Delay Time	0 minutes
Stop Delay Time	0 minutes
Minimum Run Time / Off-Time	10 minutes
Lead Pump Selection Settings	Daily Rotation
Freeze Protection Enable	Below 35°F

Additional Settings and Statuses to Show on Graphic
Current Differential Pressure Setpoint
Current Number of Cooling Requests
Active Program Overrides
Active Alarms

Alarms
High System Differential Pressure
Low System Differential Pressure
High Pump Differential Pressure
High Chilled Water Supply Temperature (Building)
Pump Failure
Pump Running in Hand
Pump VFD Fault
Pump Runtime Exceeded

## 7. NATURAL GAS BOILERS

- 1) Run Conditions:
  - a. The boiler plant shall be enabled to run upon receiving 1 (adj.) or more occupied zone heating requests, or 1 (adj.) or more unoccupied zone heating requests.
  - b. The boiler plant may also be commanded to run by a User-defined time schedule; however, the time schedule shall not prevent the boiler plant from running if the required number of heating requests are received while the plant is scheduled off.
  - c. The boiler plant shall have an outside ambient temperature lockout preventing it from operating while the outside temperature is greater than 70°F (adj.) unless there is a call for dehumidification reheat.
  - d. The boiler plant shall be enabled for freeze protection whenever the outside ambient temperature is less than 35°F (adj.).
  - e. To prevent short cycling, the boilers shall be enabled for and be disabled for a minimum period of 10 minutes each (adj.), unless shutdown on safeties.
  - f. The boilers shall operate subject to their own internal safeties and controls.
  - g. Alarms shall be provided as follows:
    - i. Boiler Alarm: Boiler is reporting an internal alarm.
- 2) Boiler Start / Stop Sequence:
  - a. When the boiler plant is activated, the control system will start the lead hot water pump (serving the secondary loop to the building) and enable the boiler. **The boiler's internal factory-installed controller** will start the boiler pump (primary pump). The boiler will operate according to its own internal controls to maintain the hot water supply temperature at setpoint.
  - b. If the boiler entering water temperature is below 120°F when the boiler is commanded to start, the cold start bypass valve shall be commanded open **by the boiler's internal factory-installed controller** to recirculate warm water to the boiler inlet. The bypass valve position shall be controlled to maintain the boiler entering water temperature at 120°F or greater. After the hot water system has reached operating temperature, the bypass valve shall remain fully closed.
  - c. When the hot water system is deactivated, the control system will disable the boilers. After the boilers have been commanded OFF for 5 minutes (adj.) the control system will stop the secondary loop hot water pump.

- 3) **Boiler Controller Interface:** The boiler manufacturer shall provide a BACnet interface which allows the following control or monitoring points:
  - a. Boiler enable / disable.
  - b. Boiler supply water temperature setpoint.
  - c. Boiler burner status and/or percent output.
  - d. Boiler alarm status.
  
- 4) **Hot Water Supply Temperature Setpoint:**
  - a. The design hot water supply temperature setpoint is 180°F (adj.).
  - b. A setpoint reset sequence shall be provided. The hot water supply temperature setpoint will incrementally increase from a minimum setpoint of 140°F (adj.) at 65°F (adj.) outside ambient, up to a maximum of 180°F (adj.) at 40°F (adj.) outside ambient.
  
- 5) **Boiler Pump Status Monitoring:** The boiler pump run status shall be monitored.
  
- 6) **Hot Water Temperature Monitoring:**
  - a. The supply and return water temperatures of the building loop shall be monitored.
  - b. The entering and leaving water temperature of each boiler shall be monitored.
  - c. Alarms shall be provided as follows:
    - i. **Boiler Low Leaving Water Temp:** The boiler leaving water temperature is less than 100°F (adj.) for 15 minutes (adj.) while the boiler is enabled.
    - ii. **Boiler High Leaving Water Temp:** The boiler leaving water temperature is greater than 200°F (adj.). Disable the boiler until the alarm is manually reset. Continue to run the hot water loop pump until the hot water temperature drops below 180°F (adj.).

## Natural Gas Boiler Points Summary

*Typical of Each*

Point Name	Point Type				Show on Graphic
	AI	DI	AO	DO	
Building HWS Temperature	X				X
Building HWR Temperature	X				X
Boiler Leaving Water Temp.	X				X
Boiler Entering Water Temp.	X				X
HW Supply Temp Setpoint			X		X
Boiler Enable/Disable				X	X
Burner Output %	X				X
Boiler Alarm Status		X			X
Boiler Pump Run Status		X			X
<b>Totals</b>	<b>5</b>	<b>2</b>	<b>1</b>	<b>1</b>	
	<b>9</b>				

Additional Settings and Statuses to Show on Graphic
Current Number of Heating Requests
Current Schedule Status (Enabled or Disabled)
Active Program Overrides
Active Alarms

Alarms
High Boiler Leaving Water Temperature
Low Boiler Leaving Water Temperature
Boiler Internal Alarm

Adjustable Control Settings (At Minimum)	Initial Setting
Occupied Zone Heating Requests to Enable	1 or more
Unoccupied Zone Heating Requests to Enable	1 or more
Hot Water Supply Temperature Setpoint	180°F
HW Supply Temperature Setpoint Reset Settings	SEE SEQUENCE
Boiler Enable Delay Time	0 minutes
Boiler Disable Delay Time	0 minutes
Minimum Boiler Run Time / Off-Time	10 minutes
Outside Ambient Temperature Lockout	Above 70°F
Freeze Protection Enable	Below 35°F

## **8. CONSTANT VOLUME SECONDARY HOT WATER PUMPS**

- 1) Run Conditions:
  - a. The lead hot water system pump shall be controlled to run anytime the boiler plant is enabled.
  - b. The pump shall run for freeze protection anytime the outside air temperature is less than 35°F (adj.).
  - c. Alarms shall be provided as follows:
    - i. Pump Failure: The pump status is OFF for 2 minutes (adj.) after being commanded ON.
    - ii. Pump Running in Hand: The pump status is ON for 10 minutes (adj.) after being commanded OFF.
    - iii. Pump Runtime Exceeded: Status runtime exceeds a User-definable limit.
- 2) Hot Water Pump Start / Stop Sequence:
  - a. When the boiler plant is enabled, the control system will start the lead hot water pump.
  - b. If the lead pump fails to start, the control system shall activate the Pump Failure Alarm and attempt to start the lag pump.
  - c. The pump shall have a User-adjustable delay on stop. The pump shall continue to run for 5 minutes (adj.) after the boilers have been commanded off.
- 3) Hot Water Pump Lead/Lag Operation:
  - a. The hot water pumps are redundant, so only one pump shall operate at a time.
  - b. The designated lead pump shall rotate upon one of the following conditions (User-selectable):
    - i. Manually through a software switch.
    - ii. If pump runtime hours (adj.) are exceeded.
    - iii. Daily, weekly, or monthly.

4) Bypass Control:

- a. The differential pressure between the building hot water supply and return pipes shall be monitored. Refer to the piping schematics for pressure sensor location.
- b. If the differential pressure increases above the maximum pressure setpoint, the bypass control valve shall open and be controlled to the maximum pressure setpoint to prevent the pumps from dead-heading. Refer to the piping schematics for the bypass valve location, and the recommended maximum pressure setpoint.

**Constant Volume Secondary HW Pump Points Summary**

*Typical of Each*

Point Name	Point Type				Show on Graphic
	AI	DI	AO	DO	
Pump Start/Stop				X	X
Pump Run Status		X			X
HW System Differential Press.	X				X
Bypass Valve Control			X		X
<b>Totals</b>	<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>	
	<b>4</b>				

Additional Settings and Statuses to Show on Graphic
Active Program Overrides
Active Alarms

Alarms
Pump Failure
Pump Running in Hand
Pump Runtime Exceeded

Adjustable Control Settings (At Minimum)	Initial Setting
Start Delay Time	0 minutes
Stop Delay Time	5 minutes
Lead Pump Selection Settings	Daily Rotation
Freeze Protection Enable	Below 35°F
Maximum Differential Pressure Setpoint	SEE DRAWINGS



## **9. CHW / GAS HEAT PACKAGED SINGLE-ZONE CV ROOFTOP UNITS**

- 1) Run Conditions
  - a. The control system shall command the Packaged Rooftop Unit (RTU) to run according to a User-defined occupied/unoccupied time schedule with the following settings:
    - i. In occupied mode the RTU shall operate continuously while cooling and heating is controlled to maintain a 74°F (adj.) zone cooling setpoint and a 68°F (adj.) zone heating setpoint.
    - ii. In unoccupied mode (night setback) the RTU shall cycle on and off as needed to maintain an 85°F (adj.) zone cooling setpoint and a 55°F (adj.) zone heating setpoint, with a +/-2°F (adj.) offset. To prevent short-cycling the RTU fan shall run for and be off for a minimum period of 5 minutes each (adj.).
  - b. Zone Occupant Override: A timed local override control shall allow an occupant to override the schedule and place the system into occupied mode for a set period of time, adjustable by the control system operator. At the expiration of this time, control of the system shall automatically return to the schedule. For chilled water systems, we recommend that the override function remain locked off to avoid unscheduled plant operation.
  - c. Alarms shall be provided as follows:
    - i. High Zone Temp: The zone temperature is greater than the cooling setpoint by 5°F (adj.) after the RTU has been commanded to run for 60 minutes (adj.).
    - ii. Low Zone Temp: The zone temperature is less than the heating setpoint by 5°F (adj.) after the RTU has been commanded to run for 60 minutes (adj.).
- 2) RTU Start/Stop Sequence
  - a. When the RTU is called to run, the building control system will signal the RTU to start. The RTU factory-installed controller will set the return air damper and outside air damper positions, command the supply fan to run, and enable heating as required to meet the zone temperature setpoint. The building control system shall enable cooling if required to meet the zone temperature setpoint.
  - b. When the RTU is called to stop, the building control system will signal the RTU to stop. The RTU factory-installed controller will stop the supply air fan, fully close the outside air damper, and disable heating. The building control system shall disable cooling.

- c. During unoccupied mode: the unit shall operate in full recirculation mode with the outside air damper closed.
- 3) Supply Fan Control:
- a. The building control system shall have control of the supply fan VFD speed setpoint.
  - b. The supply fan shall run at full constant speed anytime the RTU is commanded to run, unless noted otherwise. The supply fan maximum speed setting shall be determined by the test and balance contractor to achieve design air flow.
  - c. Exceptions:
    - i. The supply fan shall operate at 60% (adj.) speed during unoccupied mode operation.
    - ii. The supply fan shall operate at reduced speed during dehumidification mode operation. Refer to dehumidification sequence description.
  - d. The supply fan on/off status shall be monitored by the control system.
  - e. Alarms shall be provided as follows:
    - i. Supply Fan Failure: The fan status is off 2 minutes (adj.) after being commanded on.
    - ii. Supply Fan in Hand: The fan status is on 2 minutes (adj.) after being commanded off.
    - iii. Supply Fan Runtime Exceeded: Status runtime exceeds a User-definable limit.
- 4) Cooling Control:
- a. The building control system shall have control of the cooling coil valve.
  - b. When the zone temperature is above the zone cooling setpoint, the control system shall adjust the cooling coil valve position to maintain the zone temperature at the zone cooling setpoint.
  - c. Cooling shall be disabled whenever the supply fan status is OFF, except when the cooling valve is commanded open for freeze protection.
  - d. Cooling shall be disabled whenever the outside ambient temperature is below 40°F (adj.).

- 5) Heating Control:
- a. The RTU factory-installed controller shall have control of the heater.
  - b. When the zone temperature is below the zone heating setpoint, the factory controller shall adjust the gas furnace output to maintain the zone temperature at the heating setpoint.
- 6) Temperature Monitoring:
- a. The control system shall monitor the RTU mixed air temperature, chilled water cooling coil leaving air temperature, and supply air temperature.
  - b. Alarms shall be provided as follows:
    - i. High Supply Air Temp: The supply air temperature is greater than 120°F (adj.) for 5 minutes (adj). Disable the RTU until the alarm is manually reset.
    - ii. Low Supply Air Temp: The supply air temperature is less than 35°F (adj.) for 5 minutes (adj.). Disable the RTU until the alarm is manually reset.
- 7) Freeze Protection:
- a. If the outside ambient temperature falls below 35°F (adj.) during unoccupied mode, the chilled water valve shall open to a minimum position of 10% (adj.). The chilled water pumps will also be commanded to run to circulate water throughout the entire system (refer to pump sequence of operation).
  - b. If the chilled water coil freeze-stat is status is tripped:
    - i. The cooling coil valve shall be opened to a minimum position of 30% (adj.).
    - ii. The RTU shall be commanded to run in unoccupied mode (the outside air damper shall fully close and the return air damper shall fully open for 100% recirculation). The RTU shall be controlled to the occupied heating setpoint.
    - iii. The supply fan shall run to recirculate warm building air through the cooling coil.
    - iv. The heat section shall operate to maintain the occupied heating setpoint.

- c. Alarms shall be provided as follows:
  - i. Freeze-Stat Trip: The unit shall operate as specified above and generate an alarm upon receiving a freeze-stat trip status.
  - ii. Freeze Protection Failure: If the mixed air temperature remains below 35°F (adj.) for 15 minutes (adj.) after the freeze-stat is tripped, shut down the RTU and generate an alarm. The cooling coil valve shall remain open.

8) Dehumidification:

- a. **If the RTU is specified to have dehumidification on the Equipment Control List**, provide a relative humidity sensor located in the zone served or in the return air duct; refer to the Equipment List for RH sensor locations. Provide the following alarms:
  - i. High Relative Humidity: The relative humidity is greater than 65% (adj.).
- b. For RTUs with “**Reheat**” dehumidification specified on the Equipment List:
  - i. If the relative humidity exceeds 60% (adj.) while in occupied mode or unoccupied mode, the system shall be forced into dehumidification mode operation:
    - 1. The cooling coil shall be controlled to provide maximum cooling, down to a minimum coil leaving air temperature of 52°F (adj.). If cooling is not available from the central plant, the system will request cooling and wait until requisite number of requests are satisfied to activate the central plant.
    - 2. The heater section will be allowed to operate simultaneously with the cooling coil. The heater shall be controlled by the RTU factory controller to maintain the zone temperature at the occupied cooling setpoint. Ensure that the heater is available for reheat, and not locked out due to outside ambient temperature in the factory controller.
    - 3. The supply air fan shall operate at 80% (adj.) speed during dehumidification mode.
  - ii. The system shall operate in dehumidification mode until the relative humidity falls below 55% (adj.)

9) Carbon Dioxide (CO2) Demand-Controlled Ventilation:

- a. CO2 demand-controlled ventilation will be controlled by the RTU factory-installed controller.
- b. **If the RTU is specified to have “CO2 DCV” on the Equipment Control List,** provide a CO2 sensor located in the zone served or in the return air duct; refer to the Equipment List for CO2 sensor locations. The CO2 sensor shall be connected to the RTU factory-installed controller. The factory controller shall monitor the zone CO2 concentration and use it as a reference to control outside the air volume per the factory-programmed sequence.
- c. The building control system shall set the maximum CO2 setpoint at 1000 PPM (adj.) during occupied mode.
- d. The building control system shall read the measured CO2 PPM from the RTU factory controller. Alarms shall be provided as follows:
  - i. High CO2 Concentration: The measured CO2 concentration is greater than 1200 PPM (adj.) for 15 minutes (adj.) while the system is running in occupied mode.

10) Economizer Operation (**when Economizer is specified on the Equipment List**):

- a. Economizer mode shall be controlled by the RTU factory-installed controller.
- b. When the outside air temperature is below 70°F (adj.) AND the outside air dew point is 57°F, the factory controller shall enable economizer mode.
- c. The economizer mode shall be locked out below 50°F (adj.) to prevent excessive heating load.
- d. The building control system shall keep the cooling coil valve closed while economizer mode is active. The cooling coil valve will only be allowed to open if the outside air damper position is 100% and the zone temperature rises above the cooling setpoint.

## CHW / Gas Heat Packaged Single-Zone CV RTU Points Summary

*Typical of Each*

Point Name	Point Type				Show on Graphic
	AI	DI	AO	DO	
Zone Temperature Sensor	X				X
Zone Temperature Output			X		
Zone Temperature Setpoint			X		X
Zone Occupant Override		X			X
Zone or RA Relative Humidity (1)	X				X
CO2 PPM Read (2)	X				X
CO2 Setpoint (2)			X		X
Outside Air Temperature	X				X
Outside Air Relative Humidity	X				X
Supply Air Temperature	X				X
Mixed Air Temperature	X				X
CHW Coil Leaving Air Temp.	X				X
Freezestat Trip Status		X			X
RTU Start/Stop				X	X
Occupied/Unoccupied				X	X
Unit Operating Mode Status	X				X
Supply Fan VFD Speed Setpoint			X		X
Supply Fan VFD Speed	X				X
Supply Fan Status		X			X
Cooling Valve Control			X		X
Heater Output	X				X
Outside Air Damper Position	X				X
OA Damper Minimum Setpoint			X		X
Reset Alarm				X	
<b>Totals</b>	<b>12</b>	<b>3</b>	<b>6</b>	<b>3</b>	
	<b>24</b>				

Additional Settings and Statuses to Show on Graphic
Current Zone Temperature Setpoint
Current Schedule Status (Occupied or Unoccupied)
Dehumidification Mode Status (1)
Active Program Overrides
Active Alarms

Alarms
High Zone Temperature
Low Zone Temperature
Supply Fan Failure
Supply Fan Running in Hand
Supply Fan Runtime Exceeded
High Supply Air Temperature
Low Supply Air Temperature
Freezestat Trip
Freeze Protection Failure
High Relative Humidity (1)
High CO2 Concentration (2)

**NOTES:**

- 1) When Dehumidification specified on the equipment list.
- 2) When CO2 DCV specified on the equipment list.
- 3) When Economizer specified on the equipment list.
- 4) Disable the factory heating lockout if it prevents reheat during dehumidification mode.

Adjustable Control Settings (At Minimum)	Initial Setting
Occupied Zone Temperature Cooling Setpoint	74°F
Occupied Zone Temperature Heating Setpoint	68°F
Unoccupied Zone Temperature Cooling Setpoint	85°F
Unoccupied Zone Temperature Heating Setpoint	55°F
Zone Occupant Override Time	0 min. / DISABLED
Minimum Fan Runtime/Off-Time	5 minutes
Outside Air Damper Minimum Ventilation Setpoint	SET BY T&B
Occupied Mode Maximum Supply Fan VFD Speed	SET BY T&B
Unoccupied Mode Supply Fan VFD Speed	60% / 36 Hz
Cooling OAT Lockout	Below 40°F
Heating OAT Lockout (on factory-installed controller)	Above 70°F (4)
Freeze Protection Enable OAT	Below 35°F
Maximum Relative Humidity Setpoint (1)	60%
Dehumidification Setpoint (1)	55%
Dehumidification CHW Coil LAT Setpoint (1)	52°F
Dehumidification Mode Supply Fan VFD Speed (1)	80% / 48 Hz
Occupied Maximum CO2 PPM Setpoint (2)	1000 PPM
Economizer High Limit OA Dry Bulb Temperature (3)	70°F
Economizer High Limit OA Dew Point Temperature (3)	57°F
Economizer Low Limit OA Dry Bulb Temperature (3)	50°F



## **10. CHW / GAS HEAT PACKAGED SINGLE-ZONE VAV ROOFTOP UNITS**

- 1) Run Conditions
  - a. The control system shall command the Packaged Rooftop Unit (RTU) to run according to a User-defined occupied/unoccupied time schedule with the following settings:
    - i. In occupied mode the RTU shall operate continuously while cooling and heating is controlled to maintain a 74°F (adj.) zone cooling setpoint and a 68°F (adj.) zone heating setpoint.
    - ii. In unoccupied mode (night setback) the RTU shall cycle on and off as needed to maintain an 85°F (adj.) zone cooling setpoint and a 55°F (adj.) zone heating setpoint, with a +/-2°F (adj.) offset. To prevent short-cycling the RTU fan shall run for and be off for a minimum period of 5 minutes each (adj.).
  - b. Zone Occupant Override: A timed local override control shall allow an occupant to override the schedule and place the system into occupied mode for a set period of time, adjustable by the control system operator. At the expiration of this time, control of the system shall automatically return to the schedule. For chilled water systems, we recommend that the override function remain locked off to avoid unscheduled plant operation.
  - c. Alarms shall be provided as follows:
    - i. High Zone Temp: The zone temperature is greater than the cooling setpoint by 5°F (adj.) after the RTU has been commanded to run for 60 minutes (adj.).
    - ii. Low Zone Temp: The zone temperature is less than the heating setpoint by 5°F (adj.) after the RTU has been commanded to run for 60 minutes (adj.).
- 2) RTU Start/Stop Sequence
  - a. When the RTU is called to run, the building control system will signal the RTU to start. The RTU factory-installed controller will set the return air damper and outside air damper positions, command the supply fan to run, and enable heating as required to meet the zone temperature setpoint. The building control system shall enable cooling if required to meet the zone temperature setpoint.
  - b. When the RTU is called to stop, the building control system will signal the RTU to stop. The RTU factory-installed controller will stop the supply air fan, fully

close the outside air damper, and disable heating. The building control system shall disable cooling.

- c. During unoccupied mode: the unit shall operate in full recirculation mode with the outside air damper closed.

3) Supply Fan Control:

- a. The building control system shall have control of the supply fan VFD speed setpoint.
- b. The supply fan shall run anytime the RTU is commanded to run, unless shutdown on safeties.
- c. During cooling mode, the RTU shall be controlled to supply air at a constant temperature and variable air volume. The control system shall adjust the supply fan VFD speed to maintain the zone temperature at the cooling setpoint. The fan speed shall be controlled to operate between the minimum and maximum speed settings.
- d. The supply fan VFD maximum speed setting shall be determined by the test and balance contractor to achieve design air flow. The minimum speed shall be 20% (adj.).
- e. During heating mode, the RTU shall be controlled to supply air at variable temperature and constant air volume. The supply fan VFD will operate at the maximum speed setting.
- f. The supply fan on/off status shall be monitored by the control system.
- g. Alarms shall be provided as follows:
  - i. Supply Fan Failure: The fan status is off 2 minutes (adj.) after being commanded on.
  - ii. Supply Fan in Hand: The fan status is on 2 minutes (adj.) after being commanded off.
  - iii. Supply Fan Runtime Exceeded: Status runtime exceeds a User-definable limit.

4) Cooling Control:

- a. The building control system shall have control of the cooling coil valve.
- b. During cooling mode, the supply air temperature setpoint shall be 54°F (adj.). An optional supply air temperature reset sequence shall be provided, based on a correlation to outside ambient temperature.



- c. When the supply air temperature is above the setpoint temperature, the control system shall adjust the cooling coil valve position to maintain the supply air temperature at setpoint.
  - d. If the supply air fan is operating at minimum speed and the zone temperature falls below the zone cooling setpoint, the cooling coil valve shall be controlled to maintain the zone temperature at the cooling setpoint. If the zone temperature rises above the zone cooling setpoint and the supply air temperature is at the supply air temperature setpoint, the supply fan will be allowed speed up and resume variable air volume control.
  - e. Cooling shall be disabled whenever the supply fan status is OFF, except when the cooling valve is commanded open for freeze protection.
  - f. Cooling shall be disabled whenever the zone temperature is below the heating setpoint.
  - g. Cooling shall be disabled whenever the outside ambient temperature is below 40°F (adj.).
- 5) Heating Control:
- a. The RTU factory-installed controller shall have control of the heater.
  - b. During heating mode, the supply air temperature shall be variable.
  - c. When the zone temperature is below the zone heating setpoint, the factory controller shall adjust the gas furnace output to maintain the zone temperature at the heating setpoint.
- 6) Temperature Monitoring:
- a. The control system shall monitor the RTU mixed air temperature, chilled water cooling coil leaving air temperature, and supply air temperature.
  - b. Alarms shall be provided as follows:
    - i. High Supply Air Temp: The supply air temperature is greater than 120°F (adj.) for 5 minutes. Disable the RTU until the alarm is manually reset.
    - ii. Low Supply Air Temp: The supply air temperature is less than 35°F (adj.) for 5 minutes. Disable the RTU until the alarm is manually reset.

- 7) Freeze Protection:
- a. If the outside ambient temperature falls below 35°F (adj.) during unoccupied mode, the chilled water valves shall open to a minimum position of 10% (adj.). The chilled water pumps will also be commanded to run to circulate water throughout the entire system (refer to pump sequence of operation).
  - b. If the chilled water coil freeze-stat is status is tripped:
    - i. The cooling coil valve shall be opened to a minimum position of 30% (adj.).
    - ii. The RTU shall be commanded to run in unoccupied mode (the outside air damper shall fully close and the return air damper shall fully open for 100% recirculation). The RTU shall be controlled to the occupied heating setpoint.
    - iii. The supply fan shall run to recirculate warm building air through the cooling coil.
    - iv. The heat section shall operate to maintain the occupied heating setpoint.
  - c. Alarms shall be provided as follows:
    - i. Freeze-Stat Trip: The unit shall operate as specified above and generate an alarm upon receiving a freeze-stat trip status.
    - ii. Freeze Protection Failure: If the mixed air temperature remains below 35°F (adj.) for 15 minutes (adj.) after the freeze-stat is tripped, shut down the RTU and generate an alarm. The cooling coil valve shall remain open.
- 8) Dehumidification:
- a. **If the RTU is specified to have dehumidification on the Equipment Control List**, provide a relative humidity sensor located in the zone served or in the return air duct; refer to the Equipment List for RH sensor locations. Provide the following alarms:
    - i. High Relative Humidity: The relative humidity is greater than 65% (adj.).
  - b. For RTUs with **“Reheat”** dehumidification specified on the Equipment List:
    - i. If the relative humidity exceeds 60% (adj.) while in occupied mode or unoccupied mode, the system shall be forced into dehumidification mode operation:

1. The cooling coil shall be controlled to provide maximum cooling, down to a minimum coil leaving air temperature of 52°F (adj.). If cooling is not available from the central plant, the system will request cooling and wait until requisite number of requests are satisfied to activate the central plant.
  2. The heater section will be allowed to operate simultaneously with the cooling coil. The heater shall be controlled by the RTU factory controller to maintain the zone temperature at the occupied cooling setpoint. Ensure that the heater is available for reheat, and not locked out due to outside ambient temperature in the factory controller.
  3. The supply air fan shall operate at 80% (adj.) speed during dehumidification mode.
- ii. The system shall operate in dehumidification mode until the relative humidity falls below 55% (adj.)
- 9) Carbon Dioxide (CO2) Demand-Controlled Ventilation:
- a. CO2 demand-controlled ventilation will be controlled by the RTU factory-installed controller.
  - b. **If the RTU is specified to have “CO2 DCV” on the Equipment Control List**, provide a CO2 sensor located in the zone served or in the return air duct; refer to the Equipment List for CO2 sensor locations. The CO2 sensor shall be connected to the RTU factory-installed controller. The factory controller shall monitor the zone CO2 concentration and use it as a reference to control outside the air volume per the factory-programmed sequence.
  - c. The building control system shall set the maximum CO2 setpoint at 1000 PPM (adj.) during occupied mode.
  - d. The building control system shall read the measured CO2 PPM from the RTU factory controller. Alarms shall be provided as follows:
    - i. High CO2 Concentration: The measured CO2 concentration is greater than 1200 PPM (adj.) for 15 minutes (adj.) while the system is running in occupied mode.
- 10) Economizer Operation (**when Economizer is specified on the Equipment List**):
- a. Economizer mode shall be controlled by the RTU factory-installed controller.
  - b. When the outside air temperature is below 70°F (adj.) AND the outside air dew point is 57°F, the factory controller shall enable economizer mode.

- c. The economizer mode shall be locked out below 50°F (adj.) to prevent excessive heating load.
- d. The building control system shall keep the cooling coil valve closed while economizer mode is active. The cooling coil valve will only be allowed to open if the outside air damper position is 100% and the zone temperature rises above the cooling setpoint.

## CHW / Gas Heat Packaged Single-Zone VAV RTU Points Summary

*Typical of Each*

Point Name	Point Type				Show on Graphic
	AI	DI	AO	DO	
Zone Temperature Sensor	X				X
Zone Temperature Output			X		
Zone Temperature Setpoint			X		X
Zone Occupant Override		X			X
Zone or RA Relative Humidity (1)	X				X
CO2 PPM Read (2)	X				X
CO2 Setpoint (2)			X		X
Outside Air Temperature	X				X
Outside Air Relative Humidity	X				X
Supply Air Temperature	X				X
Mixed Air Temperature	X				X
CHW Coil Leaving Air Temp.	X				X
Freezestat Trip Status		X			X
RTU Start/Stop				X	X
Occupied/Unoccupied				X	X
Unit Operating Mode Status	X				X
Supply Fan VFD Speed Setpoint			X		X
Supply Fan VFD Speed	X				X
Supply Fan Status		X			X
Cooling Valve Control			X		X
Heater Output	X				X
Outside Air Damper Position	X				X
OA Damper Minimum Setpoint			X		X
Reset Alarm				X	
<b>Totals</b>	<b>12</b>	<b>3</b>	<b>6</b>	<b>3</b>	
	<b>24</b>				

Additional Settings and Statuses to Show on Graphic
Current Zone Temperature Setpoint
Current Supply Air Temperature Setpoint
Current Schedule Status (Occupied or Unoccupied)
Dehumidification Mode Status (1)
Active Program Overrides
Active Alarms

Alarms
High Zone Temperature
Low Zone Temperature
Supply Fan Failure
Supply Fan Running in Hand
Supply Fan Runtime Exceeded
High Supply Air Temperature
Low Supply Air Temperature
Freezestat Trip
Freeze Protection Failure
High Relative Humidity (1)
High CO2 Concentration (2)

**NOTES:**

- 1) When Dehumidification specified on the equipment list.
- 2) When CO2 DCV specified on the equipment list.
- 3) When Economizer specified on the equipment list.
- 4) Disable the factory heating lockout if it prevents reheat during dehumidification mode.

Adjustable Control Settings (At Minimum)	Initial Setting
Occupied Zone Temperature Cooling Setpoint	74°F
Occupied Zone Temperature Heating Setpoint	68°F
Unoccupied Zone Temperature Cooling Setpoint	85°F
Unoccupied Zone Temperature Heating Setpoint	55°F
Zone Occupant Override Time	0 min. / DISABLED
Minimum Fan Runtime/Off-Time	5 minutes
Outside Air Damper Minimum Ventilation Setpoint	SET BY T&B
Supply Fan Maximum VFD Speed	SET BY T&B
Supply Fan Minimum VFD Speed	20% / 12 Hz
Cooling Mode Supply Air Temperature Setpoint	54°F
Cooling OAT Lockout	Below 40°F
Heating OAT Lockout (on factory-installed controller)	Above 70°F (4)
Freeze Protection Enable OAT	Below 35°F
Maximum Relative Humidity Setpoint (1)	60%
Dehumidification Setpoint (1)	55%
Dehumidification CHW Coil LAT Setpoint (1)	52°F
Dehumidification Mode Supply Fan VFD Speed (1)	80% / 48 Hz
Occupied Maximum CO2 PPM Setpoint (2)	1000 PPM
Economizer High Limit OA Dry Bulb Temperature (3)	70°F
Economizer High Limit OA Dew Point Temperature (3)	57°F
Economizer Low Limit OA Dry Bulb Temperature (3)	50°F



## **11. CHW / GAS HEAT PACKAGED ROOFTOP UNITS WITH ERV**

- 1) Run Conditions
  - a. The control system shall command the Packaged Rooftop Unit (RTU) to run according to a User-defined occupied/unoccupied time schedule with the following settings:
    - i. In occupied mode the RTU shall operate continuously while cooling and heating is controlled to maintain a 74°F (adj.) zone cooling setpoint and a 68°F (adj.) zone heating setpoint.
    - ii. In unoccupied mode (night setback) the RTU shall cycle on and off as needed to maintain an 85°F (adj.) zone cooling setpoint and a 55°F (adj.) zone heating setpoint, with a +/-2°F (adj.) offset. To prevent short-cycling the RTU fan shall run for and be off for a minimum period of 5 minutes each (adj.).
  - b. Zone Occupant Override: A timed local override control shall allow an occupant to override the schedule and place the system into occupied mode for a set period of time, adjustable by the control system operator. At the expiration of this time, control of the system shall automatically return to the schedule. For chilled water systems, we recommend that the override function remain locked off to avoid unscheduled plant operation.
  - c. Alarms shall be provided as follows:
    - i. High Zone Temp: The zone temperature is greater than the cooling setpoint by 5°F (adj.) after the RTU has been commanded to run for 60 minutes (adj.).
    - ii. Low Zone Temp: The zone temperature is less than the heating setpoint by 5°F (adj.) after the RTU has been commanded to run for 60 minutes (adj.).
- 2) RTU Start/Stop Sequence
  - a. When the RTU is called to run, the building control system will signal the RTU to start. The RTU factory-installed controller will set the return air, recirculation air and outside air damper positions, command the supply and exhaust fans to run, enable the energy wheel to run, and enable heating as required to meet the zone temperature setpoint. The building control system shall enable cooling if required to meet the zone temperature setpoint.
  - b. When the RTU is called to stop, the building control system will signal the RTU to stop. The RTU factory-installed controller will stop the supply and exhaust air fans, stop the energy wheel, fully close the outside air and return air dampers, and disable heating. The building control system shall disable cooling.

- c. During unoccupied mode: the unit shall operate in full recirculation mode with the outside air damper closed, exhaust fan off, and energy wheel off.

3) Supply Fan Control:

- a. The building control system shall have control of the supply fan VFD speed setpoint.
- b. The supply fan shall run at full constant speed anytime the RTU is commanded to run, unless noted otherwise. The supply fan maximum speed setting shall be determined by the test and balance contractor to achieve design air flow.
- c. Exceptions:
  - i. The supply fan shall operate at 60% (adj.) speed during unoccupied mode operation.
- d. The supply fan on/off status shall be monitored by the control system.
- e. Alarms shall be provided as follows:
  - i. Supply Fan Failure: The fan status is off 2 minutes (adj.) after being commanded on.
  - ii. Supply Fan in Hand: The fan status is on 2 minutes (adj.) after being commanded off.
  - iii. Supply Fan Runtime Exceeded: Status runtime exceeds a User-definable limit.

4) Exhaust Fan Control:

- a. The building control system shall have control of the exhaust fan VFD speed setpoint.
- b. The exhaust fan shall run at the design exhaust air flow speed during normal occupied operation. The exhaust fan speed setting shall be determined by the test and balance contractor to achieve design exhaust air flow.
- c. Exceptions:
  - i. The exhaust fan shall operate at variable speed during economizer mode operation. Refer to the economizer sequence description. The maximum economizer exhaust fan speed setting shall be determined by the test and balance contractor to equal the supply air flow.

- ii. The exhaust fan shall operate at variable speed proportional to the outside air damper position if the unit is specified to have CO2 demand-controlled ventilation on the Equipment Control List. Refer to the CO2 DCV sequence description.
  - d. The fan on/off status shall be monitored by the control system.
  - e. Alarms shall be provided as follows:
    - i. Exhaust Fan Failure: The fan status is off 2 minutes (adj.) after being commanded on.
    - ii. Exhaust Fan in Hand: The fan status is on 2 minutes (adj.) after being commanded off.
    - iii. Exhaust Fan Runtime Exceeded: Status runtime exceeds a User-definable limit.
- 5) Cooling Control:
  - a. The building control system shall have control of the cooling coil valve.
  - b. When the zone temperature is above the zone cooling setpoint, the control system shall adjust the cooling coil valve position to maintain the zone temperature at the zone cooling setpoint.
  - c. Cooling shall be disabled whenever the supply fan status is OFF, except when the cooling valve is commanded open for freeze protection.
  - d. Cooling shall be disabled whenever the outside ambient temperature is below 40°F (adj.).
- 6) Heating Control:
  - a. The RTU factory-installed controller shall have control of the heater.
  - b. When the zone temperature is below the zone heating setpoint, the factory controller shall adjust the gas furnace output to maintain the zone temperature at the heating setpoint.
- 7) Energy Recovery Wheel Control - The energy recovery wheel will be controlled by the RTU factory-installed controller.
- 8) Temperature and Humidity Monitoring:
  - a. The control system shall monitor the RTU return air temperature, mixed air temperature, mixed air relative humidity, cooling coil leaving air temperature, and supply air temperature.



- b. Alarms shall be provided as follows:
  - i. High Supply Air Temp: The supply air temperature is greater than 120°F (adj.) for 5 minutes (adj.). Disable the RTU until the alarm is manually reset.
  - ii. Low Supply Air Temp: The supply air temperature is less than 35°F (adj.) for 5 minutes (adj.). Disable the RTU until the alarm is manually reset.

9) Freeze Protection:

- a. If the outside ambient temperature falls below 35°F (adj.) during occupied mode, the outside air damper setpoint shall be set to no greater than 50% open and the exhaust fan shall run no greater than 50% speed to increase the recirculation of warm building air across the chilled water coil.
- b. If the outside ambient temperature falls below 35°F (adj.) during unoccupied mode, the chilled water valves shall open to a minimum position of 10% (adj.). The chilled water pumps will also be commanded to run to circulate water throughout the entire system (refer to pump sequence of operation).
- c. If the chilled water coil freeze-stat is status is tripped:
  - i. The cooling coil valve shall be opened to a minimum position of 30% (adj.).
  - ii. The RTU shall be commanded to run in unoccupied mode (the outside air damper shall fully close, the exhaust fan shall be off, and the recirculation air damper shall fully open for 100% recirculation). The RTU shall be controlled to the occupied heating setpoint.
  - iii. The supply fan shall run to recirculate warm building air through the cooling coil.
  - iv. The heat section shall operate to maintain the occupied heating setpoint.
- d. Alarms shall be provided as follows:
  - i. Freeze-Stat Trip: The unit shall operate as specified above and generate an alarm upon receiving a freeze-stat trip status.
  - ii. Freeze Protection Failure: If the mixed air temperature remains below 35°F (adj.) for 15 minutes (adj.) after the freeze-stat is tripped, shut down the RTU and generate an alarm. The cooling coil valve shall remain open.

10) Dehumidification:

- a. **If the RTU is specified to have dehumidification on the Equipment Control List**, provide a relative humidity sensor located in the zone served or in the return air duct; refer to the Equipment List for RH sensor locations. Provide the following alarms:
  - i. High Relative Humidity: The relative humidity is greater than 65% (adj.).
- b. For RTUs with **“Reheat”** dehumidification specified on the Equipment List:
  - i. If the relative humidity exceeds 60% (adj.) while in occupied mode or unoccupied mode, the system shall be forced into dehumidification mode operation:
    - 1. The cooling coil shall be controlled to provide maximum cooling, down to a minimum coil leaving air temperature of 52°F (adj.). If cooling is not available from the central plant, the system will request cooling and wait until requisite number of requests are satisfied to activate the central plant.
    - 2. The heater section will be allowed to operate simultaneously with the cooling coil. The heater shall be controlled by the RTU factory controller to maintain the zone temperature at the occupied cooling setpoint. Ensure that the heater is available for reheat, and not locked out due to outside ambient temperature in the factory controller.
    - 3. The supply air fan shall operate at 80% (adj.) speed during dehumidification mode.
  - ii. The system shall operate in dehumidification mode until the relative humidity falls below 55% (adj.)

11) Carbon Dioxide (CO2) Demand-Controlled Ventilation:

- a. CO2 demand-controlled ventilation will be controlled by the RTU factory-installed controller.
- b. **If the RTU is specified to have “CO2 DCV” on the Equipment Control List**, provide a CO2 sensor located in the zone served or in the return air duct; refer to the Equipment List for CO2 sensor locations. The CO2 sensor shall be connected to the RTU factory-installed controller. The factory controller shall monitor the zone CO2 concentration and use it as a reference to control outside the air volume by adjusting the outside air damper per the factory-programmed sequence. The outside air damper will be controlled between the design ventilation position and fully closed.

- c. The building control system shall adjust the RTU exhaust fan speed percentage to match the outside air damper open percent. The exhaust fan will operate at the design exhaust airflow speed when the outside air damper at the design ventilation position and will shut off when the outside air damper is 0% open.
- d. The building control system shall set the maximum CO2 setpoint at 1000 PPM (adj.) during occupied mode.
- e. The building control system shall read the measured CO2 PPM from the RTU factory controller. Alarms shall be provided as follows:
  - i. High CO2 Concentration: The measured CO2 concentration is greater than 1200 PPM (adj.) for 15 minutes (adj.) while the system is running in occupied mode.

12) Economizer Operation (**when Economizer is specified on the Equipment List**):

- a. Economizer mode shall be controlled by the RTU factory-installed controller. However, the exhaust fan will be controlled by the building control system as detailed below.
- b. When the outside air temperature is below 70°F (adj.) AND the outside air dew point is 57°F, the factory controller shall enable economizer mode.
- c. The economizer mode shall be locked out below 50°F (adj.) to prevent excessive heating load.
- d. While economizer mode is enabled:
  - i. The factory controller will control the energy wheel, energy wheel bypass dampers, outside air damper, and recirculation air damper per the factory-programmed sequence.
  - ii. The building control system shall adjust the RTU exhaust fan speed percentage to match the outside air damper open percent. The exhaust fan will operate at its maximum speed setting (equal to supply air flow) when the outside air damper is 100% open and will shut off when the outside air damper is 0% open.
  - iii. The building control system shall keep the cooling coil valve closed while economizer mode is active. The cooling coil valve will only be allowed to open if the outside air damper position is 100% and the zone temperature rises above the cooling setpoint.

## CHW / Gas Heat Packaged RTU w/ ERV Points Summary

*Typical of Each*

Point Name	Point Type				Show on Graphic
	AI	DI	AO	DO	
Zone Temperature Sensor	X				X
Zone Temperature Output			X		
Zone Temperature Setpoint			X		X
Zone Occupant Override		X			X
Zone or RA Relative Humidity (1)	X				X
CO2 PPM Read (2)	X				X
CO2 Setpoint (2)			X		X
Outside Air Temperature	X				X
Outside Air Relative Humidity	X				X
Supply Air Temperature	X				X
Mixed Air Temperature	X				X
Mixed Air Relative Humidity	X				X
Return Air Temperature	X				X
CHW Coil Leaving Air Temp.	X				X
Freezestat Trip Status		X			X
RTU Start/Stop				X	X
Occupied/Unoccupied				X	X
Unit Operating Mode Status	X				X
Supply Fan VFD Speed Setpoint			X		X
Supply Fan VFD Speed	X				X
Supply Fan Status		X			X
Exhaust Fan VFD Speed Setpoint			X		X
Exhaust Fan VFD Speed	X				X
Exhaust Fan Status		X			X
Cooling Valve Control			X		X
Heater Output	X				X
Outside Air Damper Position	X				X
OA Damper Minimum Setpoint			X		X
Energy Wheel Speed	X				X
Reset Alarm				X	
<b>Totals</b>	<b>16</b>	<b>4</b>	<b>7</b>	<b>3</b>	<b>30</b>

Additional Settings and Statuses to Show on Graphic
Current Zone Temperature Setpoint
Current Schedule Status (Occupied or Unoccupied)
Dehumidification Mode Status (1)
Active Program Overrides
Active Alarms

Alarms
High Zone Temperature
Low Zone Temperature
Supply Fan Failure
Supply Fan Running in Hand
Supply Fan Runtime Exceeded
Exhaust Fan Failure
Exhaust Fan Running in Hand
Exhaust Fan Runtime Exceeded
High Supply Air Temperature
Low Supply Air Temperature
Freezestat Trip
Freeze Protection Failure
High Relative Humidity (1)
High CO2 Concentration (2)

**NOTES:**

- 1) When Dehumidification specified on the equipment list.
- 2) When CO2 DCV specified on the equipment list.
- 3) When Economizer specified on the equipment list.
- 4) Disable the factory heating lockout if it prevents reheat during dehumidification mode.

Adjustable Control Settings (At Minimum)	Initial Setting
Occupied Zone Temperature Cooling Setpoint	74°F
Occupied Zone Temperature Heating Setpoint	68°F
Unoccupied Zone Temperature Cooling Setpoint	85°F
Unoccupied Zone Temperature Heating Setpoint	55°F
Zone Occupant Override Time	0 min. / DISABLED
Minimum Fan Runtime/Off-Time	5 minutes
Outside Air Damper Minimum Ventilation Setpoint	SET BY T&B
Occupied Mode Maximum Supply Fan VFD Speed	SET BY T&B
Unoccupied Mode Supply Fan VFD Speed	60% / 36 Hz
Occupied Mode Exhaust Fan VFD Speed	SET BY T&B
Cooling OAT Lockout	Below 40°F
Heating OAT Lockout (on factory-installed controller)	Above 70°F (4)
Freeze Protection Enable OAT	Below 35°F
Maximum Relative Humidity Setpoint (1)	60%
Dehumidification Setpoint (1)	55%
Dehumidification CHW Coil LAT Setpoint (1)	52°F
Dehumidification Mode Supply Fan VFD Speed (1)	80% / 48 Hz
Occupied Maximum CO2 PPM Setpoint (2)	1000 PPM
Economizer High Limit OA Dry Bulb Temperature (3)	70°F
Economizer High Limit OA Enthalpy (3)	57°F
Economizer Low Limit OA Dry Bulb Temperature (3)	50°F
Economizer Maximum Exhaust Fan VFD Speed (3)	SET BY T&B

(Supply Air CFM = Design Supply Air CFM)

(Exhaust Air CFM = Design Exhaust Air CFM)

(Exhaust Air CFM = Design Supply Air CFM)



## **12. CHW / GAS HEAT PACKAGED MULTI-ZONE VAV ROOFTOP UNITS**

- 1) Run Conditions
  - a. The RTU shall be enabled to run by a User-defined occupied/unoccupied time schedule, or when any zone associated with the RTU is in occupied mode.
  - b. The RTU shall be enabled to run whenever 2 (adj.) or more unoccupied zones call for heating or cooling.
  - c. To prevent short-cycling the supply fan shall run for and be off for a minimum period of 15 minutes each (adj.).
  
- 2) RTU Start/Stop Sequence
  - a. When the RTU is called to run, the building control system will signal the RTU to start. The RTU factory-installed controller will set the return air damper and outside air damper positions, command the supply fan to run, and enable heating as required to meet the zone temperature setpoint. The building control system shall enable cooling if required to meet the zone temperature setpoint.
  - b. When the RTU is called to stop, the building control system will signal the RTU to stop. The RTU factory-installed controller will stop the supply air fan, fully close the outside air damper, and disable heating. The building control system shall disable cooling.
  - c. During unoccupied mode: the unit shall operate in full recirculation mode with the outside air damper closed.
  
- 3) Supply Fan Control:
  - a. The building control system shall have control of the supply fan VFD speed setpoint.
  - b. The supply fan shall run anytime the RTU is commanded to run, unless shutdown on safeties.
  - c. The building control system shall measure the duct static pressure and adjust the supply fan VFD speed to maintain the duct static pressure at 1.5" w.g. (adj.). The fan VFD shall be controlled to operate between the minimum and maximum speed settings.
  - d. The supply fan VFD maximum speed and duct static pressure settings shall be determined by the test and balance contractor to achieve design air flow. The minimum speed shall be 20% (adj.).

- e. The supply fan on/off status shall be monitored by the control system.
- f. Alarms shall be provided as follows:
  - i. Supply Fan Failure: The fan status is off 2 minutes (adj.) after being commanded on.
  - ii. Supply Fan in Hand: The fan status is on 2 minutes (adj.) after being commanded off.
  - iii. Supply Fan Runtime Exceeded: Status runtime exceeds a User-definable limit.
  - iv. High Duct Static Pressure: The duct static pressure is greater than 2.5" w.c. (adj.). Disable the RTU until the alarm is manually reset.
- 4) Supply Air Temperature Setpoint: The supply air temperature setpoint shall be 54°F (adj.). An optional supply air temperature reset sequence shall also be provided. The reset sequence may be a correlation to outside ambient temperature, or a trim-and-respond algorithm.
- 5) Cooling Control:
  - a. The building control system shall have control of the cooling coil valve.
  - b. When the supply air temperature is above the setpoint temperature, the control system shall adjust the cooling coil valve position to maintain the supply air temperature at setpoint.
  - c. Cooling shall be disabled whenever the supply fan status is OFF, except when the cooling valve is commanded open for freeze protection.
  - d. Cooling shall be disabled whenever the outside ambient temperature is below 40°F (adj.).
- 6) Heating Control:
  - a. The RTU factory-installed controller shall have control of the heater.
  - b. When the supply air temperature is below the setpoint temperature, the factory controller shall adjust the gas furnace output to maintain the supply air temperature at setpoint.
- 7) Temperature Monitoring:
  - a. The control system shall monitor the RTU mixed air temperature, chilled water cooling coil leaving air temperature, and supply air temperature.

- b. Alarms shall be provided as follows:
    - i. High Supply Air Temp: The supply air temperature is greater than 120°F (adj.) for 5 minutes (adj.). Disable the RTU until the alarm is manually reset.
    - ii. Low Supply Air Temp: The supply air temperature is less than 35°F (adj.) for 5 minutes (adj.). Disable the RTU until the alarm is manually reset.
- 8) Freeze Protection:
- a. If the outside ambient temperature falls below 35°F (adj.) during unoccupied mode, the chilled water valves shall open to a minimum position of 10% (adj.). The chilled water pumps will also be commanded to run to circulate water throughout the entire system (refer to pump sequence of operation).
  - b. If the chilled water coil freeze-stat is status is tripped:
    - i. The cooling coil valve shall be opened to a minimum position of 30% (adj.).
    - ii. The RTU shall be commanded to run in unoccupied mode (the outside air damper shall fully close and the return air damper shall fully open for 100% recirculation). The RTU shall be controlled to the occupied heating setpoint.
    - iii. The supply fan shall run to recirculate warm building air through the cooling coil.
    - iv. The heat section shall operate to maintain the occupied heating setpoint.
  - c. Alarms shall be provided as follows:
    - i. Freeze-Stat Trip: The unit shall operate as specified above and generate an alarm upon receiving a freeze-stat trip status.
    - ii. Freeze Protection Failure: If the mixed air temperature remains below 35°F (adj.) for 15 minutes (adj.) after the freeze-stat is tripped, shut down the RTU and generate an alarm. The cooling coil valve shall remain open.
- 9) Carbon Dioxide (CO2) Demand-Controlled Ventilation:
- a. CO2 demand-controlled ventilation will be controlled by the RTU factory-installed controller.

- b. **If the RTU is specified to have “CO2 DCV” on the Equipment Control List,** provide a CO2 sensor located in the return air duct. The CO2 sensor shall be connected to the RTU factory-installed controller. The factory controller shall monitor the zone CO2 concentration and use it as a reference to control outside the air volume per the factory-programmed sequence.
  - c. The building control system shall set the maximum CO2 setpoint at 1000 PPM (adj.) during occupied mode.
  - d. The building control system shall read the measured CO2 PPM from the RTU factory controller. Alarms shall be provided as follows:
    - i. High CO2 Concentration: The measured CO2 concentration is greater than 1200 PPM (adj.) for 15 minutes (adj.) while the system is running in occupied mode.
- 10) Economizer Operation (**when Economizer is specified on the Equipment List**):
- a. Economizer mode shall be controlled by the RTU factory-installed controller.
  - b. When the outside air temperature is below 70°F (adj.) AND the outside air dew point is 57°F, the factory controller shall enable economizer mode.
  - c. The economizer mode shall be locked out below 50°F (adj.) to prevent excessive heating load.
  - d. The building control system shall keep the cooling coil valve closed while economizer mode is active. The cooling coil valve will only be allowed to open if the outside air damper position is 100% and the supply air temperature rises above setpoint.



## CHW / Gas Heat Packaged Multi-Zone VAV RTU Points Summary

*Typical of Each*

Point Name	Point Type				Show on Graphic
	AI	DI	AO	DO	
Supply Air Temperature Setpoint			X		X
CO2 PPM Read (2)	X				X
CO2 Setpoint (2)			X		X
Outside Air Temperature	X				X
Outside Air Relative Humidity	X				X
Supply Air Temperature	X				X
Mixed Air Temperature	X				X
CHW Coil Leaving Air Temp.	X				X
Freezestat Trip Status		X			X
RTU Start/Stop				X	X
Occupied/Unoccupied				X	X
Unit Operating Mode Status	X				X
Supply Fan VFD Speed Setpoint			X		X
Supply Fan VFD Speed	X				X
Supply Fan Status		X			X
Duct Static Pressure	X				X
Cooling Valve Control			X		X
Heater Output	X				X
Outside Air Damper Position	X				X
OA Damper Minimum Setpoint			X		X
Reset Alarm				X	
<b>Totals</b>	<b>11</b>	<b>2</b>	<b>5</b>	<b>3</b>	<b>21</b>

Additional Settings and Statuses to Show on Graphic
Current Supply Air Temperature Setpoint
Current Schedule Status (Occupied or Unoccupied)
Current Number of Zone Requests
Active Program Overrides
Active Alarms

Alarms
Supply Fan Failure
Supply Fan Running in Hand
Supply Fan Runtime Exceeded
High Duct Static Pressure
High Supply Air Temperature
Low Supply Air Temperature
Freezestat Trip
Freeze Protection Failure
High Zone CO2 Concentration (2)

**NOTES:**

- 1) Note not used.
- 2) When CO2 DCV specified on the equipment list.
- 3) When Economizer specified on the equipment list.
- 4) Disable the factory heating lockout if it prevents reheat during dehumidification mode.

Adjustable Control Settings (At Minimum)	Initial Setting
Minimum Fan Runtime/Off-Time	15 minutes
Duct Static Pressure Setpoint	1.5" WC
Outside Air Damper Minimum Ventilation Setpoint	SET BY T&B
Supply Fan Maximum VFD Speed	SET BY T&B
Supply Fan Minimum VFD Speed	20% / 12 Hz
Supply Air Temperature Setpoint	54°F
Cooling OAT Lockout	Below 40°F
Heating OAT Lockout (on factory-installed controller)	Above 70°F (4)
Freeze Protection Enable OAT	Below 35°F
Occupied Maximum CO2 PPM Setpoint (2)	1000 PPM
Economizer High Limit OA Dry Bulb Temperature (3)	70°F
Economizer High Limit OA Dew Point Temperature (3)	57°F
Economizer Low Limit OA Dry Bulb Temperature (3)	50°F



### **13. DX PACKAGED ROOFTOP UNITS**

- 1) Run Conditions
  - a. The control system shall command the Packaged Rooftop Unit (RTU) to run according to a User-defined occupied/unoccupied time schedule with the following settings:
    - i. In occupied mode the RTU shall operate continuously while cooling and heating is controlled to maintain a 74°F (adj.) zone cooling setpoint and a 68°F (adj.) zone heating setpoint, with a +/-1.5°F (adj.) offset.
    - ii. In unoccupied mode (night setback) the RTU shall cycle on and off as needed to maintain an 85°F (adj.) zone cooling setpoint and a 55°F (adj.) zone heating setpoint, with a +/-1.5°F (adj.) offset. To prevent short-cycling the RTU fan shall run for and be off for a minimum period of 5 minutes each (adj.).
  - b. Zone Unoccupied Override: A timed local override control shall allow an occupant to override the schedule and place the system into occupied mode for 30 minutes (adj.). At the expiration of this time, control of the system shall automatically return to the schedule.
  - c. The supply fan shall run anytime the RTU is commanded to run, unless shutdown on safeties. The fan on/off status shall be monitored by the control system.
  - d. Alarms shall be provided as follows:
    - i. Supply Fan Failure: The fan status is off 2 minutes (adj.) after being commanded on.
    - ii. Supply Fan in Hand: The fan status is on 2 minutes (adj.) after being commanded off.
    - iii. Supply Fan Runtime Exceeded: Status runtime exceeds a User-definable limit.
    - iv. High Zone Temp: The zone temperature is greater than the cooling setpoint by 5°F (adj.) after the RTU has been commanded to run for 60 minutes (adj.).
    - v. Low Zone Temp: The zone temperature is less than the heating setpoint by 5°F (adj.) after the RTU has been commanded to run for 60 minutes (adj.).

- 2) RTU Start/Stop Sequence
  - a. When the RTU is called to run, the control system will command the supply fan to run and enable cooling or heating as required to meet the zone temperature setpoint.
  - b. If the RTU has a motorized outside air damper, the control system shall open the damper to the design ventilation position during occupied mode operation only. The outside air damper shall remain closed during unoccupied mode.
  - c. When the RTU is called to stop, the control system shall stop the supply air fan, fully close the outside air damper, and disable cooling and heating.
  
- 3) Cooling Control:
  - a. When the zone temperature is above the zone cooling setpoint, the control system shall activate or deactivate compressor stages as required to maintain the zone temperature at the cooling setpoint.
  - b. To prevent short-cycling, the compressors shall have a minimum on and off time of 2 minutes (adj.)
  - c. Cooling shall be disabled if the supply fan status is OFF.
  - d. Cooling shall be disabled whenever the outside ambient temperature is below 40°F (adj.).
  
- 4) Heating Control:
  - a. When the zone temperature is below the zone heating setpoint, the control system shall activate or deactivate heater stages as required to maintain the zone temperature at the heating setpoint.
  - b. Heating shall be disabled if the supply fan status is OFF.
  - c. Heating shall be disabled whenever the outside ambient temperature is above 70°F (adj.).
  
- 5) Temperature Monitoring:
  - a. The control system shall monitor the RTU mixed air temperature and supply air temperature.
  - b. Alarms shall be provided as follows:

- i. High Supply Air Temp: The supply air temperature is greater than 120°F (adj.) for 5 minutes (adj.). Disable the RTU until the alarm is manually reset.
  - ii. Low Supply Air Temp: The supply air temperature is less than 40°F (adj.) 5 minutes (adj.). Disable the RTU until the alarm is manually reset.
  
- 6) Dehumidification:
  - a. **If the RTU is specified to have dehumidification on the Equipment Control List**, provide a relative humidity sensor located in the zone served. Provide the following alarms:
    - i. High Relative Humidity: The relative humidity is greater than 65% (adj.).
  
  - b. For RTUs with **“Hot Gas Reheat”** dehumidification specified on the Equipment List:
    - i. The RTU is equipped with a hot-gas reheat coil.
    - ii. If the zone relative humidity exceeds 60% (adj.) while in occupied mode or unoccupied mode, the system shall be forced into dehumidification operation.
    - iii. The cooling coil and hot-gas reheat coil shall be operated in tandem to dehumidify the supply air until the zone relative humidity falls below 55% (adj.) while maintaining the zone temperature at the occupied cooling setpoint. A status indicator shall be provided on the control system graphic to indicate whenever dehumidification mode is active.
  
  - c. For RTUs with **“Cycle Max Cool”** dehumidification specified on the Equipment List:
    - i. If the zone relative humidity exceeds 65% (adj.) while in occupied mode or unoccupied mode, the system shall be forced into dehumidification operation:
      - 1. The control system shall force the RTU into maximum cooling for a period of 15 minutes (adj.) with the outside air damper fully closed. The maximum cooling period shall be stopped early if the zone temperature falls below 65°F (adj.) to prevent overcooling.
      - 2. Next, the system will enter a warm-up period, activating heat if necessary until the zone temperature equals or exceeds the occupied cooling setpoint. There shall also be a time delay to

ensure the warm-up period lasts for a minimum of 5 minutes (adj.) before allowing the dehumidification cycle to repeat.

3. If the zone relative humidity is above the maximum setpoint after the warm-up period, the maximum cooling dehumidification cycle will repeat.
4. If the zone relative humidity is below the maximum setpoint after the warm-up period, the system will return to normal occupied or unoccupied mode per the time schedule.

7) **Carbon Dioxide (CO<sub>2</sub>) Demand-Controlled Ventilation (if “CO<sub>2</sub> DCV” is specified on the Equipment List):**

- a. Provide a CO<sub>2</sub> sensor located in the zone served. The control system shall monitor the zone CO<sub>2</sub> concentration and use it as a reference to control outside the air volume.
- b. While the RTU is operating in occupied mode, the 2-position outside air damper shall be opened or closed based on CO<sub>2</sub>:
  - i. The outside air damper shall open to the maximum design ventilation position at or above 1000 PPM (adj.).
  - ii. The outside air damper shall be fully closed at or below 800 PPM (adj.).
- c. Alarms shall be provided as follows:
  - i. High Zone CO<sub>2</sub> Concentration: The zone air CO<sub>2</sub> concentration is greater than 1200 PPM (adj.) for 15 minutes (adj.) while the system is running in occupied mode and the outside air damper is commanded open.
  - ii. occupied mode and the outside air damper is commanded open.

8) **Economizer Operation (if “Economizer” specified on the equipment list):**

- a. When the outside air temperature is between 70°F and 40°F (adj.) AND the outside air enthalpy is 28 Btu/lb (adj.) or less, the control system or factory-installed unit controller shall enable economizer mode.
- b. While economizer mode is enabled, the outside air damper and return air damper will be controlled to maximize free cooling:
  - a. Control dampers to 100% outside air (0% return air) for maximum cooling, and to the design ventilation position for maximum heating as required to meet the temperature setpoint.

- b. If the outside air damper is fully open and more cooling is required, the cooling system shall be enabled. The outside air damper shall not begin to close until the cooling system is no longer required to maintain setpoint.
  - c. If the outside air damper is closed to the design ventilation position and more heating is required, the heating system shall be enabled. The outside air damper shall not begin to open until the heating system is no longer required to maintain setpoint.
- c. Economizer mode shall have priority over CO2 Demand-Controlled Ventilation (if present) to override outside air damper control fully open even if ventilation is not required to meet the CO2 setpoint.

## DX Packaged RTU Points Summary

*Typical of Each*

Point Name	Point Type				Show on Graphic
	AI	DI	AO	DO	
Zone Temperature	X				X
Occupant Override		X			X
Zone/RA Relative Humidity (2)	X				X
Zone/RA CO2 Concentration (5)	X				X
Supply Air Temperature	X				X
Mixed Air Temperature	X				X
Supply Fan Start/Stop				X	X
Supply Fan Run Status		X			X
Cooling Stage 1				X	X
Cooling Stage 2 (1)				X	X
Heating Stage 1				X	X
Heating Stage 2 (1)				X	X
Hot Gas Reheat Coil Status (3)		X			X
Outside Air Damper Control (6)			X	X	X
<b>Totals</b>	<b>5</b>	<b>3</b>	<b>1</b>	<b>6</b>	
	<b>15</b>				

Additional Settings and Statuses to Show on Graphic
Current Zone Temperature Setpoint
Current Schedule Status (Occupied or Unoccupied)
Dehumidification Mode Status (2)
Economizer Mode Status (5)
Active Program Overrides
Active Alarms

Alarms
High Zone Temperature
Low Zone Temperature
Supply Fan Failure
Supply Fan Running in Hand
Supply Fan Runtime Exceeded
High Supply Air Temperature
Low Supply Air Temperature
High Relative Humidity (2)
High CO2 Concentration (4)

Adjustable Control Settings (At Minimum)	Initial Setting
Occupied Zone Temperature Cooling Setpoint	74°F
Occupied Zone Temperature Heating Setpoint	68°F
Unoccupied Zone Temperature Cooling Setpoint	85°F
Unoccupied Zone Temperature Heating Setpoint	55°F
Zone Temperature Cooling/Heating Offset (Drift)	+/-1.5°F
Occupancy Override Run Time	30 minutes
Minimum Fan Run Time / Off-Time	5 minutes
Minimum Compressor Runtime/Off-Time	2 minutes
Cooling OAT Lockout	Below 40°F
Heating OAT Lockout	Above 70°F
Relative Humidity Setpoint (2)	SEE SEQUENCE
Maximum CO2 Setpoint (4)	1000 PPM
Economizer High Limit OA Dry Bulb Temperature (4)	70°F
Economizer High Limit OA Enthalpy (5)	28 BTU/LB
Economizer Low Limit OA Dry Bulb Temperature (5)	40°F
Minimum CO2 Setpoint (5)	800 PPM

**NOTES:**

- 1) Verify number of heat/cool stages per unit
- 2) When dehumidification specified on the equipment list.
- 3) Only for units with a hot-gas reheat coil.
- 4) When CO2 DCV specified on the equipment list.
- 5) When Economizer specified on the equipment list.
- 6) Modulating damper for Economizer-equipped units.



## **14. HYDRONIC FAN COIL UNIT**

- 1) Run Conditions
  - a. The control system shall command the Fan Coil Unit (FCU) to run according to a User-defined occupied/unoccupied time schedule with the following settings:
    - i. In occupied mode the FCU shall operate continuously while cooling and heating is controlled to maintain a 74°F (adj.) zone cooling setpoint and a 68°F (adj.) zone heating setpoint.
    - ii. In unoccupied mode (night setback) the FCU shall cycle on and off as needed to maintain an 85°F (adj.) zone cooling setpoint and a 55°F (adj.) zone heating setpoint, with a +/-2°F (adj.) offset. To prevent short-cycling the FCU fan shall run for and be off for a minimum period of 5 minutes each (adj.).
  - b. Zone Occupant Override: A timed local override control shall allow an occupant to override the schedule and place the system into occupied mode for a set period of time, adjustable by the control system operator. At the expiration of this time, control of the system shall automatically return to the schedule. For chilled water systems, we recommend that the override function remain locked off to avoid unscheduled plant operation.
  - c. Alarms shall be provided as follows:
    - i. High Zone Temp: The zone temperature is greater than the cooling setpoint by 5°F (adj.) after the FCU has been commanded to run for 60 minutes (adj.).
    - ii. Low Zone Temp: The zone temperature is less than the heating setpoint by 5°F (adj.) after the FCU has been commanded to run for 60 minutes (adj.).
- 2) Start/Stop Sequence
  - a. When the FCU is called to run, the control system will command the supply fan to run and enable cooling or heating as required to meet the zone temperature setpoint.
  - b. The control system shall open the outside air damper to the design ventilation position during occupied mode operation only. The outside air damper shall have a delay of 30 minutes (adj.) before opening during occupied mode start-up. The outside air damper shall remain closed during unoccupied mode.
  - c. When the FCU is called to stop, the control system shall stop the supply air fan, fully close the outside air damper, and disable cooling and heating.



- 3) Supply Fan Control:
  - a. The supply fan shall run at constant speed anytime the FCU is commanded to run.
  - b. The supply fan on/off status shall be monitored by the control system.
  - c. Alarms shall be provided as follows:
    - i. Supply Fan Failure: The fan status is off 2 minutes (adj.) after being commanded on.
    - ii. Supply Fan in Hand: The fan status is on 2 minutes (adj.) after being commanded off.
    - iii. Supply Fan Runtime Exceeded: Status runtime exceeds a User-definable limit.
- 4) Cooling Control:
  - a. When the zone temperature is above the zone cooling setpoint, the control system shall adjust the cooling coil valve position to maintain the zone temperature at the zone cooling setpoint.
  - b. Cooling shall be disabled if the supply fan status is OFF.
  - c. Cooling shall be disabled whenever the outside ambient temperature is below 40°F (adj.).
- 5) Heating Control:
  - a. When the zone temperature is below the zone heating setpoint, the control system shall adjust the heating coil valve position to maintain the zone temperature at the heating setpoint.
  - b. Heating shall be disabled if the supply fan status is OFF.
  - c. Heating shall be disabled whenever the outside ambient temperature is above 70°F (adj.), unless there is a call for dehumidification reheat.
- 6) Temperature Monitoring:
  - a. The control system shall monitor the FCU entering/return air temperature, chilled water cooling coil leaving air temperature, and supply air temperature.
  - b. Alarms shall be provided as follows:

- i. High Supply Air Temp: The supply air temperature is greater than 120°F (adj.) 5 minutes (adj.). Disable the FCU until the alarm is manually reset.
- ii. Low Supply Air Temp: The supply air temperature is less than 35°F (adj.) 5 minutes (adj.). Disable the FCU until the alarm is manually reset.

7) Dehumidification:

- c. **If the FCU is specified to have dehumidification on the Equipment Control List,** provide a relative humidity sensor located in the zone served. Provide the following alarms:
  - i. High Relative Humidity: The relative humidity is greater than 65% (adj.).
- d. For FCUs with **“HW Reheat”** dehumidification specified on the Equipment List:
  - i. If the relative humidity exceeds 60% (adj.) while in occupied mode or unoccupied mode, the system shall be forced into dehumidification mode operation:
    - 1. The cooling coil shall be controlled to provide maximum cooling, down to a minimum coil leaving air temperature of 52°F (adj.). If cooling is not available from the central plant, the system will request cooling and wait until requisite number of requests are satisfied to activate the central plant.
    - 2. The heating coil will be allowed to operate simultaneously with the cooling coil. The heating coil shall be controlled to maintain the zone temperature at the occupied cooling setpoint.
  - ii. The system shall operate in dehumidification mode until the relative humidity falls below 55% (adj.)

8) Carbon Dioxide (CO2) Demand-Controlled Ventilation:

- a. **If the FCU is specified to have “CO2 DCV” on the Equipment Control List,** provide a CO2 sensor located in the zone served. The control system shall monitor the zone CO2 concentration and use it as a reference to control outside the air volume.
- b. While the FCU is operating in occupied mode, the 2-position outside air damper shall be opened or closed based on CO2:
  - i. The outside air damper shall open to the maximum design ventilation position at or above 1000 PPM (adj.).
  - ii. The outside air damper shall be fully closed at or below 800 PPM (adj.).

- c. Alarms shall be provided as follows:
  - ii. High CO2 Concentration: The measured CO2 concentration is greater than 1200 PPM (adj.) for 15 minutes (adj.) while the system is running in occupied mode and the outside air damper is commanded open.

9) Economizer Operation (**when Economizer is specified on the Equipment List**):

- a. When the outside air temperature is below 70°F (adj.) AND the outside air enthalpy is 28 Btu/lb (adj.) or less (65% RH), the control system shall enable economizer mode during scheduled occupied operation only.
- b. The economizer mode shall be locked out below 50°F (adj.) to prevent excessive heating load.
- c. While economizer mode is enabled:
  - i. The tempered outside air damper shall close fully. The economizer damper and return air damper will be controlled to maintain the zone temperature setpoint:
    - 1. Control dampers to 100% outside air and 0% return air for maximum cooling.
    - 2. Control dampers to 30% outside air and 60% return air for maximum heating.
  - ii. If the outside air damper is fully open and more cooling is required, then the chilled water valve shall be controlled to meet the zone temperature setpoint.
  - iii. If the outside air damper is closed to the minimum position and more heating is required, then the hot water valve shall be controlled to meet the zone temperature setpoint.
- d. Economizer mode shall have priority over CO2 Demand-Controlled Ventilation (if present) to override outside air damper control as described.

## Hydronic Fan Coil Unit Points Summary

*Typical of Each*

Point Name	Point Type				Show on Graphic
	AI	DI	AO	DO	
Zone Temperature	X				X
Zone Occupant Override		X			X
Zone Relative Humidity (1)	X				X
Zone CO2 PPM (2)	X				X
Supply Air Temperature	X				X
Entering Air Temperature	X				X
CHW Coil Leaving Air Temp.	X				X
Supply Fan Start/Stop				X	X
Supply Fan Run Status		X			X
Cooling Valve Control			X		X
Heating Valve Control			X		X
Outside Air Damper Control				X	X
Return Air Damper Control (3)			X		X
Economizer Damper Control (3)			X		X
<b>Totals</b>	<b>6</b>	<b>2</b>	<b>4</b>	<b>2</b>	
	<b>14</b>				

Additional Settings and Statuses to Show on Graphic
Current Zone Temperature Setpoint
Current Schedule Status (Occupied or Unoccupied)
Dehumidification Mode Status (1)
Economizer Mode Status (3)
Active Program Overrides
Active Alarms

Alarms
High Zone Temperature
Low Zone Temperature
Supply Fan Failure
Supply Fan Running in Hand
Supply Fan Runtime Exceeded
High Supply Air Temperature
Low Supply Air Temperature
High Relative Humidity (1)
High CO2 Concentration (2)

Adjustable Control Settings (At Minimum)	Initial Setting
Occupied Zone Temperature Cooling Setpoint	74°F
Occupied Zone Temperature Heating Setpoint	68°F
Unoccupied Zone Temperature Cooling Setpoint	85°F
Unoccupied Zone Temperature Heating Setpoint	55°F
Minimum Fan Runtime/Off-Time	5 minutes
Zone Occupant Override Time	0 min. / DISABLED
Outside Air Damper Delay at Start-Up	30 minutes
Cooling OAT Lockout	Below 40°F
Heating OAT Lockout	Above 70°F
Maximum Relative Humidity Setpoint (1)	60%
Dehumidification Setpoint (1)	55%
Dehumidification CHW Coil LAT Setpoint (1)	52°F
Occupied Maximum CO2 PPM Setpoint (2)	1000 PPM
Economizer High Limit OA Dry Bulb Temperature (3)	70°F
Economizer High Limit OA Enthalpy (3)	28 BTU/LB
Economizer Low Limit OA Dry Bulb Temperature (3)	50°F

**NOTES:**

- 1) When Dehumidification specified on the equipment list.
- 2) When CO2 DCV specified on the equipment list.
- 3) When Economizer specified on the equipment list.



## **15. HYDRONIC OUTSIDE AIR HANDLING UNIT**

- 1) Run Conditions
  - a. The control system shall command the Outside Air Handling Unit (OAHU) to run according to a User-defined occupied/unoccupied time schedule, or when any zone served by the OAHU is in occupied mode.
- 2) Start/Stop Sequence
  - a. When the OAHU is called to run, the control system will open the outside air damper, command the supply fan to run and enable cooling or heating as required to meet the supply air temperature setpoint.
  - b. The supply fan start shall be delayed if the outside ambient temperature is less than 35°F (adj.) to avoid triggering the freeze-stat. The hot water coil valve will open to 100% (adj.), and the supply fan will not be allowed to start until the boiler system hot water supply temperature is above 100°F (adj.). After the supply fan is allowed to start, the system will resume normal operation.
  - c. When the OAHU is called to stop, the control system shall stop the supply air fan, close the outside air damper, and disable cooling and heating.
- 3) Supply Fan Control:
  - a. The supply fan shall run anytime the OAHU is commanded to run, unless shut down on safeties.
  - b. The control system shall measure duct static pressure and adjust the supply fan VFD speed to maintain the duct static pressure at 1.0" w.g. (adj.). The fan VFD shall be controlled to operate between the minimum and maximum speed settings.
  - c. The supply fan VFD maximum speed and duct static pressure settings shall be determined by the test and balance contractor to achieve design air flow. The minimum speed shall be 15% (adj.).
  - d. The supply fan on/off status shall be monitored by the control system.
  - e. Alarms shall be provided as follows:
    - i. Supply Fan Failure: The fan status is off 2 minutes (adj.) after being commanded on.
    - ii. Supply Fan in Hand: The fan status is on 2 minutes (adj.) after being commanded off.

- iii. Supply Fan Runtime Exceeded: Status runtime exceeds a User-definable limit.
  - iv. Supply Fan VFD Fault: Fan VFD is reporting an error.
  - v. High Duct Static Pressure: The duct static pressure is greater than 2.5" w.c. (adj.). Disable the OAHU until the alarm is manually reset.
- 4) Supply Air Temperature Setpoint:
  - a. During cooling mode, the supply air temperature setpoint shall be 54°F (adj.). Cooling mode shall be enabled when the outside air temperature is above 55°F (adj.).
  - b. During heating mode, the supply air temperature setpoint shall be 60°F (adj.). Heating mode shall be enabled when the outside air temperature is below 50°F (adj.).
  - c. When neither cooling mode nor heating mode are active, the OAHU shall supply unconditioned outside air (cooling and heating locked out).
- 5) Cooling Control:
  - a. When the supply air temperature is above the cooling setpoint, the control system shall adjust the cooling coil valve position to maintain the supply air temperature at setpoint.
  - b. Cooling shall be disabled if the supply fan status is OFF.
  - c. Cooling shall be disabled whenever the OAHU is in heating mode.
- 5) Heating Control:
  - a. When the supply air temperature is below the heating setpoint, the control system shall adjust the heating coil valve position to maintain the supply air temperature at setpoint.
  - b. Heating shall be disabled if the supply fan status is OFF.
  - c. Heating shall be disabled whenever the OAHU is in cooling mode.
- 6) Temperature Monitoring:
  - a. The control system shall monitor the OAHU entering (outside) air temperature and supply air temperature.
  - b. Alarms shall be provided as follows:

- i. High Supply Air Temp: The supply air temperature is greater than 120°F (adj.) 5 minutes (adj.). Disable the OAHU until the alarm is manually reset.
- ii. Low Supply Air Temp: The supply air temperature is less than 35°F (adj.) 5 minutes (adj.). Disable the OAHU until the alarm is manually reset.

7) Freeze Protection:

- a. If the freeze-stat status is tripped, stop the supply air fan, close the outside air damper, and open the cooling coil and heating coil valves 30% (adj.).
- b. Alarms shall be provided as follows:
  - i. Freeze-Stat Trip: The unit shall operate as specified above and generate an alarm upon receiving a freeze-stat trip status.

**Hydronic Outside Air Handling Unit Points Summary**

*Typical of Each*

Point Name	Point Type				Show on Graphic
	AI	DI	AO	DO	
Supply Air Temperature	X				X
Outside Air Temperature	X				X
Freezestat Trip Status		X			X
Supply Fan Start/Stop				X	X
Supply Fan VFD Speed			X		X
Supply Fan Run Status		X			X
Supply Fan VFD Fault		X			X
Duct Static Pressure	X				X
Cooling Valve Control			X		X
Heating Valve Control			X		X
Outside Air Damper Control			X		X
<b>Totals</b>	<b>3</b>	<b>3</b>	<b>4</b>	<b>1</b>	
	<b>11</b>				

Additional Settings and Statuses to Show on Graphic
Current Supply Air Temperature Setpoint
Current Schedule Status (Occupied or Unoccupied)
Current Number of Zone Requests
Active Program Overrides
Active Alarms

Alarms
Supply Fan Failure
Supply Fan Running in Hand
Supply Fan Runtime Exceeded
Supply Fan VFD Fault
High Duct Static Pressure
High Supply Air Temperature
Low Supply Air Temperature
Freezestat Trip

Adjustable Control Settings (At Minimum)	Initial Setting
Duct Static Pressure Setpoint	1" WC
Maximum Supply Fan VFD Speed	SET BY T&B
Minimum Supply Fan VFD Speed	15% / 9 Hz
Cooling Mode Supply Air Temperature Setpoint	54°F (OAT > 55°F)
Heating Mode Supply Air Temperature Setpoint	60°F (OAT < 50°F)

**NOTES:**



## **16. DX SPLIT SYSTEM HEAT PUMPS**

- 1) Run Conditions
  - a. The control system shall command the Heat Pump to run according to a User-defined occupied/unoccupied time schedule with the following settings:
    - i. In occupied mode, the Heat Pump shall operate continuously while cooling and heating are controlled to maintain a 74°F (adj.) zone cooling setpoint and a 68°F (adj.) zone heating setpoint, with a +/-1.5°F (adj.) offset.
    - ii. In unoccupied mode (night setback) the Heat Pump shall cycle on and off as needed to maintain an 85°F (adj.) zone cooling setpoint and a 55°F (adj.) zone heating setpoint, with a +/-1.5°F (adj.) offset. To prevent short-cycling, the AHU fan shall run for and be off for a minimum period of 5 minutes each (adj.).
  - b. Zone Unoccupied Override: A timed local override control shall allow an occupant to override the schedule and place the system into occupied mode for 30 minutes (adj.). At the expiration of this time, control of the system shall automatically return to the schedule.
  - c. The supply fan shall run anytime the Heat Pump is commanded to run, unless shutdown on safeties. The fan on/off status shall be monitored by the control system.
  - d. Alarms shall be provided as follows:
    - i. Supply Fan Failure: The fan status is off 2 minutes (adj.) after being commanded on.
    - ii. Supply Fan in Hand: The fan status is on 2 minutes (adj.) after being commanded off.
    - iii. Supply Fan Runtime Exceeded: Status runtime exceeds a User-definable limit.
    - iv. High Zone Temp: The zone temperature is greater than the cooling setpoint by 5°F (adj.) after the Heat Pump has been commanded to run for 60 minutes (adj.).
    - v. Low Zone Temp: The zone temperature is less than the heating setpoint by 5°F (adj.) after the Heat Pump has been commanded to run for 60 minutes (adj.).



- 2) Heat Pump Start/Stop Sequence
  - a. When the Heat Pump is called to run, the control system shall command the supply fan to run and enable cooling or heating as required to meet the zone air temperature setpoint.
  - b. If the Heat Pump has a motorized outside air damper, the control system shall open the damper to the design ventilation volume position during occupied mode operation only. The outside air damper shall remain closed during unoccupied mode.
  - c. When the Heat Pump is called to stop, the control system shall stop the supply air fan, fully close the outside air damper and disable cooling and heating.
- 3) Cooling Control:
  - a. When the zone temperature is above the zone cooling setpoint, the control system shall activate or deactivate compressors compressor stages as required to maintain the zone temperature at the cooling setpoint.
  - b. To prevent short-cycling, the compressors shall have a minimum on and off time of 2 minutes (adj.)
  - c. Cooling shall be disabled if the supply fan status is OFF.
  - d. Cooling shall be disabled whenever the outside ambient temperature is below 40°F (adj.).
- 4) Heating Control:
  - a. When the zone temperature is below the zone heating setpoint, the control system shall operate the Heat Pump with the reversing valve in heating mode. The control system shall activate or deactivate compressor stages as required to maintain the zone temperature at the heating setpoint
  - b. The control system shall operate the auxiliary electric heater if the zone temperature is 2°F (adj.) or more below setpoint while the system is operating in heating mode.
  - c. Heating shall be disabled if the supply fan status is OFF.
  - d. Heating shall be disabled whenever the outside ambient temperature is above 70°F (adj.).
- 5) Temperature Monitoring:
  - a. The control system shall monitor the Heat Pump mixed air temperature and supply air temperature.

- b. Alarms shall be provided as follows:
  - i. High Supply Air Temp: The supply air temperature is greater than 120°F (adj.) 5 minutes (adj.). Disable the Heat Pump until the alarm is manually reset.
  - ii. Low Supply Air Temp: The supply air temperature is less than 40°F (adj.) 5 minutes (adj.). Disable the Heat Pump until the alarm is manually reset.

6) Dehumidification:

- a. **If the Heat Pump is specified to have dehumidification on the Equipment Control List**, provide a relative humidity sensor located in the zone served. Provide the following alarms:
  - i. High Relative Humidity: The relative humidity is greater than 65% (adj.).
- b. For Heat Pumps with **“Cycle Max Cool”** dehumidification specified on the Equipment List:
  - i. If the zone relative humidity exceeds 65% (adj.) while in occupied mode or unoccupied mode, the system shall be forced into dehumidification operation:
    1. The control system shall force the Heat Pump into maximum cooling for a period of 15 minutes (adj.) with the outside air damper (if present) fully closed. The maximum cooling period shall be stopped early if the zone temperature falls below 65°F (adj.) to prevent overcooling.
    2. Next, the system will enter a warm-up period, activating heat if necessary until the zone temperature equals or exceeds the occupied cooling setpoint. There shall also be a time delay to ensure the warm-up period lasts for a minimum of 5 minutes (adj.) before allowing the dehumidification cycle to repeat.
    3. If the zone relative humidity is above the maximum setpoint after the warm-up period, the maximum cooling dehumidification cycle will repeat.
    4. If the zone relative humidity is below the maximum setpoint after the warm-up period, the system will return to normal occupied or unoccupied mode per the time schedule.

- 7) Carbon Dioxide (CO2) Demand-Controlled Ventilation (if “CO2 DCV” is specified on the Equipment List):
- a. Provide a CO2 sensor located in the zone served. The control system shall monitor the zone CO2 concentration and use it as a reference to control outside the air volume.
  - b. While the Heat Pump is operating in occupied mode, the 2-position outside air damper shall be opened or closed based on CO2:
    - i. The outside air damper shall open to the maximum design ventilation position at or above 1000 PPM (adj.).
    - ii. The outside air damper shall be fully closed at or below 800 PPM (adj.).
  - c. Alarms shall be provided as follows:
    - i. High Zone CO2 Concentration: The zone air CO2 concentration is greater than 1200 PPM (adj.) for 15 minutes (adj.) while the system is running in occupied mode and the outside air damper is commanded open.

## DX Heat Pump Split System Points Summary

*Typical of Each*

Point Name	Point Type				Show on Graphic
	AI	DI	AO	DO	
Zone Temperature	X				X
Occupant Override		X			X
Zone Relative Humidity (2)	X				X
Zone CO2 Concentration (3)	X				X
Supply Air Temperature	X				X
Mixed Air Temperature	X				X
Supply Fan Start/Stop				X	X
Supply Fan Run Status		X			X
Cooling/Heating Stage 1				X	X
Cooling/Heating Stage 2 (1)				X	X
Auxiliary Heat				X	X
Reversing Valve Control				X	X
Outside Air Damper Open/Close				X	X
<b>Totals</b>	<b>5</b>	<b>2</b>	<b>0</b>	<b>6</b>	
	<b>13</b>				

Additional Settings and Statuses to Show on Graphic
Current Zone Temperature Setpoint
Current Schedule Status (Occupied or Unoccupied)
Dehumidification Mode Status (2)
Active Program Overrides
Active Alarms

Alarms
High Zone Temperature
Low Zone Temperature
Supply Fan Failure
Supply Fan Running in Hand
Supply Fan Runtime Exceeded
High Supply Air Temperature
Low Supply Air Temperature
High Zone Relative Humidity (2)
High Zone CO2 Concentration (3)

Adjustable Control Settings (At Minimum)	Initial Setting
Occupied Zone Temperature Cooling Setpoint	74°F
Occupied Zone Temperature Heating Setpoint	68°F
Unoccupied Zone Temperature Cooling Setpoint	85°F
Unoccupied Zone Temperature Heating Setpoint	55°F
Zone Temperature Cooling/Heating Offset (Drift)	+/-1.5°F
Occupancy Override Run Time	30 minutes
Minimum Fan Run Time / Off-Time	5 minutes
Minimum Compressor Runtime/Off-Time	2 minutes
Cooling OAT Lockout	Below 40°F
Heating OAT Lockout	Above 70°F
Maximum Relative Humidity Setpoint (2)	SEE SEQUENCE
Maximum CO2 Setpoint (3)	1000 PPM
Minimum CO2 Setpoint (3)	800 PPM

**NOTES:**

- 1) Verify number of heat/cool stages per unit
- 2) When dehumidification specified on the equipment list.
- 3) When CO2 DCV specified on the equipment list.

