23 00 00 – HVAC General Requirements

DIVISION 23 – Heating, Ventilating, and Air Conditioning

STATEMENT OF PURPOSE & BACKGROUND

- General Information regarding HVAC requirements throughout the district.
- Revision history of section:
  - 05/27/2021 (date of adoption)
  - 10/28/2022
  - 01/25/2023
  - 12/28/2023 *(clarified radiation cover and accessories)*

GENERAL INFORMATION AND REQUIREMENTS

- Provide one-line diagrams and valve schedules as part of construction documents.
- Selective Demolition and Salvage
  - Remove abandoned duct, equipment, devices, conduit and wiring and close/fill any wall, floor, ceiling, roof penetrations where abandoned items are removed.
  - Remove and save all American Automatrix field level controllers and thermostats on sites that are no longer be needed. Turn over controllers to SPPS, including the following models: MC, GC, GX, RX, DX, GPC1, GPC2, SBC-VAV, TC1s, and all thermostats.
- Air intakes:
  - All fresh air intakes on HVAC equipment, including rooftop units, shall be equipped with bird screening only. No insect screen is permitted.
  - Air intake screens must be serviceable per code and must be serviceable from the inside.
  - When locating fresh air intakes, consider proximity to parking lots and bus loading areas to avoid bringing in exhaust fumes.
- Access for service and maintenance:
  - Provide access doors in ducts as necessary to accomplish maintenance. Access doors shall be a minimum of 24” x 24”, but at least one dimension of 30” minimum is preferable.
  - When an air intake plenum is used, reinforce the bottom of the duct to allow a worker to enter the duct without deforming or damaging the duct floor.
  - Verify that locations for servicing filters and other components are easily reachable, within established safety zones, and comply with all applicable codes.
- Provide cooling to Main Data Frames (MDF), typical. Consultant should review with Owner options for cooling MDFs at project sites.
- Split systems for elevator machine rooms shall have local, wall-mounted controls; remote control is not permitted.
- Radiation:
  - Specify heavy duty slope-top radiation enclosure; Basis of Design ‘Guardian GSBS 12P’ Or prior approved equal. - 12 ga. cover and related accessories.

SPPS Preferred Manufacturers

Equipment Type	Manufacturer	Notes
Steam Boilers	• L.E.S. / Aldrich • Cleaver-Brooks • Superior • Burnham Commercial	
Hot Water Boilers	• Cleaver-Brooks • Superior • Burnham Commercial	
Condensing Boilers	• Aerco • Lochinvar • RBI	
Burners	• Power Flame • Industrial Combustion (I.C.) • Cleaver-Brooks	
Pumps	• Bell & Gossett (B&G) • Taco • Armstrong	
Air Handling Units	• Daikin • York • Trane • Haakon Industries	
Roof Top Units	• Daikin • Trane • York	Prefer Air Handling Units (AHUs) located within buildings; avoid Roof Top Units (RTUs) wherever possible.
Make Up Air Units	• Titan • Greenheck	
Outside Air Dampers	• Greenheck	
Exhaust Fans	• Greenheck Vari-Green • Cook	Direct-drive wherever possible
Chillers	• Daikin • Trane	Air-cooled chillers only; no water-cooled chillers

Energy Recovery Units	• XeteX • Venmar	Prefer Flat plate type Energy Recovery Units (ERUs) over wheel-type ERUs where feasible.

- COMMON CONTROLS NOTES AND SEQUENCES:
  - See the common control notes and standard operating sequences and schematics that follow. Designers are to use the SPPS standard sequences as their starting place in developing operating sequences appropriate for the systems in place in their projects.
  - Light green colored text is a note to the designer.
  - Other text color indicates a choice needs to be made. Mostly choices will be in red text, but where there are multiple choices to be made within a single section, other colors are used.

End of Section

SAINT PAUL PUBLIC SCHOOLS
CONTROL DOCUMENT STANDARDS

DOCUMENT INTENT:

These control sequence and schematic templates are provided by Saint Paul Public Schools to help design engineers conform to district standards when designing projects. These are for reference only; it is expected that sequence language will need to be changed, added, and/or deleted and schematics will need to be modified based on project requirements prior to issuing documents to bidders. All questions regarding these documents should be directed to the relevant SPPS project manager.

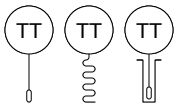
CONTROL POINT LEGEND:

ALM	ALARM	FBK	FEEDBACK	RLAF	RELIEF AIR FLOW
BLDP	BUILDING PRESSURE	FIRE	FIRE ALARM	RLAH	RELIEF AIR HUMIDITY
BYPV	BYPASS VALVE	FRZ	FREEZESTAT	RLAP	RELIEF AIR PRESSURE
CAP	CAPACITY	GAS	NATURAL GAS CONSUMPTION	RLAT	RELIEF AIR TEMPERATURE
CES	CLOSED END SWITCH	HIP	HIGH PRESSURE SAFETY	RLAD	RELIEF AIR DAMPER
CHWF	CHILLED WATER FLOW	HTGV	HEATING VALVE	RAD	RETURN AIR DAMPER
CHWP	CHILLED WATER PRESSURE	HWF	HOT WATER FLOW	RAF	RETURN AIR FLOW
CHWT	CHILLED WATER TEMPERATURE	HWP	HOT WATER PRESSURE	RAH	RETURN AIR HUMIDITY
CLGV	COOLING VALVE	HWT	HOT WATER TEMPERATURE	RAP	RETURN AIR PRESSURE
CMD	COMMAND	ISOV	ISOLATION VALVE	RAQ	RETURN AIR QUALITY (CO2)
CRT	CURRENT	LOP	LOW PRESSURE SAFETY	RAT	RETURN AIR TEMPERATURE
CWF	CONDENSER WATER FLOW	MAF	MIXED AIR FLOW	SMK	SMOKE DETECTOR
CWP	CONDENSER WATER PRESSURE	MAP	MIXED AIR PRESSURE	SPD	SPEED
CWT	CONDENSER WATER TEMPERATURE	MAT	MIXED AIR TEMPERATURE	SPT	SETPOINT
DAD	DISCHARGE AIR DAMPER	OAD	OUTSIDE AIR DAMPER	STS	STATUS
DAF	DISCHARGE AIR FLOW	OAF	OUTSIDE AIR FLOW	ZNH	ZONE HUMIDITY
DAH	DISCHARGE AIR HUMIDITY	OAH	OUTSIDE AIR HUMIDITY	ZNO	ZONE OCCUPANCY SENSOR
DAP	DISCHARGE AIR PRESSURE	OAT	OUTSIDE AIR TEMPERATURE	ZNP	ZONE PRESSURE
DAT	DISCHARGE AIR TEMPERATURE	OES	OPEN END SWITCH	ZNQ	ZONE QUALITY (CO2)
ENRG	ELECTRICAL ENERGY CONSUMPTION	PWR	POWER	ZNT	ZONE TEMPERATURE

POINT TABLE ABBREVIATIONS:

AI	=	ANALOG INPUT
AO	=	ANALOG OUTPUT
DI	=	DIGITAL/BINARY INPUT
DO	=	DIGITAL/BINARY OUTPUT
INT	=	INTEGRATION POINT
NET	=	NETWORK POINT
R	=	READABLE POINT
R/W	=	READABLE AND WRITABLE POINT
#	=	TOTAL NUMBER OF POINTS OF THAT TYPE

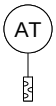
SYMBOL LEGEND



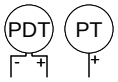
TEMPERATURE SENSORS (BULB, SENSOR, WELL)

LOW TEMPERATURE SWITCH

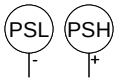
HUMIDITY SENSOR



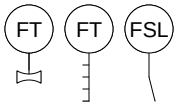
AIR QUALITY SENSOR (CO2, CO, ETC…)



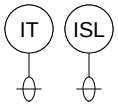
PRESSURE SENSORS (DIFFERENTIAL, STATIC/GAUGE)



PRESSURE SWITCHES (LOW, HIGH)



FLOW SENSORS, SWITCH (WATER, AIR, SWITCH)

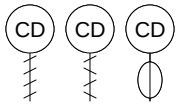


CURRENT SENSOR, SWITCH

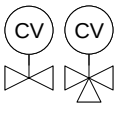
OCCUPANCY SWITCH

POWER METER

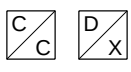
NATURAL GAS METER



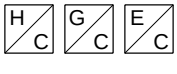
CONTROL DAMPERS (PARALLEL, OPPOSED, ROUND)



CONTROL VALVES (TWO-WAY, THREE-WAY)



COOLING COILS (WATER, DIRECT-EXPANSION)



HEATING COILS (WATER, GAS, ELECTRIC

VARIABLE FREQUENCY DRIVE, MOTOR STARTER

COMMON CONTROL NOTES

A. CONTROL DEVICE COMPATIBILITY
   1. Contractor shall be responsible for notifying the design team prior to final controls point check-out if any new or existing controls devices or equipment (valves, dampers, actuators, sensors, controllers, etc.) are not capable of meeting the designed sequence of operations.

B. DDC POINT ADJUSTABILITY DEFINITION
   1. Front graphic page setpoints, (adj.)
      a. Software point values followed by (adj.) shall be adjustable by operators on front graphic screens. These values are expected to be adjusted frequently by operators.
   2. Back graphic page setpoints, (mod.)
      a. Software point values followed by (mod.) shall be modifiable by operator on back graphic screens. These values may be rarely adjusted by more advanced operators. These values shall be placed on back graphic screens, requiring two mouse clicks to access. Intent is to guide operators toward (adj.) values first, and allow advanced users to drill-down deeper and modify the (mod.) setpoints when required.
   3. Parameters
      a. Software point values without any following annotations are not required to be placed on graphic screens. However, modifications to these values shall be readily available using software programming tool. It is not acceptable to require additional steps, such as downloading controllers to apply these modifications.
   4. Hardware Input Points
      a. Operator override of hardware input points is not required.
   5. Hardware Output Points
      a. Operator override of hardware output points is required. Operators with more advanced privileges override these points.

C. DISTRICT-STANDARD GLOBAL LOGIC
   1. The following logic has been developed to allow the district to manage high-level programming logic that must influence equipment across all sites. Global programming exists, but must be linked to all equipment included in this project as necessary.
      a. Peak Demand Limiting (PDL)
         i. When active, automatic PDL logic will step each site through a series of measures to reduce energy consumption. Exceptions to be made for critical environment units, coordinate with district.
            a. Level 1:
               i. AHU discharge air temperature setpoints are adjusted by +/- 5°F
               ii. Space temperature setpoints are adjusted by +/- 2°F
               iii. Scheduled hallway lights are turned off, where motion lights are also present
            b. Level 2:
               i. AHU discharge air temperature setpoints are adjusted by +/- 10°F
               ii. Space temperature setpoints are adjusted by +/- 2°F
               iii. Bathroom exhaust fans are turned off
            c. Level 3:
               i. Chillers and associated pumps are turned off
               ii. DX cooling is turned off
            d. Level 4:
               i. Scheduled classroom lights are turned off, where motion lights are also present

ii. Scheduled inboard lights are turned off, where dual-schedule lighting is used
iii. AHUs are cycled at regular intervals

b. Polar Vortex
   i. When this mode is enabled, all HVAC equipment is indexed to an occupied state. This occurs at a higher priority than ANY scheduling, including optimized start, and disregards current security key status.
   ii. Warmup mode and safety interlocks will remain functional during this mode.
   iii. Minimum outside air damper position will be locked at 0%
   iv. Upon expiration of Polar Vortex mode, outside air damper will slowly resume normal operation over a period of 10 min. (adj.).

c. IAQ Overrides
   i. IAQ overrides shall be used to add a flat percentage to all outside air damper minimum positions, district-wide, with the intent of manually increasing ventilation in all buildings during mild outside air conditions.
   ii. Dampers shall still be allowed to fully close when units are not running.
   iii. Separate overrides shall be available for sites without mechanical cooling and sites with mechanical cooling.
   iv. Each site shall individually have the ability to override the district-wide IAQ override value, for that site only.
   v. An additional setpoint shall be available for units with mechanical cooling at sites that otherwise do not have mechanical cooling (typically administration AHUs with DX cooling). This setpoint shall allow operators to prevent excess energy use by these specific units, while still bringing in additional outside air for the rest of the building.

d. Extended Ventilation
   i. Extended ventilation logic exposes several setpoints that allow building operators to configure how and when equipment will enable outside of normal occupied times. This logic was originally hidden and would only run equipment if it had been off/stagnant for a long period of time, but was modified/exposed to allow greater operator control.
   ii. Site-level setpoints shall also be available, and shall take precedence over district-wide setpoints.
   iii. Automation team shall be able to manually trigger/cancel extended ventilation mode, district-wide.

e. Valve Overrides
   i. Sites with chilled water shall incorporate district-wide chilled water valve logic. This logic is used to force all valves full open in the winter to assist with draining coils, without graphics displaying 100% open chilled water coils.
   ii. Site-level overrides shall take precedence over district-wide override.

f. Night Cooling
   i. Logic shall take advantage of cool night air to pre-cool buildings before the heat of the day sets in.
   ii. Unoccupied cooling setpoints shall temporarily be reduced, only in the morning, and only when outside air temperature is below setpoints.

D. STANDARD TEMPERATURE SETPOINTS
   1. All points shown in this table shall be the default setpoints (adj.) shown on equipment graphics.
   2. A differential of 4°F (adj.) shall be applied to unoccupied setpoints to prevent equipment from rapidly cycling on and off. Equipment shall be indexed to run immediately upon rising above the unoccupied cooling setpoint or falling below the unoccupied heating setpoint, and continue to run until the differential has been met.

3. A differential of 1°F (adj.) shall be applied to occupied setpoints to prevent heating and cooling from rapidly cycling on and off. Equipment shall begin conditioning immediately upon rising above the occupied cooling setpoint or falling below the occupied heating setpoint, and continue to run until the differential has been met.
    a. This does not apply to equipment that modulates to maintain the active occupied or standby setpoint.

	Heating			Cooling		
Zone Description	Unoccupied	Standby	Occupied	Occupied	Standby	Unoccupied
Auditoriums	64°F	-2°F	70°F	75°F	+2°F	85°F
Cafeteria	64°F	-2°F	70°F	75°F	+2°F	85°F
Classrooms	64°F	-2°F	70°F	75°F	+2°F	85°F
Computer Labs	64°F	-2°F	70°F	75°F	+2°F	85°F
Corridors/Halls	64°F	-2°F	70°F	75°F	+2°F	85°F
Gymnasium	64°F	-2°F	70°F	75°F	+2°F	85°F
Locker Room	64°F	-2°F	70°F	75°F	+2°F	85°F
Media Center	64°F	-2°F	70°F	75°F	+2°F	85°F
Multipurpose Room	64°F	-2°F	70°F	75°F	+2°F	85°F
Offices	64°F	-2°F	70°F	75°F	+2°F	85°F
Restrooms	64°F	-2°F	70°F	75°F	+2°F	85°F
School Shops	64°F	-2°F	70°F	75°F	+2°F	85°F
Storage Rooms	64°F	-4°F	70°F	75°F	+4°F	85°F
Swimming Pool Rooms	70°F	N/A	80°F	83°F	N/A	90°F
Building Entry Vestibules	64°F	-4°F	70°F	75°F	+4°F	85°F

E. AHU/RTU, HARDWIRED SAFETIES
1. Safety devices, safeties, must be hardwired. They shall not be passed via software through direct digital controller (DDC).
2. A secondary set of contacts from each safety shall be input to the BAS and a software alarm generated upon change of state.
3. Safety contacts shall be wired such that a closed circuit is a normal condition whenever possible.
    a. Fire/Smoke safety.
        i. Building fire alarm system relays, duct smoke detectors, test switches, etc. shall be furnished and installed by others.
        ii. Connect via dry contacts to devices as instructed by building fire alarm system provider.
        iii. Upon trip, all unit fans to stop, outside air damper and exhaust/relief air damper to close.
    b. Low temperature limit, freeze protection safety.
        i. Provide auto reset, low temperature cutout switch that trips if temperature falls below 35°F (adjustable at device).
        ii. Upon trip, all unit fans to stop, outside air damper and exhaust/relief air damper to close, and unit heating valves to open.
    c. High supply duct pressure cut-out safety.
        i. Provide manual reset pressure cutout switch measuring static pressure in the ductwork as shown in the schematic. Set limit to +3.0 in. wc (adjustable at device).
        ii. Upon trip, all unit fans to stop, outside air damper and exhaust/relief air damper to close.
    d. Low return duct pressure cut-out safety. [Designer Note: use if there is some restriction on return ductwork, such as return VAVs or fire/smoke dampers.]

i. Provide manual reset pressure cutout switch measuring static pressure in the ductwork as shown in the schematic. Set limit to -2.0 in. wc (adjustable at device).
ii. Upon trip, all unit fans to stop, outside air damper and exhaust/relief air damper to close.

e. Low mixed air duct pressure cut-out safety. [Designer Note: use if there is ductwork susceptible to collapsing between OA/RA dampers and unit fan, when mixing dampers are not part of AHU.]
i. Provide manual reset pressure cutout switch measuring static pressure in the ductwork as shown in the schematic. Set limit to -2.0 in. wc (adjustable at device).
ii. Upon trip, all unit fans to stop, outside air damper and exhaust/relief air damper to close.

f. High drain pan level safety. [Designer Note: uncommon in AHUs, usually for FCUs, HPs, etc. Required when risk of damage is involved]
i. Provide auto reset level switch mounted in the cooling coil drain pan. Trip level shall be set such that it trips before the drain pan overflows.
ii. Upon trip, cooling valve(s) shall close.

F. TIME SCHEDULING AND OPTIMIZED START

1. There shall be a minimum of two building time schedules, for use with different areas of the building or usage patterns. For example, one schedule may represent the overall building hours, and another might represent when school is in session or when office workers typically arrive.
2. Every unit, including AHUs, VAVs, EFs, CUHs, etc. shall allow operators to select which time schedule applies via the unit graphic. The selection shall have options for each building time schedule, a custom time schedule specific to unit, “Always Occupied,” and “Always Unoccupied.” For terminal units, such as VAVs, there shall be an additional option of “Follow AHU,” allowing terminal units to simply match the time schedule mode of the associated AHU.
a. The purpose of time schedule selection is to allow easier management of time schedules. Operators may strategically configure selections, so with minimal effort an entire building can be effectively re-scheduled as needed.
b. Equipment utilizing “Follow AHU” schedule shall also match optimized start and unoccupied calls for operation (heating, cooling, dehumidification, extended unoccupancy, cold interior) [Designer note: match unoccupied states with AHU sequence]
3. All time schedules shall have a single holiday schedule linked to them, which shall take precedence over normal time scheduling and leave the building unoccupied. Holidays to be configured per US calendar; coordinate with owner.
4. All time schedules shall have a single school break schedule linked to them, which shall take precedence over normal time scheduling and leave the building unoccupied.
5. All time schedules shall have a single school event schedule linked to them, which shall take precedence over normal time scheduling, holiday scheduling, and school break scheduling and leave the building occupied all day.
6. When the building security system status indicates it is armed, all units shall be indexed to unoccupied. When the system is disarmed, normal operation shall resume. This shall not prevent the function of optimized start sequencing or other global logic programming.
7. Any unit that provides temperature control (not EFs, lighting, etc.) shall include optimized start programming. Optimized start feature shall start the unit early, prior to the time schedule transitioning to occupied. The amount of early run time shall vary daily in order to achieve average zone air temperature between the occupied heating and cooling setpoints. It is intended that the Operator will schedule zones exactly with occupancy, no padding for early run time. This optimized start feature will ensure the spaces served by this unit are

comfortable upon the arrival of occupants. Outside air temperature and past early run time performance shall additionally influence the optimized start programming. Limit unit to a maximum of 90 minutes (adj.) of early run time. If central heating plant is off, optimized start for heating purposes shall be suppressed. Optimized start for cooling purposes shall be suppressed if there is no source of cooling (chilled water, DX, or economizer).

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Security System Armed/Disarmed Status			1					

G. MOTOR CONTROL

1. Fans and pumps with VFDs:
   a. Each VFD shall include a minimum of three points – DDC outputs to issue command and speed, and DDC input to receive power (kW).
   b. Power shall be used to determine motor status. Appropriate threshold for motor status shall be field determined for each motor. For example, if power is greater than 0.2 kW the motor shall be considered on. Virtual status value shall be included on the graphics.
   c. Each VFD shall also include a hardwired safety to stop the unit, taking priority over any local hand overrides. Refer to HARDWIRED SAFETIES paragraph.
2. Fans and pumps with ECMs:
   a. Each ECM shall include three wired points, not via integration – DDC outputs to issue command and speed, confirm with ECM manufacturer exactly what inputs are accepted. DDC inputs to receive current (Amps). Provide a single analog current sensor for each ECM, installed on one phase wire of incoming power feed. Analog current sensor shall be used to determine virtual power. For the purposes of the virtual power calculation below, assume the power factor to be 1.0. Therefore, power value shall be approximate.
   b. Power calculation equation for <u>single phase</u> equipment:
      i. Virtual Power [kW] = Voltage [V] * Current [A] * Power Factor / 1,000.
   c. Power calculation equation for <u>three phase</u> equipment:
      i. Virtual Power [kW] = Voltage [V] * Current [A] * Power Factor * 1.73 / 1,000.
   d. Power calculation equation for <u>single phase</u> equipment with additional Wraps:
      i. Virtual Power [kW] = Voltage [V] * (Current [A] / # of Wraps) * Power Factor / 1,000.
   e. Power calculation equation for <u>three phase</u> equipment with additional Wraps:
      i. Virtual Power [kW] = Voltage [V] * (Current [A] / # of Wraps) * Power Factor * 1.73 / 1,000.
   f. Virtual power shall be used to determine virtual run status. Virtual power greater than field-determined, appropriate value, virtual run status shall be determined on.
      i. The field-determined, appropriate threshold value for the virtual run status shall be greater than the virtual power associated with stand-by or keep-alive current of the ECM.
      ii. A time delay of 45 seconds (mod.) shall be implemented to prevent false status indications when the ECM is being powered down. The virtual status shall encounter this time delay when going from On to Off to ensure the ECM has come to a full stop.
   g. For ECMs as part of a fan array with multiple fans wired to an array controller, it is acceptable to use common DDC outputs to issue a single command and speed for the whole array. Individual current inputs shall be provided for each fan to allow for determination of individual fan failure. If array controller includes a common alarm indicating individual fan failure, it is acceptable to use that as an input along with a single current sensor on the power to the whole array.
   h. The wired points for command and speed, virtual power (kW), and virtual run status shall be displayed on unit graphic. Current is not required for display on graphic.

i. Each ECM, or array controller shall also include a hardwired safety to stop the unit, taking priority over any local hand overrides. Refer to HARDWIRED SAFETIES paragraph.

j. In the event one of the fans is failed or manually shut off, the other supply fans shall be allowed to ramp up to the maximum allowable fan speed, as set by the VFD start-up technician, to maintain the calculated discharge air static pressure setpoint. This speed shall not be limited by the max fan speed setting determined by the balancer for minimum outside ventilation control.

3. Fans and pumps with combination motor starters or disconnects:
   a. Each motor/combination motor starter or disconnect shall include two wired points – DDC output to issue command, and DDC input to receive current (Amps). Provide a single analog current sensor for each motor/combination motor starter or disconnect, installed on one phase wire of incoming power feed. Analog current sensor shall be used to determine virtual power. For the purposes of the virtual power calculation below, assume the power factor to be 0.9. Therefore, power value shall be approximate.
   b. Power calculation equation for <u>single phase</u> equipment:
      i. Virtual Power [kW] = Voltage [V] * Current [A] * Power Factor / 1,000.
   c. Power calculation equation for <u>three phase</u> equipment:
      i. Virtual Power [kW] = Voltage [V] * Current [A] * Power Factor * 1.73 / 1,000.
   d. Virtual power shall be used to determine virtual run status. Virtual power greater than field-determined, appropriate value, virtual run status shall be determined on.
   e. The wired point for command, virtual power (kW), and virtual run status shall be displayed on unit graphic. Current is not required for display on graphic.
   f. Each motor/combination motor starter or disconnect shall also include a hardwired safety to stop the unit, taking priority over any local hand overrides. Refer to HARDWIRED SAFETIES paragraph.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
VFD Command				1				A
VFD Speed		1						
VFD Power (kW)	1							
ECM Command				1				A
ECM Speed		1						
ECM Current (Amps)	1							
ECM Array Controller Alarm			1					B
Motor Command				1				A
Motor Current (Amps)	1							

Notes:
A. Provide additional hardwired safety to stop the unit, taking priority over any local hand overrides.
B. Where applicable

H. PRESSURE INDEPENDENT VALVE SETUP

1. Provide easy means for exact flow ranges for all pressure independent valves to be set via software rather than by using any kind of mechanical stop. Stroke time or maximum control signal shall be set to match design flow for each coil. Provide a graphic table of these values for each valve to allow future adjustment of flow ranges as necessary.

I. POINT NAMING - TYPICAL

1. It is required that a logical and consistent point naming strategy be used. If the client currently has a naming convention in place, this shall be used.

2. Actual point names of Boolean, Numeric, Enumerated and String points shall be simple short names that are repeated as much as possible throughout system to take advantage of batch commands. For example, there should be many points throughout the system with the name “Zn_Temp” The key is that these repeat points are all in different, uniquely named folders. The full point name shall be derived from folder structure naming and extracted as needed automatically by the BAS. For example, when a point alarms and is issued to the alarm log, the full point name, extracted from the folder structure shall be included in the alarm message so it is known exactly which Zn_Temp of all the Zn_Temps throughout the system is in alarm.
3. Title case is used in this naming strategy to efficiently group abbreviations without the need to use several separator characters. When it is prudent to use a separator character, the use of the underscore character is preferred. Total character count in point naming is limited.
4. Order of text within the point name from left to right is important. Often alphabetical sorting techniques are inherent within BAS systems. This point naming strategy takes advantage of this by starting with broad location in the left-most characters and narrowing to fine detail in the right-most characters, all the while attempting to group like items.

J. ALARMING - TYPICAL
1. It is required that a logical and consistent alarm strategy be used. The alarm strategy described here may be used or an alternative strategy may be submitted for engineer’s approval prior to implementation.
2. If the Owner has a standardized alarming scheme, follow their requirements.
3. Additional, non-typical alarm extensions shall be added for specific situations described within the control sequences in drawing set.
4. Include alarm handling software to report all alarm conditions monitored and transmitted through DDC controllers, gateways and other network devices.
5. Include first in, first out handling of alarms according to alarm priority ranking.
6. Alarm handling shall be active at all times to ensure that alarms are processed even if an operator is not currently signed on to DDC system.
7. Full point name shall be included in every alarm message, including the name of the mechanical system, and building, as required.
8. Full point name shall be included in every alarm message, including the name of the mechanical system, and building, as required.
9. End-users shall be able to define additional alarms for any point in the system.
10. Alarms shall not be audible.
11. Alarm routing via email shall be configured and sent through Supervisor server.
12. Classes: Three alarm classes as described here shall be programmed for each building. Create a separate console recipient for the three classes at each building. Intent is to provide a limited view of alarms in the log that pertain only to a particular building.
    a. Level 3 - Class for maintenance type notifications. Log is checked daily/weekly.
    b. Level 2 - Class for most alarms. Log is checked throughout the day.
    c. Level 1 - Class for critical alarms. Emails are sent immediately
13. Types: Four alarm types as described here shall be programmed. Examples are shown here to set the level of expectation to apply these types of alarms to each of these typical situations.
    a. Supervisory Alarms, where the BAS system monitors itself. Programming to issue an alarm when a predicted result is not achieved as the result of a programmed control action, typically applies to outputs. All supervisory alarms shall have the prefix “SUP” in the alarm message to immediately provide more insight into how and why this alarm appeared on the alarm log.
        i. Command fail alarm shall be sent to the BAS any time the fan or pump start/stop and status don't match for 2 minutes (adj.).
        ii. Setpoint alarms, only active when control is active. For example, ZnTemp alarms shall only alarm when area is occupied, and has been occupied long

enough for the temperatures to be normal. Setpoint alarms shall be sent to the BAS anytime a sensed value is not within tolerance of setpoint value within 15 minutes (adj.).

iii. Economizer fault detection alarms as defined by ICC (IECC)-2018 C403.2.4.7 shall be included.

b. Range Alarms, where an input sensor is outside of its operating range. Indicates when a sensor has failed, power to the sensor has failed, wiring has been shorted or opened, etc. It is required to determine how every controller reads both an open and short for every input and program a specific range alarm for each. All range alarms shall have the prefix “RNG” in the alarm message to immediately provide more insight into how and why this alarm appeared on the alarm log.

i. Hi limit alarm shall be sent to the BAS anytime an input sensor reads near the top of its range, and this value is above its normal control range. For example, outside air temperature reading of 150 °F.

ii. Lo limit alarm shall be sent to the BAS anytime an input sensor reads near the bottom of its range, and this value is below its normal control range. For example, outside air temperature reading of -60 °F.

c. Absolute Alarms, where an input sensor is above or below a fixed threshold. Or where an alarm contact closes. All absolute alarms shall have the prefix “ABS” in the alarm message to immediately provide more insight into how and why this alarm appeared on the alarm log.

i. Hi limit alarm shall be sent to the BAS anytime an input sensor reads above the high limit threshold. For example, when kitchen freezer temperature is greater than 0°F (adj) for a minimum of 10 minutes (adj). Or when kitchen cooler temperature is greater than 37°F (adj) for a minimum of 10 minutes (adj).

ii. Lo limit alarm shall be sent to the BAS anytime an input sensor reads below the low limit threshold. For example, any room temperature less than 40 °F.

iii. Discrete alarms shall be sent to the BAS anytime a monitored contact changes to an alarm state. For example, freezestat device trips or inhibitor chemical running low contact remains closed for 10 minutes (adj).

d. Communication Alarms, where a controller is offline. All communication alarms shall have the prefix “COM” in the alarm message to immediately provide more insight into how and why this alarm appeared on the alarm log.

i. Any controller communication alarm shall be sent to the BAS anytime communication is lost to a controller for 10 minutes (adj).

K. HISTORY TRENDING – TYPICAL

1. It is required that a logical and consistent history trend strategy be used. The history trend strategy described here may be used or alternative strategy may be submitted for engineer’s approval prior to implementation. The typical history trends listed here show common situations, it is expected that additional history trends be added when applicable.
2. History trend extensions shall be added and configured for all typical situations described here. This includes every hardware point and every calculated software point that changes automatically by way of program logic.
3. Full point name shall be included in every trend name, including the name of the mechanical system, and building, as required.
4. All indicated trend configuration parameter values to be user adjustable.
5. All history trends shall store at minimum (5) years’ worth of data before rolling to overwrite data. It is understood that change of value (COV) type trend sizes will have to be estimated, configure at least 500,000 records for these.
6. History extensions shall be added at the JACE controller level and sent via the Fox network to the Niagara-4 Supervisor. History trend data shall be stored on the Niagara-4 Supervisor server.

7. End-users shall be able to define additional trends for any point in the system.
8. Change of Value (COV) trends are where a sample is logged whenever the value changes by a specified amount.
    a. Boolean and Enumerated point COV trends shall log a sample every change of state. Examples of Boolean or Enumerated points are; fan command, fan status and current mode.
    b. For Numeric points, COV trends are not recommended, use Interval trends instead.
9. Interval trends are where a sample is logged according to a preset regular time interval.
    a. Numeric point Interval trends log interval times shall be set as:
        i. 15-minute intervals for slower variables such as; outside temp, room temp, return temp, etc.
        ii. 3-minute intervals for faster variables such as; discharge air temp, heating valve signal, building static pressure, etc.
    b. For Boolean and Enumerated points, Interval trends are not recommended, use COV trends instead.

DOAS MULTIPLE ZONE AIR HANDLING UNIT SEQUENCE

A. ADDITIONAL REFERENCE

1. Refer to Common Controls Notes for additional information related to this sequence.
2. Refer to specification sections 23 09 00 and 23 09 23 for additional information related to this sequence.

B. EMERGENCY SAFETY/LIMIT CONTROLS

1. See Common Controls Notes for details on safeties.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Fire Alarm Safety Sts			1					
Freezestat Alarm Safety Sts			1					
High SA Duct Press Safety Sts			1					
Low RA Duct Press Safety Sts			1					
Cooling Drain Pan High Level Safety Sts			1					

Notes:

C. SOFTWARE FREEZESTAT

1. If the discharge air temperature falls below 35°F (adj.) for 1 minute (adj.) the unit shall shut down.
   a. Fans shall be commanded off.
   b. Outside and relief air dampers shall be commanded closed.
   c. Heating valve shall be commanded open.
2. After 15 minutes (adj.) if the discharge temperature has risen above 55°F (adj.), the unit shall be allowed to start again.
3. If the software freezestat trips 3 times in one hour, the unit shall remain off until manually reset via a button on the graphics.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Discharge Air Temperature	1							
Supply Fan Command				1			Off	
Relief Fan Command				1			Off	
Outside Air Damper		1					Closed	
Return Air Damper		1					Open	
Relief Air Damper		1					Closed	
Heating Valve Signal		1					Open	

Notes:

D. UNIT SCHEDULE CONTROL

1. Refer to Common Controls Notes for details on unit scheduling and optimized start.
2. Morning warm-up mode shall be allowed only when unit has started early, prior to the time schedule transitioning to occupied, as a result of optimized start feature. Morning warm-up mode shall be enabled immediately upon start-up whenever average zone temperature is less than 65°F (adj.) and disabled when average zone temperature rises above 67°F or when time schedule transitions to occupied. During morning warm-up mode, all VAV box primary air dampers shall fully utilize the warm primary air in addition to opening their reheat and radiation valves as required to meet occupied room temperature heating setpoint.
   a. For units dependent on central plant heat, morning warm-up mode shall be disabled when the central heating plant is off.

3. When the unit is unoccupied it shall cycle on to maintain the average zone temperature between the unoccupied heating and cooling setpoints. Unit shall also cycle on if the minimum zone temperature falls below 50°F (adj.) or maximum zone humidity rises above 60% (adj.). There shall be a 4°F (adj.) or 5% (adj.) differential for unoccupied operation.
4. Large electrical loads within the unit (supply fans without VFDs, DX cooling coils) shall be staggered in start time from other large electrical loads in the building to prevent large in-rush currents when the building cycles into an occupied mode.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Outside Air Temperature						1		
Average Zone Air Temperature						1		
Central HW Available						1		
Minimum Zone Temperature						1		
Maximum Zone Humidity						1		
Security Key Armed/Disarmed Status						1		

Notes:

E. DISCHARGE AIR TEMPERATURE SETPOINT TRIM & RESPOND CONTROL

1. Unit State:
   a. Cooling State:
      i. When the supply fan is on, morning warm-up mode has expired, and unit is not in heating state as described next, the unit shall be in cooling state.
   b. Heating State:
      i. When supply fan is on, morning warm-up mode has expired, and discharge air temperature is less than the minimum discharge air temperature setpoint (SPmin) minus 3°F (adj.) and all cooling has been off for 5 minutes (adj.), the unit shall enter heating state. Heating state shall remain engaged until discharge air temperature is greater than calculated discharge air temperature setpoint plus 3°F (adj.) for 5 minutes (adj.), then unit shall transition to cooling state.
2. Occupied discharge temperature setpoint reset shall be based on “Trim and Respond” logic as described in ASHRAE Guideline 36 Section 5.1.14.
   a. Discharge temperature setpoint shall reset between a maximum (SPmax) of 70°F (adj.) and a minimum (SPmin) of 55°F (adj.). Adjustments up and down (described in c. and d. below) shall occur every time step (T) of 3 minutes (adj.).
   b. A Zone Cooling Request (r) is generated when the Zone Cooling Demand, as defined in the respective zone-level equipment sequence, rises above 95%. The Zone Cooling Request is then multiplied by the respective zone importance multiplier, set to 1 (adj.) by default. The sum of these values across all the zones served by the unit results in the total cooling requests (R). The number of ignored requests (I) shall be set to 1 (adj.).
   c. When R≤I the setpoint shall increase by the trim amount (SPtrim) of 0.2°F (adj.).
   d. When R>I the setpoint shall decrease by the respond amount (SPres) of 0.5°F (adj.) multiplied by R minus I. This will allow a quicker response to greater values of R.
3. Provide a graphic screen with report table showing the VAV box designation and the real-time Zone Cooling Demand for each VAV box along with the zone importance multiplier.
4. Unoccupied Mode:
   a. Upon an unoccupied cooling call, the discharge air temperature setpoint shall be fixed at low threshold setpoint value of 55°F (adj.).
   b. Upon an unoccupied heating call, the discharge air temperature setpoint shall be fixed at the morning warm up setpoint of 90°F (adj.).

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Discharge Air Temperature	1							
Sum of Zone Cooling Requests (R)						1		

Notes:

F. DISCHARGE AIR STATIC PRESSURE SETPOINT TRIM & RESPOND CONTROL

1. Discharge static pressure setpoint reset shall be based on “Trim and Respond” logic as described in ASHRAE Guideline 36 Section 5.1.14.
    a. Discharge static pressure setpoint shall reset between a maximum (SPmax) determined by the balancer, initially set to 1.20 in. wc. (adj.) and a minimum (SPmin) of 0.50 in. wc (adj.). Adjustments up and down (described in c. and d. below) shall occur every time step (T) of 2 minutes (adj.).
    b. A Zone Pressure Request (r) is generated when the VAV damper opens above 95%. This value is then multiplied by the respective zone importance multiplier, set to 1 (adj.) by default. The sum of these values across all the zones served by the unit results in the total pressure requests (R). The number of ignored requests (I) shall be set to 1 (adj.).
    c. When R≤I the setpoint shall decrease by the trim amount (SPtrim) of 0.02 in. wc (adj.).
    d. When R>I the setpoint shall increase by the respond amount (SPres) of 0.03 in. wc (adj.) multiplied by R minus I. This will allow a quicker response to greater values of R.
2. Provide a graphic screen with report table showing the VAV box designation and the real-time damper position and airflow for each VAV box along with the zone importance multiplier.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Sum of Zone Pressure Requests (R)						1		

Notes:

G. SUPPLY FAN CONTROL – VARIABLE AIR VOLUME

1. Refer to Common Control Notes for details on fan/motor control.
2. Fan shall be commanded on during occupied mode and optimized start mode.
3. Fans shall shut down when disabled by operators by the manual software enable point to allow for maintenance shutdowns without nuisance alarming.
    a. This is not a replacement for typical lock-out tag-out procedures and other safe maintenance procedures.
4. Fan shall also be commanded on intermittently in the following conditions:
    a. Unoccupied calls for heating or cooling as described in paragraph above.
    b. Extended unoccupied air circulation.
        i. Enable fan approximately once every 24 hrs (adj.), for a 30-minute (adj.) duration, if fan does not already run at least once a day to satisfy an unoccupied heating or cooling call. This is to prevent prolonged stagnant air during long unoccupied periods.
    c. Cold unit interior air circulation.
        i. When the unit is off and the minimum of the mixed air and discharge air temperature sensors falls below 45°F (adj.). Include a minimum on time of 15 minutes (adj.).
    d. Unoccupied dehumidification
        i. A dehumidification request is generated when the unit is off and the maximum zone humidity rises above the unoccupied dehumidification setpoint.

5. When commanded on, the supply fan speed shall modulate to maintain discharge air static pressure at the calculated discharge air static pressure setpoint.
6. The supply fan speed shall ramp slowly to prevent pressure trip on startup.
7. Total supply airflow shall be summed from terminal units. Value shall be trended and displayed on graphics.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Supply Fan Command				1			Off	
Supply Fan Current (Amps)	#							A
Supply Fan Array Alarm			1					
Supply Fan Speed Signal		1					Min.	
Discharge Air Static Pressure	1							
Mixed Air Temperature	1							
Discharge Air Temperature	1							

Notes:
A. See approved AHU submittal for fan quantity.

H. RELIEF FAN CONTROL
1. Refer to Common Control Notes for details on fan/motor control.
2. Relief fan shall run continuously during occupied mode.
3. Relief fan shall run along with supply fan in unoccupied mode only when outside air is being used for free cooling.
4. Fans shall shut down when disabled by operators by the manual software enable point to allow for maintenance shutdowns without nuisance alarming. This is not a replacement for typical lock-out tag-out procedures and other safe maintenance procedures.
5. Relief fan speed shall track supply fan speed with a percentage offset. Relief fan speed shall range from minimum speed to 100%.
    a. Offset shall modulate from -40% (adj.) to +10% (adj.) to maintain the building pressure at a setpoint of 0.01 in. w.c. (adj.).
        i. For example – if the supply fan speed is 60%, relief fan speed shall modulate between 30% and 70% as needed to maintain building pressure at setpoint.
    b. As building pressure increases above setpoint, offset shall increase towards maximum and the relief fan shall modulate towards maximum speed.
6. Building Pressure Control Strategy
    a. For the anchor building pressure zone, there shall be a single pressure sensor installed with the positive port in a main corridor at least 30 feet from the main entrance, and the negative port outside the main entrance at least 10 feet from the entrance. There shall be a single pressure control loop driving the offsets for all units controlling building pressure within this anchor building pressure zone. The output of this loop shall be referred to as the Building Pressure Anchor Control Zone Signal. Setpoint shall be +0.01 in. wc. (adj.).
    b. Other building pressure zones within the building shall be identified as isolated areas where air does not freely communicate with the anchor building pressure zone. For these other building pressure zones, there shall be a single pressure sensor installed with the positive port in the isolated zone and the negative port in the building pressure anchor control zone. There shall be a single pressure control loop driving the offsets for all units controlling building pressure within this building pressure zone. The output of this loop shall be referred to as the Building Pressure Control Zone # Signal, where a “#” is assigned to each isolated pressure zone. Setpoint shall be neutral +0.00 in. wc. (adj.).

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Relief Fan Command				1			Off	
Relief Fan Current (Amps)	#							A
Relief Fan Array Alarm			1					
Relief Fan Speed Signal		1					Min.	
Building Pressure	1							B
Building Pressure Control Signal						1		B
Supply Fan Speed Signal		1					Min.	

Notes:
A. See approved AHU submittal for fan quantity.
B. One sensor and PID control loop shared by all units within a pressure control zone.

I. DAMPER CONTROL
1. During occupied mode, the outside air damper and relief damper shall be open and the recirculation damper shall be closed.
2. When the unit is operating during unoccupied hours (including optimal start routines) the outside air and relief dampers shall be closed, and the recirculation damper shall be open. Outside air and relief dampers shall only be open during unoccupied operation when outside air is used for cooling.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Relief Air Damper Command				1			Closed	
Outside Air Damper Command				1			Closed	
Recirculation Air Damper Command				1			Open	

Notes:

J. ENTHALPY HEAT EXCHANGER CONTROL
1. Temperature Control
   a. **Summer Operation**, engage when outdoor air enthalpy is greater than return air enthalpy plus 0.5 btu/lb (adj.). Summer-operation shall remain engaged until outdoor air enthalpy is less than return air enthalpy, then transition to off-operation.
      i. Bypass dampers fully closed.
   b. **Off Operation**, engage whenever not in summer operation or winter operation.
      i. Bypass dampers fully open.
   c. **Winter Operation**, engage when outside air temperature is less than calculated discharge air temperature setpoint minus 4°F (adj.). Winter operation shall remain engaged until outside air temperature is greater than calculated discharge air temperature setpoint minus 2°F (adj.), then transition to off-operation.
      i. Bypass dampers are modulated to maintain mixed air temperature at 2°F (adj.) less than calculated discharge air temperature setpoint.
2. Frost Control
   a. Whenever outside air temperature is less than 32°F (adj.), the frost control sequence shall be active and take priority over the temperature control sequence above.
   b. Limit the relief fan speed by modulating it to maintain heat exchanger relief air humidity below 90%RH (adj.).
   c. If heat exchanger relief air relative humidity exceeds 92%RH (adj.) for 10 minutes (adj.), turn off relief fan for 30-minutes (adj.). After 30-minute off period has expired, relief fan to resume the frost control strategy.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Relief Fan Speed		1						
Energy Wheel Bypass Damper		2						
Outside Air Temperature						1		
Outside Air Humidity						1		
Return Air Temperature	1							
Return Air Humidity	1							
Mixed Air Temperature	1							
Relief Air Temperature	1							
Relief Air Humidity	1							

K. ENERGY WHEEL & BYPASS DAMPER CONTROL

1. Temperature Control
   a. **Summer Operation**, engage when outdoor air enthalpy is greater than return air enthalpy plus 0.5 btu/lb (adj.). Summer-operation shall remain engaged until outdoor air enthalpy is less than return air enthalpy, then off-operation.
      i. Wheel bypass dampers fully closed. Wheel at full speed.
   b. **Off Operation**, engage whenever not in summer operation or winter operation.
      i. Wheel bypass dampers fully open, and wheel is off.
   c. **Winter Operation**, engage when outside air temperature is less than calculated discharge air temperature setpoint minus 4°F (adj.). Winter operation shall remain engaged until outside air temperature is greater than calculated discharge air temperature setpoint minus 2°F (adj.), then off-operation.
      i. Wheel is commanded on. Bypass dampers are modulated in sequence with wheel speed to maintain mixed air temperature at 2°F (adj.) less than calculated discharge air temperature setpoint.
      ii. As mixed air temperature rises above setpoint, wheel is modulated slower to minimum speed, then bypass dampers begin to modulate open.
      iii. As mixed air temperature falls below setpoint, bypass dampers begin to modulate to full closed, then wheel is modulated to a faster speed.
2. Frost Control
   a. Whenever outside air temperature is less than 32°F (adj.), the frost control sequence shall be active and take priority over the temperature control sequence above.
   b. Limit the wheel speed by modulating it to maintain wheel relief air humidity below 90%RH (adj.).
   c. If wheel relief air relative humidity exceeds 92%RH (adj.) for 10 minutes (adj.), turn off wheel for 30-minutes (adj.). After 30-minute off period has expired, wheel to resume the frost control strategy.
3. Whenever unit is unoccupied or wheel is in off-operation, the energy wheel shall run at minimum speed for 20 seconds (adj.) every 1 hour (adj.) to extend longevity of the wheel mechanical components and prevent odors.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Energy Wheel Command				1				
Energy Wheel Power (kW)	1				R			
Energy Wheel Frequency (Hz)	1				R			
Energy Wheel Status			1					
Energy Wheel Speed		1						
Energy Wheel Bypass Damper		2						
Outside Air Temperature						1		

Outside Air Humidity						1		
Return Air Temperature	1							
Return Air Humidity	1							
Mixed Air Temperature	1							
Relief Air Temperature	1							
Relief Air Humidity	1							

L. COOLING CONTROL – MULTIPLE CHILLED WATER COILS

1. Mechanical cooling shall only occur when unit supply fan status is proven on, cooling state is active, and outside air temperature is greater than 50°F (adj.). Mechanical cooling shall be off all other times.
2. Control strategy intent for mechanical cooling is to stage coils on and off for comfort control. It is not acceptable to modulate individual cooling stages at some middle capacity level for comfort control as this may result in excessive zone humidity.
3. The **Cooling Demand** shall be based on the discharge temperature setpoint reset, refer to Discharge Air Temperature Setpoint Control section.
    a. As discharge air temperature setpoint decreases from high to low setpoint values, the **Cooling Demand** shall increase linearly from 0% to 100%.
4. When either return air relative humidity or maximum zone humidity rises above the dehumidification setpoint of 60%RH (adj.), the **Cooling Demand** shall be forced to 100% until the relative humidity falls back below the setpoint minus a differential of 5%RH.
5. Cooling coils shall be staged in order to provide maximum dehumidification.
    a. As the **Cooling Demand** increases to 50% (adj.), the valve for the bottom coil shall be opened and remain open until the **Cooling Demand** decreases to 5% (adj.).
    b. As the **Cooling Demand** increases to 100% (adj.), the valve for the top coil shall be opened and remain open until the **Cooling Demand** decreases to 50% (adj.).
    c. Units with a single cooling coil shall duty-cycle to vary cooling capacity.
        i. **Cooling Demand** less than 10%, cooling stage off.
        ii. **Cooling Demand** between 10% and 90%. Cooling stage cycle time shall vary linearly from [5-minutes on / 25-minutes off] to [25-minutes on / 5-minutes off].
        iii. **Cooling Demand** greater than 90%, cooling stage on continuously.
    d. At no point shall cooling stages be allowed to short-cycle at a rate of less than 5-minutes open or closed.
6. When a cooling coil is being utilized, the cooling valve signal shall be limited in order to maintain the leaving water temperature at or above a setpoint of 54°F (adj.) to prevent over-flowing the coil. When dehumidification is active as described above, this setpoint shall be lowered to 50°F (adj.) to ensure maximum dehumidification. In order to maintain flow, this limit shall not allow the signal to drop below 20% (adj.).

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Cooling Valve Signal		#					Last	A
Return Air Relative Humidity	1							
Maximum Zone Humidity						1		
Cooling Coil Leaving Water Temperature	#							
Outside Air Temperature						1		

Notes:
A. Point to be included in system maximum calculation for cooling plant.

M. COOLING CONTROL – VARIABLE DX

1. When in cooling state, outside air temperature is greater than 55°F (adj.), and economizer control is active, the outside air dampers shall be modulated first in sequence with DX

cooling. Outside air dampers must be fully open prior to DX being enabled and shall remain open until DX is fully off or economizer is disabled.

2. When economizer is disabled, the outside air dampers are ignored and DX shall control as described below.
3. When enabled as described above, DX cooling shall stage up and down to maintain the discharge air temperature at setpoint.
   a. Stages shall enable when the discharge air temperature is 5°F (adj.) above setpoint and disable when it is 5°F (adj.) below setpoint.
   b. Individual stages shall have a minimum-on time and minimum-off time of 10 minutes (adj.). There shall be a 5-minute (adj.) inter-stage delay.
4. Any modulation of individual stages shall only be done to maintain the cooling coil leaving air temperature at or above the maximum cooling setpoint of 52°F (adj.).
5. [Designer Note: if coil discharge temp sensor may be difficult to install (for example, if HGRH coil is immediately after cooling coil), use this suction pressure approach instead of above.] Any modulation of individual stages shall only be done to prevent excessively cold conditions. The variable capacity compressor signal shall modulate to prevent the suction pressure from dropping below a level equivalent to a temperature of 40°F. Refer to refrigerant pressure/temperature charts for the selected refrigerant. For example, R-410a shall not drop below 120 psi (adj.).
6. When either return air relative humidity or maximum zone humidity rises above the dehumidification setpoint of 60%RH (adj.), dehumidification shall be activated. When the relative humidity falls back below the setpoint minus a differential of 5%RH, dehumidification shall be deactivated.
   a. When dehumidification is active, cooling shall stage and modulate up to maintain the cooling coil leaving temperature at the maximum cooling setpoint of 52°F (adj.).
   b. When dehumidification is active, cooling shall stage and modulate up to maintain the suction pressure at the equivalent of 40°F.
   c. If the average zone temperature falls below 70°F, the hot gas reheat shall be enabled and modulate to maintain the discharge temperature at the calculated setpoint.
7. DX cooling shall be off when unit is off. This shall supersede any active minimum-on or inter-stage timer.
8. DX condensing unit electrical current shall be monitored and used to calculate power similar to as described in Common Control Notes motor control.

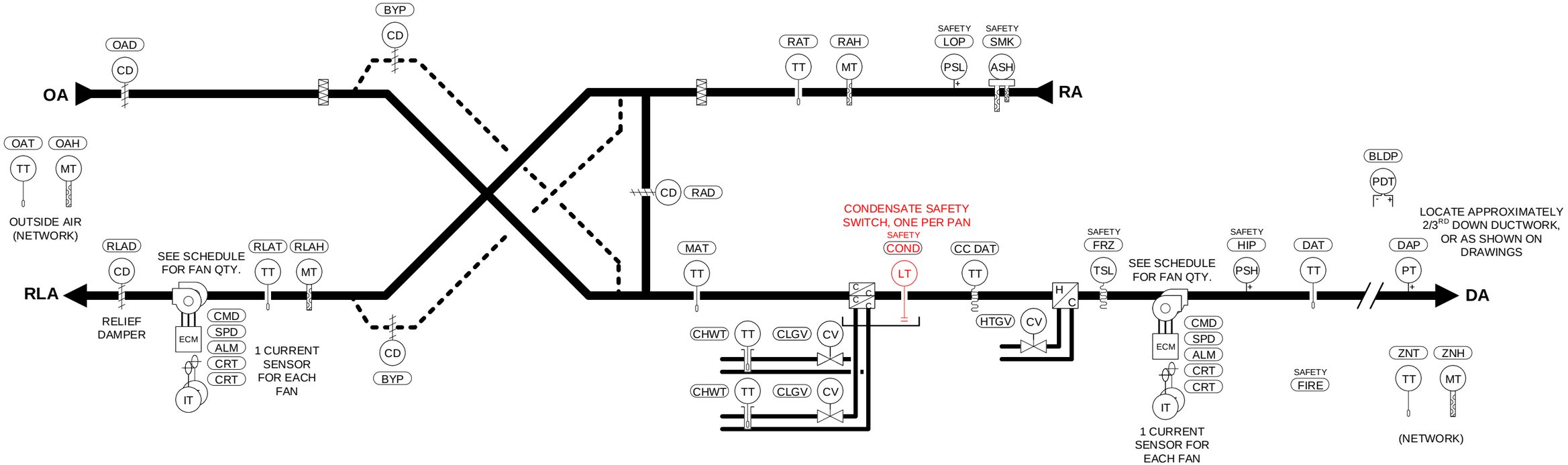
HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
DX Cooling Stage Command				#			Off	
DX Variable Capacity Compressor Signal		1					Min.	
DX Suction Pressure	1							
DX Condensing Unit Current (Amps)	1							
Cooling Coil Leaving Air Temperature	1							
Discharge Air Temperature	1							
Hot Gas Reheat Signal		1					Min.	
Return Air Relative Humidity	1							
Maximum Zone Humidity						1		
Average Zone Temperature						1		
Outside Air Temperature						1		

N. HEATING CONTROL – HEATING WATER COIL

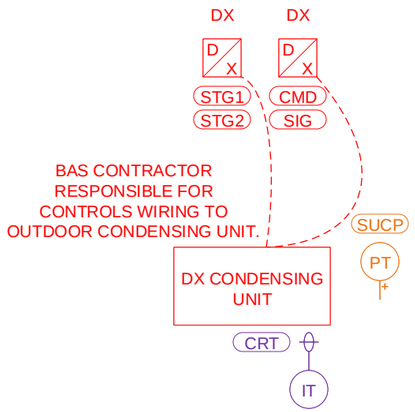
1. When in heating state or morning warm-up mode, the heating valve shall modulate as required to maintain discharge air temperature at the minimum setpoint of 55°F (adj.). As discharge air temperature falls below setpoint, the heating valve is modulated more open.

2. When dehumidification is active as described in COOLING CONTROL above, the heating coil valve shall modulate to maintain the discharge temperature at the minimum setpoint.
3. When supply fan is on and unit is not in heating or morning warm-up mode or dehumidification mode, heating valve shall be closed.
4. Whenever supply fan is off and the outside air temperature is greater than 40°F (adj.), the heating coil valve shall be closed. When the outside air temperature is less than 40°F (adj.), the heating coil valve shall modulate to heat the interior of the unit as follows:
    a. The heating coil valve shall modulate to maintain the minimum of the mixed air temperature and discharge air temperature at a setpoint of 50°F (adj.).
    b. As a back-up measure, if the mixed air temperature ever falls below 40°F, the heating coil valve shall be commanded fully open and remain open until mixed air temperature reaches 55°F.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Heating Valve Signal		1					Open	
Mixed Air Temperature	1							
Discharge Air Temperature	1							
Outside Air Temperature						1		



DEDICATED OUTSIDE AIR HANDLING UNIT



FOR REFERENCE ONLY.
LAST REVISED 6/23/2022

MULTIPLE ZONE AIR HANDLING UNIT SEQUENCE

A. ADDITIONAL REFERENCE

1. Refer to Common Controls Notes for additional information related to this sequence.
2. Refer to specification sections 23 09 00 and 23 09 23 for additional information related to this sequence.

B. EMERGENCY HARDWIRED SAFETY/LIMIT CONTROLS

1. See Common Controls Notes for details on safeties.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Fire Alarm Safety Sts			1					
Freezestat Alarm Safety Sts			1					
High SA Duct Press Safety Sts			1					
Low RA Duct Press Safety Sts			1					
Cooling Drain Pan High Level Safety Sts			1					

Notes:

C. SOFTWARE FREEZESTAT

1. If the discharge air temperature falls below 35°F (adj.) for 1 minute (adj.) the unit shall shut down.
   a. Fans shall be commanded off.
   b. Outside and relief air dampers shall be commanded closed.
   c. Heating valve shall be commanded open.
2. After 15 minutes (adj.) if the discharge temperature has risen above 55°F (adj.), the unit shall be allowed to start again.
3. If the software freezestat trips 3 times in one hour, the unit shall remain off until manually reset via a button on the graphics.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Discharge Air Temperature	1							
Supply Fan Command				1			Off	
Return Fan Command				1			Off	
Outside Air Damper		1					Closed	
Return Air Damper		1					Open	
Relief Air Damper		1					Closed	
Heating Valve Signal		1					Open	

Notes:

D. UNIT SCHEDULE CONTROL

1. Refer to Common Controls Notes for details on unit scheduling and optimized start.
2. Morning warm-up mode shall be allowed only when unit has started early, prior to the time schedule transitioning to occupied, as a result of optimized start feature. Morning warm-up mode shall be enabled immediately upon start-up whenever average zone temperature is less than 65°F (adj.) and disabled when average zone temperature rises above 67°F or when time schedule transitions to occupied. During morning warm-up mode, all VAV box primary air dampers shall fully utilize the warm primary air in addition to opening their reheat and radiation valves as required to meet occupied room temperature heating setpoint.
   a. For units dependent on central plant heat, morning warm-up mode shall be disabled when the central heating plant is off.

3. When the unit is unoccupied it shall cycle on to maintain the average zone temperature between the unoccupied heating and cooling setpoints. Unit shall also cycle on if the minimum zone temperature falls below 50°F (adj.) or maximum zone humidity rises above 60% (adj.). There shall be a 4°F (adj.) or 5% (adj.) differential for unoccupied operation.
4. Large electrical loads within the unit (supply fans without VFDs, DX cooling coils) shall be staggered in start time from other large electrical loads in the building to prevent large in-rush currents when the building cycles into an occupied mode.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Outside Air Temperature						1		A
Average Zone Air Temperature						1		
Central HW Available						1		
Minimum Zone Temperature						1		
Maximum Zone Humidity						1		
Security Key Armed/Disarmed Status						1		

Notes:
A. Only one sensor required for building, value to be shared over network. Fail at last value.

E. DISCHARGE AIR TEMPERATURE SETPOINT TRIM & RESPOND CONTROL

1. Unit State:
   a. Cooling State:
      i. When the supply fan is on, morning warm-up mode has expired, and unit is not in heating state as described next, the unit shall be in cooling state.
   b. Heating State:
      i. When supply fan is on, morning warm-up mode has expired, and discharge air temperature is less than the minimum discharge air temperature setpoint (SPmin) minus 3°F (adj.) and all cooling has been off for 5 minutes (adj.), the unit shall enter heating state. Heating state shall remain engaged until discharge air temperature is greater than calculated discharge air temperature setpoint plus 3°F (adj.) for 5 minutes (adj.), then unit shall transition to cooling state.
2. Occupied discharge temperature setpoint reset shall be based on “Trim and Respond” logic as described in ASHRAE Guideline 36 Section 5.1.14.
   a. Discharge temperature setpoint shall reset between a maximum (SPmax) of 70°F (adj.) and a minimum (SPmin) of 55°F (adj.). Adjustments up and down (described in c. and d. below) shall occur every time step (T) of 3 minutes (adj.).
   b. A Zone Cooling Request (r) is generated when the Zone Cooling Demand, as defined in the respective zone-level equipment sequence, rises above 95%. This value is then multiplied by the respective zone importance multiplier, set to 1 (adj.) by default. The sum of these values across all the zones served by the unit results in the total cooling requests (R). The number of ignored requests (I) shall be set to 1 (adj.).
   c. When R≤I the setpoint shall increase by the trim amount (SPtrim) of 0.2°F (adj.).
   d. When R>I the setpoint shall decrease by the respond amount (SPres) of 0.5°F (adj.) multiplied by R minus I. This will allow a quicker response to greater values of R.
3. Provide a graphic screen with report table showing the VAV box designation and the real-time Zone Cooling Demand for each VAV box along with the zone importance multiplier.
4. Unoccupied Mode:
   a. Upon an unoccupied cooling call, the discharge air temperature setpoint shall be fixed at low threshold setpoint value of 55°F (adj.).
   b. Upon an unoccupied heating call, the discharge air temperature setpoint shall be fixed at the morning warm up setpoint of 90°F (adj.).

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Discharge Air Temperature	1							
Sum of Zone Cooling Requests (R)						1		

Notes:

F. DISCHARGE AIR STATIC PRESSURE SETPOINT TRIM & RESPOND CONTROL

1. Discharge static pressure setpoint reset shall be based on “Trim and Respond” logic as described in ASHRAE Guideline 36 Section 5.1.14.
    a. Discharge static pressure setpoint shall reset between a maximum (SPmax) determined by the balancer, initially set to 1.20 in. wc. (adj.) and a minimum (SPmin) of 0.50 in. wc (adj.). Adjustments up and down (described in c. and d. below) shall occur every time step (T) of 2 minutes (adj.).
    b. A Zone Pressure Request (r) is generated when the VAV damper rises above 95%. This value is then multiplied by the respective zone importance multiplier, set to 1 (adj.) by default. The sum of these values across all the zones served by the unit results in the total pressure requests (R). The number of ignored requests (I) shall be set to 1 (adj.).
    c. When R≤I the setpoint shall decrease by the trim amount (SPtrim) of 0.02 in. wc (adj.).
    d. When R>I the setpoint shall increase by the respond amount (SPres) of 0.03 in. wc (adj.) multiplied by R minus I. This will allow a quicker response to greater values of R.
2. Provide a graphic screen with report table showing the VAV box designation and the real-time damper position and airflow for each VAV box along with the zone importance multiplier.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Sum of Zone Pressure Requests (R)						1		

Notes:

G. MINIMUM OUTSIDE AIR VENTILATION CONTROL – VARIABLE, WITHOUT CO2 CONTROL

1. Minimum outside air damper position setpoint shall modulate as a result of fan speed.
2. There shall be two outside air damper position setpoints to be determined together with TAB contractor based on drawings. For the purposes of balancing and this control logic, the supply fan minimum speed setpoint shall be considered the slowest fan speed required to deliver design minimum airflow and ventilation. This is different from the minimum speed setting configured in the VFD. Supply fan maximum speed setpoint shall be the fastest fan speed required to deliver design maximum airflow and ventilation with all fans running.
    a. With the supply fan at minimum speed setpoint, determine the OA damper position required to achieve the scheduled design OA airflow.
    b. With the supply fan at maximum speed setpoint, determine the OA damper position required to achieve the same scheduled design OA as above.
3. As the fan speed increases from minimum to maximum, the final outside air damper minimum position shall be determined by linearly resetting between the results from part 2 above (2.a. to 2.b.).
4. Include reset calculation programming to approximate and display on the graphic screen, the real-time percent outside airflow resulting from the varying fan speeds and damper positions. This point shall be trended and available for use by the facilities commissioning team to monitor outside airflow.
5. Minimum OA damper position setpoint shall not inhibit economizer function. If the unit calls to provide free cooling when outside air conditions are favorable, the unit shall be allowed to further modulate open outside air damper as needed.

6. Whenever the unit is operating in any mode other than occupied, such as unoccupied or optimized start, the minimum outside air damper position shall be held at 0%.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Outside Air Damper		1						
Supply Fan Speed Signal		1					Min.	

Notes:

H. SUPPLY FAN CONTROL – VARIABLE AIR VOLUME
1. Refer to Common Control Notes for details on fan/motor control.
2. Fan shall be commanded on during occupied mode and optimized start mode. Fans shall shut down when disabled by operators by the manual software enable point to allow for maintenance shutdowns without nuisance alarming.
    a. This is not a replacement for typical lock-out tag-out procedures and other safe maintenance procedures.
3. Fan shall also be commanded on intermittently in the following conditions:
    a. Unoccupied calls for heating or cooling as described in paragraph above.
    b. Extended unoccupied air circulation.
        i. Enable fan approximately once every 24 hrs (adj.), for a 30-minute (adj.) duration, if fan does not already run at least once a day to satisfy an unoccupied heating or cooling call. This is to prevent prolonged stagnant air during long unoccupied periods.
    c. Cold unit interior air circulation.
        i. When the unit is off and the minimum of the mixed air and discharge air temperature sensors falls below 45°F (adj.). Include a minimum on time of 15 minutes (adj.).
    d. Unoccupied dehumidification
        i. A dehumidification request is generated when the unit is off and the maximum zone humidity rises above the unoccupied dehumidification setpoint.
4. When commanded on, the supply fan speed shall modulate to maintain discharge air static pressure at the calculated discharge air static pressure setpoint.
5. The supply fan speed shall ramp slowly to prevent pressure trip on startup.
6. Total supply airflow shall be summed from terminal units. Value shall be trended and displayed on graphics.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Supply Fan Command				1			Off	
Supply Fan Current (Amps)	#							A
Supply Fan Array Alarm			1					
Supply Fan Speed Signal		1					Min.	
Discharge Air Static Pressure	1							
Mixed Air Temperature	1							
Discharge Air Temperature	1							

Notes:
A. See approved AHU submittal for fan quantity.

I. RETURN FAN & RELIEF DAMPER CONTROL
1. Refer to Common Control Notes for details on fan/motor control.
2. Return fan shall run continuously during occupied mode.
3. Return fan shall run along with supply fan in unoccupied mode.

4. Fans shall shut down when disabled by operators by the manual software enable point to allow for maintenance shutdowns without nuisance alarming.
    a. This is not a replacement for typical lock-out tag-out procedures and other safe maintenance procedures.
5. Relief plenum pressure setpoint determination
    a. Setpoint shall hold at +0.01 wc (adj.) until outside air damper position signal rises above 70% (adj.), where it shall release to reset control as described next. Once outside air damper position signal falls below 50% (adj.), setpoint shall return to original value.
    b. Setpoint reset control
        i. Setpoint shall reset from value above to +0.12 in. wc (adj.) as building pressure control loop increases from 0% to 100%. Refer to Building Pressure Control Strategy below for details on this control loop.
6. Return fan speed shall track supply fan speed with a percentage offset. Return fan speed shall range from minimum speed to 100%.
    a. Offset shall modulate from -40% (adj.) to +10% (adj.) to maintain the relief plenum pressure at setpoint.
    b. As relief plenum pressure increases above setpoint, offset shall decrease towards minimum and the return fan shall modulate towards minimum speed.
7. Relief damper shall track the outside air damper with a percentage offset. Relief damper position shall range from 0-100%.
    a. Offset shall reset from -40% to +10% (adj.) as building pressure control loop increases from 0% to 100%. Refer to Building Pressure Control Strategy below for details on this control loop.
8. When the unit is off, the relief damper shall remain closed.
9. Building Pressure Control Strategy
    a. For the anchor building pressure zone, there shall be a single pressure sensor installed with the positive port in a main corridor at least 30 feet from the main entrance, and the negative port outside the main entrance at least 10 feet from the entrance. There shall be a single pressure control loop driving the offsets for all units controlling building pressure within this anchor building pressure zone. The output of this loop shall be referred to as the Building Pressure Anchor Control Zone Signal. Setpoint shall be +0.01 in. wc. (adj.).
    b. Other building pressure zones within the building shall be identified as isolated areas where air does not freely communicate with the anchor building pressure zone. For these other building pressure zones, there shall be a single pressure sensor installed with the positive port in the isolated zone and the negative port in the building pressure anchor control zone. There shall be a single pressure control loop driving the offsets for all units controlling building pressure within this building pressure zone. The output of this loop shall be referred to as the Building Pressure Control Zone # Signal, where a “#” is assigned to each isolated pressure zone. Setpoint shall be neutral +0.00 in. wc. (adj.).

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Return Fan Command				1			Off	
Return Fan Current (Amps)	#							A
Return Fan Array Alarm			1					
Return Fan Speed Signal		1					Min.	
Building Pressure	1							B
Building Pressure Control Signal						1		B
Relief Air Damper Signal		1					Closed	
Relief Air Plenum Pressure	1							

Supply Fan Speed Signal		1					Min.	

Notes:
A. See approved AHU submittal for fan quantity.
B. One sensor and PID control loop shared by all units within a pressure control zone.

J. OUTSIDE AIR AND RETURN AIR DAMPER CONTROL

1. The return air damper shall inversely follow outside air damper position. As the outside air damper modulates open, the return air damper modulates closed.
2. [Designer Note: Consider %OA design of unit and what temperatures coils are designed for. 45°F setpoint may need to be decreased if paragraph is included.] Provide a low mixed air temperature control loop as an additional safety measure to quickly decrease outside air damper position prior to unit tripping on freeze protection safety. As mixed air temperature falls below 45°F (adj.), the outside air damper position shall be modulated more closed to maintain the low mixed air temperature setpoint. This control shall be at the highest priority.
3. Economizer State Decision:
   a. Enabled when the outside air enthalpy is lower than return air enthalpy minus 1.2 Btu/lb (adj.) buffer setpoint, and the outside air dewpoint is less than 58°F (adj.).
   b. Disabled when the outside air enthalpy is higher than return air enthalpy minus 0.5 Btu/lb (adj.) buffer setpoint, or the outside air dewpoint is greater than 58°F (adj.).
4. When economizer control is enabled, the outside air damper shall be modulated between the calculated minimum position and 100% in order to maintain the calculated discharge air temperature setpoint. Economizer shall be fully utilized before enabling any mechanical cooling and shall be held at 100% when mechanical cooling is active.
5. When economizer control is disabled, the outside air damper shall be held at the calculated minimum OA damper position setpoint during occupied operation.
6. When the unit is operating during unoccupied hours (including optimal start routines) the outside air damper shall be allowed to close fully, ignoring minimum OA damper position setpoint.
7. Outside damper shall be closed and return damper open when supply fan is not proving status.
8. On startup the outside air damper shall initially be held closed and gradually released to the calculated minimum position over a 10-minute (adj.) period.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Outside Air Temperature						1		A
Outside Air Humidity						1		A, B
Return Air Temperature	1							
Return Air Humidity	1							B
Mixed Air Temperature	1							C
Discharge Air Temperature	1							
Outside Air Damper Signal		1					Closed	
Return Air Damper Signal		1					Open	

Notes:
A. Only one sensor required for building, value to be shared over network. Fail at last value.
B. Enthalpy and/or dewpoint to be calculated from temperature and humidity values.

K. COOLING CONTROL – MULTIPLE CHILLED WATER COILS

1. Mechanical cooling shall only occur when unit supply fan status is proven on, cooling state is active, and outside air temperature is greater than 50°F (adj.). Mechanical cooling shall be off all other times.

2. Control strategy intent for mechanical cooling is to stage coils on and off for comfort control. It is not acceptable to modulate individual cooling stages at some middle capacity level for comfort control as this may result in excessive zone humidity.
3. The **Cooling Demand** shall be based on the discharge temperature setpoint reset, refer to Discharge Air Temperature Setpoint Control section.
    a. As discharge air temperature setpoint decreases from high to low setpoint values, the **Cooling Demand** shall increase linearly from 0% to 100%.
4. When either return air relative humidity or maximum zone humidity rises above the dehumidification setpoint of 60%RH (adj.), the **Cooling Demand** shall be forced to 100% until the relative humidity falls back below the setpoint minus a differential of 5%RH.
5. Cooling coils shall be staged in order to provide maximum dehumidification.
    a. As the **Cooling Demand** increases to 50% (adj.), the valve for the bottom coil shall be opened and remain open until the **Cooling Demand** decreases to 5% (adj.).
    b. As the **Cooling Demand** increases to 100% (adj.), the valve for the top coil shall be opened and remain open until the **Cooling Demand** decreases to 50% (adj.).
    c. Units with a single cooling coil shall duty-cycle to vary cooling capacity.
        i. **Cooling Demand** less than 10%, cooling stage off.
        ii. **Cooling Demand** between 10% and 90%. Cooling stage cycle time shall vary linearly from [5-minutes on / 25-minutes off] to [25-minutes on / 5-minutes off].
        iii. **Cooling Demand** greater than 90%, cooling stage on continuously.
    d. At no point shall cooling stages be allowed to short-cycle at a rate of less than 5-minutes open or closed.
6. When a cooling coil is being utilized, the cooling valve signal shall be limited in order to maintain the leaving water temperature at or above a setpoint of 54°F (adj.) to prevent over-flowing the coil. When dehumidification is active as described above, this setpoint shall be lowered to 50°F (adj.) to ensure maximum dehumidification. In order to maintain flow, this limit shall not allow the signal to drop below 20% (adj.).

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Cooling Valve Signal		#					Last	A
Return Air Relative Humidity	1							
Maximum Zone Humidity						1		
Cooling Coil Leaving Water Temperature	#							
Outside Air Temperature						1		

Notes:
A. Point to be included in system maximum calculation for cooling plant.

L. COOLING CONTROL – VARIABLE DX

1. When in cooling state, outside air temperature is greater than 55°F (adj.), and economizer control is active, the outside air dampers shall be modulated first in sequence with DX cooling. Outside air dampers must be fully open prior to DX being enabled and shall remain open until DX is fully off or economizer is disabled.
2. When economizer is disabled, the outside air dampers are ignored and DX shall control as described below.
3. When enabled as described above, DX cooling shall stage up and down to maintain the discharge air temperature at setpoint.
    a. Stages shall enable when the discharge air temperature is 5°F (adj.) above setpoint and disable when it is 5°F (adj.) below setpoint.
    b. Individual stages shall have a minimum-on time and minimum-off time of 10 minutes (adj.). There shall be a 5-minute (adj.) inter-stage delay.
4. Any modulation of individual stages shall only be done to maintain the cooling coil leaving air temperature at or above the maximum cooling setpoint of 52°F (adj.).

5. [Designer Note: if coil discharge temp sensor may be difficult to install (for example, if HGRH coil is immediately after cooling coil), use this suction pressure approach instead of above.] Any modulation of individual stages shall only be done to prevent excessively cold conditions. The variable capacity compressor signal shall modulate to prevent the suction pressure from dropping below a level equivalent to a temperature of 40°F. Refer to refrigerant pressure/temperature charts for the selected refrigerant. For example, R-410a shall not drop below 120 psi (adj.).
6. When either return air relative humidity or maximum zone humidity rises above the dehumidification setpoint of 60%RH (adj.), dehumidification shall be activated. When the relative humidity falls back below the setpoint minus a differential of 5%RH, dehumidification shall be deactivated.
    a. When dehumidification is active, cooling shall stage and modulate up to maintain the cooling coil leaving temperature at the maximum cooling setpoint of 52°F (adj.).
    b. When dehumidification is active, cooling shall stage and modulate up to maintain the suction pressure at the equivalent of 40°F.
    c. If the average zone temperature falls below 70°F, the hot gas reheat shall be enabled and modulate to maintain the discharge temperature at the calculated setpoint.
7. DX cooling shall be off when unit is off. This shall supersede any active minimum-on or inter-stage timer.
8. DX condensing unit electrical current shall be monitored and used to calculate power similar to as described in Common Control Notes motor control.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
DX Cooling Stage Command				#			Off	
DX Variable Capacity Compressor Signal		1					Min.	
DX Suction Pressure	1							
DX Condensing Unit Current (Amps)	1							
Cooling Coil Leaving Air Temperature	1							
Discharge Air Temperature	1							
Hot Gas Reheat Signal		1					Min.	
Return Air Relative Humidity	1							
Maximum Zone Humidity						1		
Average Zone Temperature						1		
Outside Air Temperature						1		A

Notes:
A. Only one is needed for the building. Value shall be shared across systems.

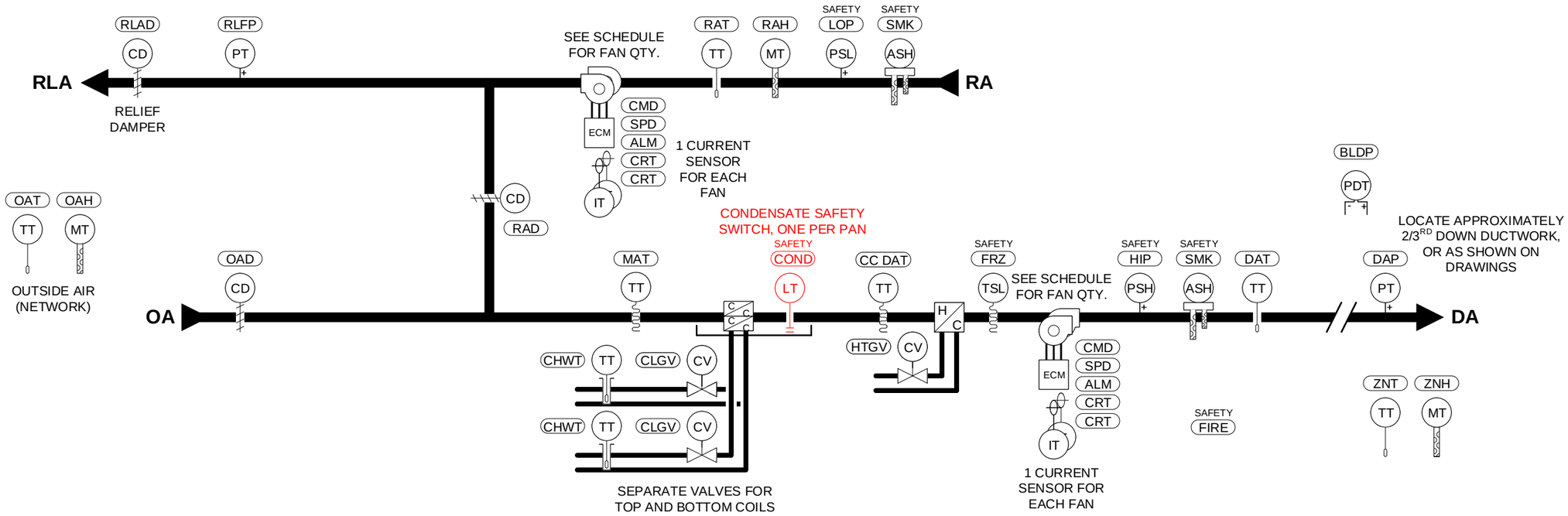
M. HEATING CONTROL – HEATING WATER COIL

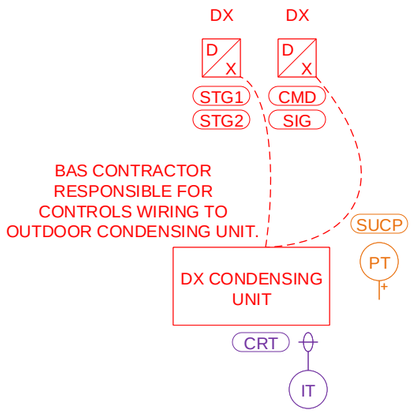
1. When in heating state or morning warm-up mode, the heating valve shall modulate as required to maintain discharge air temperature at the minimum setpoint of 55°F (adj.). As discharge air temperature falls below setpoint, the heating valve is modulated more open.
2. When dehumidification is active as described in COOLING CONTROL paragraph, the heating coil valve shall modulate to maintain the discharge temperature at the minimum active setpoint.
3. When supply fan is on and unit is not in heating or morning warm-up mode or dehumidification mode, heating valve shall be closed.
4. Whenever supply fan is off and the outside air temperature is greater than 40°F (adj.), the heating coil valve shall be closed. When the outside air temperature is less than 40°F (adj.), the heating coil valve shall modulate to heat the interior of the unit as follows:
    a. The heating coil valve shall modulate to maintain the minimum of the mixed air temperature and discharge air temperature at a setpoint of 50°F (adj.).

b. As a back-up measure, if the mixed air temperature ever falls below 40°F, the heating coil valve shall be commanded fully open and remain open until mixed air temperature reaches 55°F.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Heating Valve Signal		1					Open	
Mixed Air Temperature	1							
Discharge Air Temperature	1							
Outside Air Temperature						1		A

Notes:
A. Only one is needed for the building. Value shall be shared across systems.





MULTIPLE ZONE AIR HANDLING UNIT, VAV

FOR REFERENCE ONLY.
LAST REVISED 6/23/2022

SINGLE ZONE AIR HANDLING UNIT SEQUENCE

A. ADDITIONAL REFERENCE

1. Refer to Common Controls Notes for additional information related to this sequence.
2. Refer to specification sections 23 09 00 and 23 09 23 for additional information related to this sequence.

B. EMERGENCY SAFETY/LIMIT CONTROLS

1. See Common Controls Notes for details on safeties.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Fire Alarm Safety Sts			1					
Freezestat Alarm Safety Sts			1					
High SA Duct Press Safety Sts			1					
Low RA Duct Press Safety Sts			1					
Cooling Drain Pan High Level Safety Sts			1					

Notes:

C. SOFTWARE FREEZESTAT

1. If the discharge air temperature falls below 35°F (adj.) for 1 minute (adj.) the unit shall shut down.
   a. Fans shall be commanded off.
   b. Outside and relief air dampers shall be commanded closed.
   c. Heating valve shall be commanded open.
2. After 15 minutes (adj.) if the discharge temperature has risen above 55°F (adj.), the unit shall be allowed to start again.
3. If the software freezestat trips 3 times in one hour, the unit shall remain off until manually reset via a button on the graphics.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Discharge Air Temperature	1							
Supply Fan Command				1			Off	
Return Fan Command				1			Off	
Outside Air Damper		1					Closed	
Return Air Damper		1					Open	
Relief Air Damper		1					Closed	
Heating Valve Signal		1					Open	

Notes:

D. UNIT SCHEDULE CONTROL

1. Refer to Common Controls Notes for details on unit scheduling and optimized start.
2. Large electrical loads within the unit (supply fans without VFDs, DX cooling coils) shall be staggered in start time from other large electrical loads in the building to prevent large in-rush currents when the building cycles into an occupied mode.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Outside Air Temperature						1		A
Average Zone Air Temperature						1		
Central HW Available						1		
Security Key Armed/Disarmed Status						1		

Notes:

A. Only one sensor required for building, value to be shared over network. Fail at last value.

E. TEMPERATURE AND STATE CONTROL

1. Refer to Common Controls notes for standard zone temperature setpoints.
2. When the supply fan is on, and the zone temperature rises above the active cooling setpoint, the unit shall be in cooling state. Unit remains in this state until zone temperature drifts across the deadband and falls below active heating setpoint, when it shall be in heating state.
3. While in cooling state, the **Cooling Demand** shall modulate between 0-100% to maintain the zone temperature at the cooling setpoint.
    a. When economizer control is active, as the **Cooling Demand** increases from 0-100%, the discharge temperature setpoint shall decrease from the zone cooling setpoint (75°F) to a minimum of 55°F (adj.).
    b. When economizer is disabled or at maximum, the **Cooling Demand** shall be used to stage cooling coils as described in COOLING CONTROL paragraph.
4. While in heating state, the **Heating Demand** shall modulate between 0-100% to maintain the zone temperature at the heating setpoint.
    a. As the **Heating Demand** increases from 0-100%, the discharge temperature setpoint shall increase from the current mixed air temperature to a maximum of 85°F (adj.).
5. Unoccupied Control:
    a. Upon an unoccupied cooling call, the discharge air temperature setpoint shall be fixed at a setpoint of 55°F (adj.).
    b. Upon an unoccupied heating call, the discharge air temperature setpoint shall be fixed at a setpoint of 95°F (adj.).

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Zone Temperature	1							

Notes:

F. MINIMUM OUTSIDE AIR VENTILATION CONTROL – VARIABLE, WITHOUT CO2 CONTROL

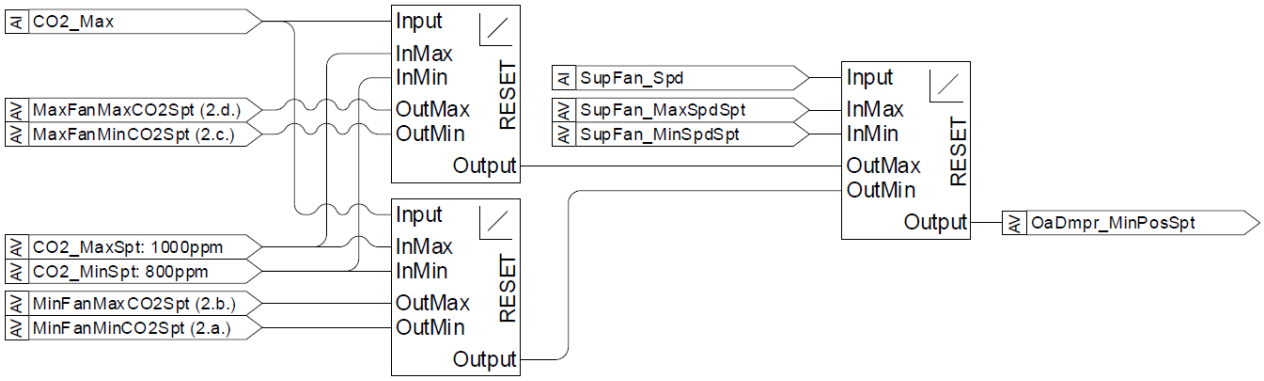
1. Minimum outside air damper position setpoint shall modulate as a result of fan speed.
2. There shall be two outside air damper position setpoints to be determined together with TAB contractor based on drawings. For the purposes of balancing and this control logic, the supply fan minimum speed setpoint shall be considered the slowest fan speed required to deliver design minimum airflow and ventilation. This is different from the minimum speed setting configured in the VFD. Supply fan maximum speed setpoint shall be the fastest fan speed required to deliver design maximum airflow and ventilation with all fans running.
    a. With the supply fan at minimum speed setpoint, determine the OA damper position required to achieve the scheduled design OA airflow.
    b. With the supply fan at maximum speed setpoint, determine the OA damper position required to achieve the same scheduled design OA as above.
3. As the fan speed increases from minimum to maximum, the final outside air damper minimum position shall be determined by linearly resetting between the results from part 2 above (2.a. to 2.b.).
4. Include reset calculation programming to approximate and display on the graphic screen, the real-time percent outside airflow resulting from the varying fan speeds and damper positions. This point shall be trended and available for use by the facilities commissioning team to monitor outside airflow.
5. Minimum OA damper position setpoint shall not inhibit economizer function. If the unit calls to provide free cooling when outside air conditions are favorable, the unit shall be allowed to further modulate open outside air damper as needed.
6. Whenever the unit is operating in any mode other than occupied, such as unoccupied or optimized start, the minimum outside air damper position shall be held at 0%.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Supply Fan Speed Signal		1					Min.	

Notes:

G. MINIMUM OUTSIDE AIR VENTILATION CONTROL – VARIABLE, WITH CO2 CONTROL

1. Minimum outside air damper position setpoint shall modulate as a result of fan speed and return air CO2 concentration.
2. There shall be four total outside air damper position setpoints to be determined together with TAB contractor based on drawings. For the purposes of balancing and this control logic, the supply fan minimum speed setpoint shall be considered the slowest fan speed required to deliver design minimum airflow and ventilation. This is different from the minimum speed setting configured in the VFD. Supply fan maximum speed setpoint shall be the fastest fan speed required to deliver design maximum airflow and ventilation with all fans running.
   a. With the supply fan at minimum speed setpoint, determine the OA damper position required to achieve the minimum “square-footage” OA airflow. This is the ventilation required based on the area of the space served or any makeup air needs.
   b. With the supply fan still at minimum speed setpoint, determine the OA damper position required to achieve the scheduled design OA airflow. This accounts for maximum ventilation required for a fully occupied zone.
   c. With the supply fan at maximum speed setpoint, determine the OA damper position required to achieve the same minimum “square-footage” OA airflow as above.
   d. With the supply fan still at maximum speed setpoint, determine the OA damper position required to achieve the same scheduled design OA as above.
3. As the return air CO2 concentration increases from 800 ppm (adj.) to 1000 ppm (adj.), the above setpoints shall be linearly reset from minimum ventilation to maximum ventilation for both fan speeds (2.a. to 2.b. and 2.c. to 2.d).
4. As the fan speed increases from minimum to maximum, the final outside air damper minimum position shall be determined by linearly resetting between the results from part 3 above (2.a/b. to 2.c/d.). See the control diagram below.



5. Include linear reset calculation to approximate the real-time percent outside airflow resulting from the varying fan speeds and damper positions. This point shall be displayed on the graphics and trended for use by the facilities commissioning team to monitor outside airflow.
6. Minimum OA damper position setpoint shall not inhibit economizer function. If the unit calls to provide free cooling when outside air conditions are favorable, the unit shall be allowed to further modulate open outside air damper as needed.
7. Whenever the unit is operating in any mode other than occupied, such as unoccupied or optimized start, the minimum outside air damper position shall be held at 0%.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Return CO2 Level	1							
Supply Fan Speed Signal		1					Min.	

Notes:

H. SUPPLY FAN CONTROL – VARIABLE AIR VOLUME

1. Refer to Common Control Notes for details on fan/motor control.
2. Fan shall be commanded on during occupied mode and optimized start mode. Fans shall shut down when disabled by operators by the manual software enable point to allow for maintenance shutdowns without nuisance alarming.
    a. This is not a replacement for typical lock-out tag-out procedures and other safe maintenance procedures.
3. Fan shall also be commanded on intermittently in the following conditions:
    a. Unoccupied calls for heating or cooling as described in paragraph above.
    b. Extended unoccupied air circulation.
        i. Enable fan approximately once every 24 hrs (adj.), for a 30-minute (adj.) duration, if fan does not already run at least once a day to satisfy an unoccupied heating or cooling call. This is to prevent prolonged stagnant air during long unoccupied periods.
    c. Cold unit interior air circulation.
        i. When the unit is off and the minimum of the mixed air and discharge air temperature sensors falls below 45°F (adj.). Include a minimum on time of 15 minutes (adj.).
4. Supply Fan Speed Setpoints
    a. Work with air balancing contractor to field determine these setpoints based on the scheduled airflow rates for this particular unit as shown on the drawings.
        i. Maximum supply fan speed setpoint. Adjust the supply fan speed to determine what speed yields the scheduled design airflow rate.
        ii. Minimum supply fan speed setpoint. Adjust the supply fan speed to determine what speed yields the scheduled minimum airflow rate. If not scheduled, assume 50% of maximum airflow.
5. Fan speed shall linearly reset from minimum to maximum as **Cooling Demand** or **Heating Demand** increases from 50% (adj.) to 100%.
    a. Speed transitions shall happen gradually, limited to 5% change every 1-minute.
    b. Coordinate with TAB to determine minimum demand to begin increasing fan speed.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Supply Fan Command				1			Off	
Supply Fan Current (Amps)	#							A
Supply Fan Array Alarm			1					
Supply Fan Speed Signal		1					Min.	
Mixed Air Temperature	1							
Discharge Air Temperature	1							

Notes:
A. See approved AHU submittal for fan quantity.

I. RETURN FAN & RELIEF DAMPER CONTROL

1. Refer to Common Control Notes for details on fan/motor control.
2. Return fan shall run continuously during occupied mode.
3. Return fan shall run along with supply fan in unoccupied mode.
4. Fans shall shut down when disabled by operators by the manual software enable point to allow for maintenance shutdowns without nuisance alarming.
    a. This is not a replacement for typical lock-out tag-out procedures and other safe maintenance procedures.
5. Relief plenum pressure setpoint determination

a. Setpoint shall hold at +0.01 wc (adj.) until outside air damper position signal rises above 70% (adj.), where it shall release to reset control as described next. Once outside air damper position signal falls below 50% (adj.), setpoint shall return to original value.
b. Setpoint reset control
   i. Setpoint shall reset from value above to +0.12 in. wc (adj.) as building pressure control loop increases from 0% to 100%. Refer to Building Pressure Control Strategy below for details on this control loop.

6. Return fan speed shall track supply fan speed with a percentage offset. Return fan speed shall range from minimum speed to 100%.
   a. Offset shall modulate from -40% (adj.) to +10% (adj.) to maintain the relief plenum pressure at setpoint.
   b. As relief plenum pressure increases above setpoint, offset shall decrease towards minimum and the return fan shall modulate towards minimum speed.
7. Relief damper shall track the outside air damper with a percentage offset. Relief damper position shall range from 0-100%.
   a. Offset shall reset from -40% to +10% (adj.) as building pressure control loop increases from 0% to 100%. Refer to Building Pressure Control Strategy below for details on this control loop.
8. When the unit is off, the relief damper shall remain closed.
9. Building Pressure Control Strategy
   a. For the anchor building pressure zone, there shall be a single pressure sensor installed with the positive port in a main corridor at least 30 feet from the main entrance, and the negative port outside the main entrance at least 10 feet from the entrance. There shall be a single pressure control loop driving the offsets for all units controlling building pressure within this anchor building pressure zone. The output of this loop shall be referred to as the Building Pressure Anchor Control Zone Signal. Setpoint shall be +0.01 in. wc. (adj.).
   b. Other building pressure zones within the building shall be identified as isolated areas where air does not freely communicate with the anchor building pressure zone. For these other building pressure zones, there shall be a single pressure sensor installed with the positive port in the isolated zone and the negative port in the building pressure anchor control zone. There shall be a single pressure control loop driving the offsets for all units controlling building pressure within this building pressure zone. The output of this loop shall be referred to as the Building Pressure Control Zone # Signal, where a "#" is assigned to each isolated pressure zone. Setpoint shall be neutral +0.00 in. wc. (adj.).

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Return Fan Command				1			Off	
Return Fan Current (Amps)	#							A
Return Fan Array Alarm			1					
Return Fan Speed Signal		1					Min.	
Building Pressure	1							B
Building Pressure Control Signal						1		B
Relief Air Damper Signal		1					Closed	
Relief Air Plenum Pressure	1							
Supply Fan Speed Signal		1					Min.	

Notes:
A. See approved AHU submittal for fan quantity.
B. One sensor and PID control loop shared by all units within a pressure control zone.

J. RELIEF FAN AND RELIEF DAMPER – REMOTE LOCATION

1. [Designer Note: in remote relief applications, additional considerations need to be made for econ decision, dehumidification, etc… because there will not be any return airflow during economizer state.]
2. Refer to Common Controls Notes for details on fan/motor control.
3. Relief damper located at the discharge of the relief fan shall be reset from 0% (adj.) to 100% (adj.) as building pressure control loop increases from 5% to 30% (adj.). Refer to Building Pressure Control Strategy below for details on this control loop.
4. Relief fan shall be commanded on whenever the relief damper signal rises above 95% (adj.) and commanded off when relief damper signal falls below 40% (adj.).
5. Relief fan speed shall be reset from 0% (adj.) to 100% (adj.) as building pressure control loop increases from 30% to 100% (adj.). Refer to Building Pressure Control Strategy below for details on this control loop.
6. Relief damper shall be closed and relief fan shall be off when the associated AHU is off, or whenever outside air temperature is below 0°F (adj.).
7. Building Pressure Control Strategy
    a. For the anchor building pressure zone, there shall be a single pressure sensor installed with the positive port in a main corridor at least 30 feet from the main entrance, and the negative port outside the main entrance at least 10 feet from the entrance. There shall be a single pressure control loop driving the offsets for all units controlling building pressure within this anchor building pressure zone. The output of this loop shall be referred to as the Building Pressure Anchor Control Zone Signal. Setpoint shall be +0.01 in. wc. (adj.).
8. Other building pressure zones within the building shall be identified as isolated areas where air does not freely communicate with the anchor building pressure zone. For these other building pressure zones, there shall be a single pressure sensor installed with the positive port in the isolated zone and the negative port in the building pressure anchor control zone. There shall be a single pressure control loop driving the offsets for all units controlling building pressure within this building pressure zone. The output of this loop shall be referred to as the Building Pressure Control Zone # Signal, where a "#" is assigned to each isolated pressure zone. Setpoint shall be neutral +0.00 in. wc. (adj.).

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Relief Fan Command				1			Off	
Relief Fan Current (Amps)	#							A
Relief Fan Array Alarm			1					
Relief Fan Speed Signal		1					Min.	
Relief Air Damper Signal		1					Closed	
Building Pressure	1							B
Building Pressure Control Signal						1		B

Notes:
A. See approved AHU submittal for fan quantity.
B. One sensor and PID control loop shared by all units within a pressure control zone.

K. OUTSIDE AIR AND RETURN AIR DAMPER CONTROL
1. The return air damper shall inversely follow outside air damper position. As the outside air damper modulates open, the return air damper modulates closed.
2. [Designer Note: Consider %OA design of unit and what temperatures coils are designed for. 45°F setpoint may need to be decreased if paragraph is included.] Provide a low mixed air temperature control loop as an additional safety measure to quickly decrease outside air damper position prior to unit tripping on freeze protection safety. As mixed air temperature falls below 45°F (adj.), the outside air damper position shall be modulated more closed to maintain the low mixed air temperature setpoint. This control shall be at the highest priority.
3. Economizer State Decision:
    a. Enabled when the outside air enthalpy is lower than return air enthalpy minus 1.2 Btu/lb (adj.) buffer setpoint, and the outside air dewpoint is less than 58°F (adj.).

b. Disabled when the outside air enthalpy is higher than return air enthalpy minus 0.5 Btu/lb (adj.) buffer setpoint, or the outside air dewpoint is greater than 58°F (adj.).

4. When economizer control is enabled, the outside air damper shall be modulated between the calculated minimum position and 100% in order to maintain the calculated discharge air temperature setpoint. Economizer shall be fully utilized before enabling any mechanical cooling and shall be held at 100% when mechanical cooling is active.
5. When economizer control is disabled, the outside air damper shall be held at the calculated minimum OA damper position setpoint during occupied operation.
6. When the unit is operating during unoccupied hours (including optimal start routines) the outside air damper shall be allowed to close fully, ignoring minimum OA damper position setpoint.
7. Outside damper shall be closed and return damper open when supply fan is not proving status.
8. On startup the outside air damper shall initially be held closed and gradually released to the calculated minimum position over a 10-minute (adj.) period.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Outside Air Temperature						1		A
Outside Air Humidity						1		A, B
Return Air Temperature	1							
Return Air Humidity	1							B
Mixed Air Temperature	1							
Discharge Air Temperature	1							
Outside Air Damper Signal		1					Closed	
Return Air Damper Signal		1					Open	

Notes:
A. Only one sensor required for building, value to be shared over network. Fail at last value.
B. Enthalpy and/or dewpoint to be calculated from temperature and humidity values.

L. ENTHALPY HEAT EXCHANGER CONTROL

1. [Designer Note: including this paragraph assumes fan in relief position. Revise earlier sections accordingly.]
2. Temperature Control
   a. **Summer Operation**, engage when outdoor air enthalpy is greater than return air enthalpy plus 0.5 btu/lb (adj.). Summer-operation shall remain engaged until outdoor air enthalpy is less than return air enthalpy, then transition to off-operation.
      i. Bypass dampers fully closed.
   b. **Off Operation**, engage whenever not in summer operation or winter operation.
      i. Bypass dampers fully open.
   c. **Winter Operation**, engage when outside air temperature is less than calculated discharge air temperature setpoint minus 4°F (adj.). Winter operation shall remain engaged until outside air temperature is greater than calculated discharge air temperature setpoint minus 2°F (adj.), then transition to off-operation.
      i. Bypass dampers are modulated to maintain mixed air temperature at 2°F (adj.) less than calculated discharge air temperature setpoint.
3. Frost Control
   a. Whenever outside air temperature is less than 32°F (adj.), the frost control sequence shall be active and take priority over the temperature control sequence above.
   b. Limit the relief fan speed by modulating it to maintain heat exchanger relief air humidity below 90%RH (adj.).
   c. If heat exchanger relief air relative humidity exceeds 92%RH (adj.) for 10 minutes (adj.), turn off relief fan for 30-minutes (adj.). After 30-minute off period has expired, relief fan to resume the frost control strategy.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Relief Fan Speed		1						
Energy Wheel Bypass Damper		2						
Outside Air Temperature						1		
Outside Air Humidity						1		
Return Air Temperature	1							
Return Air Humidity	1							
Mixed Air Temperature	1							
Relief Air Temperature	1							
Relief Air Humidity	1							
Notes:								

M. ENERGY WHEEL & BYPASS DAMPER CONTROL

1. See Common Control Notes for details on motor control.
2. Temperature Control
   a. **Summer Operation**, engage when outdoor air enthalpy is greater than return air enthalpy plus 0.5 btu/lb (adj.). Summer-operation shall remain engaged until outdoor air enthalpy is less than return air enthalpy, then off-operation.
      i. Wheel bypass dampers fully closed. Wheel at full speed.
   b. **Off Operation**, engage whenever not in summer operation or winter operation.
      i. Wheel bypass dampers fully open, and wheel is off.
   c. **Winter Operation**, engage when not economizing (minimum OA) and discharge air temperature falls 2°F (adj.) below the active setpoint for 5 minutes (adj.). Winter operation shall remain engaged until discharge air temperature is greater than setpoint plus 2°F (adj.) for 5 minutes (adj.), then off operation.
      i. Wheel is commanded on. Bypass dampers are modulated in sequence with wheel speed to maintain mixed air temperature at 2°F (adj.) less than calculated discharge air temperature setpoint.
      ii. As mixed air temperature rises above setpoint, wheel is modulated slower to minimum speed, then bypass dampers begin to modulate open.
      iii. As mixed air temperature falls below setpoint, bypass dampers begin to modulate to full closed, then wheel is modulated to a faster speed.
3. Frost Control
   a. Whenever outside air temperature is less than 32°F (adj.), the frost control sequence shall be active and take priority over the temperature control sequence above.
   b. Limit the wheel speed by modulating it to maintain wheel relief air humidity below 90%RH (adj.).
   c. If wheel relief air relative humidity exceeds 92%RH (adj.) for 10 minutes (adj.), turn off wheel for 30-minutes (adj.). After 30-minute off period has expired, wheel to resume the frost control strategy.
4. Whenever unit is unoccupied or wheel is in off-operation, the energy wheel shall run at minimum speed for 20 seconds (adj.) every 1 hour (adj.) to extend longevity of the wheel mechanical components and prevent odors.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Energy Wheel Command				1				
Energy Wheel Power (kW)	1				R			
Energy Wheel Frequency (Hz)	1				R			
Energy Wheel Status			1					
Energy Wheel Speed		1						
Energy Wheel Bypass Damper		2						
Outside Air Temperature						1		A
Outside Air Humidity						1		A

Return Air Temperature	1							
Return Air Humidity	1							
Discharge Air Temperature	1							
Mixed Air Temperature	1							
Relief Air Temperature	1							
Relief Air Humidity	1							

Notes:
A. Only one is needed for the building. Value shall be shared across systems.

N. COOLING CONTROL – MULTIPLE CHILLED WATER COILS

1. Mechanical cooling shall only occur when unit supply fan status is proven on, cooling state is active, and outside air temperature is greater than 50°F (adj.). Mechanical cooling shall be off all other times.
2. Control strategy intent for mechanical cooling is to stage coils on and off for comfort control. It is not acceptable to modulate individual cooling stages at some middle capacity level for comfort control as this may result in excessive zone humidity.
3. Use **Cooling Demand** value determined above to stage coils.
4. When return air relative humidity rises above the dehumidification setpoint of 60%RH (adj.) the **Cooling Demand** shall be forced to 100% until it falls back below the setpoint minus a hysteresis of 5%RH.
5. Whenever economizer control is active, the outside air damper shall be the first component used to provide cooling. Mechanical cooling shall be disabled until outside air dampers are fully open.
6. Cooling coils shall be staged in order to provide maximum dehumidification.
    a. As the **Cooling Demand** increases to 50% (adj.), the valve for the bottom coil shall be opened and remain open until the **Cooling Demand** decreases to 5% (adj.).
    b. As the **Cooling Demand** increases to 100% (adj.), the valve for the top coil shall be opened and remain open until the **Cooling Demand** decreases to 50% (adj.).
    c. Units with a single cooling coil shall duty-cycle to vary cooling capacity.
        i. **Cooling Demand** less than 10%, cooling stage off.
        ii. **Cooling Demand** between 10% and 90%. Cooling stage cycle time shall vary linearly from [5-minutes on / 25-minutes off] to [25-minutes on / 5-minutes off].
        iii. **Cooling Demand** greater than 90%, cooling stage on steady.
    d. At no point shall cooling stages be allowed to short-cycle at a rate of less than 5-minutes open or closed.
7. When a cooling coil is being utilized, the signal shall be limited in order to maintain the leaving water temperature at or above a setpoint of 54°F (adj.) to prevent over-flowing. When dehumidification is active as described above, this setpoint shall be lowered to 50°F (adj.) to ensure maximum dehumidification. In order to maintain flow, this shall not allow the signal to drop below 20% (adj.).

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Cooling Valve Signal		#					Last	A
Return Air Relative Humidity	1							
Cooling Coil Leaving Water Temperature	#							
Outside Air Temperature						1		B

Notes:
A. Point to be included in system maximum calculation.
B. Only one is needed for the building. Value shall be shared across systems.

O. COOLING CONTROL – VARIABLE DX

1. When economizer control is enabled, the DX cooling shall stage as the second half of the **Cooling Demand** signal. Economizer shall be fully utilized before enabling any mechanical

cooling, and shall be held at 100% when mechanical cooling is active. When economizer control is disabled, the DX cooling shall stage across the full **Cooling Demand** signal range.

a. Stages shall enable as the **Cooling Demand** signal increases, and disable once the signal falls back below the differential. Differential shall be equal to the signal range divided by the number of stages.

b. Individual stages shall have a minimum-on time and minimum-off time of 10 minutes (adj.). There shall be a 5-minute (adj.) inter-stage delay.

2. Any modulation of individual stages shall only be done to maintain the cooling coil leaving air temperature at or above the maximum cooling setpoint of 52°F (adj.).

3. [Designer Note: if coil discharge temp sensor may be difficult to install (for example, if HGRH coil is immediately after cooling coil), use this suction pressure approach instead of above.] Any modulation of individual stages shall only be done to prevent excessively cold conditions. The variable capacity compressor signal shall modulate to prevent the suction pressure from dropping below a level equivalent to a temperature of 40°F. Refer to refrigerant pressure/temperature charts for the selected refrigerant. For example, R-410a shall not drop below 120 psi (adj.).

4. When return air relative humidity rises above the dehumidification setpoint of 60%RH (adj.), dehumidification shall be activated. When the relative humidity falls back below the setpoint minus a differential of 5%RH, dehumidification shall be deactivated.

a. When dehumidification is active, cooling shall stage and modulate up to maintain the cooling coil leaving temperature at the maximum cooling setpoint of 52°F (adj.).

b. When dehumidification is active, cooling shall stage and modulate up to maintain the suction pressure at the equivalent of 40°F.

c. If the zone temperature falls below 70°F, the hot gas reheat shall be enabled and modulate to maintain the discharge temperature at the calculated setpoint.

5. DX cooling shall be off when unit is off. This shall supersede any active minimum-on or inter-stage timer.

6. DX condensing unit electrical current shall be monitored and used to calculate power similar to as described in Common Control Notes motor control.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
DX Cooling Stage Command				#			Off	
DX Variable Capacity Compressor Signal		1					Min.	
DX Suction Pressure	1							
DX Condensing Unit Current (Amps)	1							
Cooling Coil Leaving Air Temperature	1							
Discharge Air Temperature	1							
Hot Gas Reheat Signal		1					Min.	
Return Air Relative Humidity	1							
Zone Temperature						1		
Outside Air Temperature						1		A

Notes:
A. Only one is needed for the building. Value shall be shared across systems.

P. HEATING CONTROL – HEATING WATER COIL

1. When in heating state, the heating valve shall modulate as required to maintain discharge air temperature at the calculated setpoint. As discharge air temperature falls below setpoint the heating valve is modulated more open.

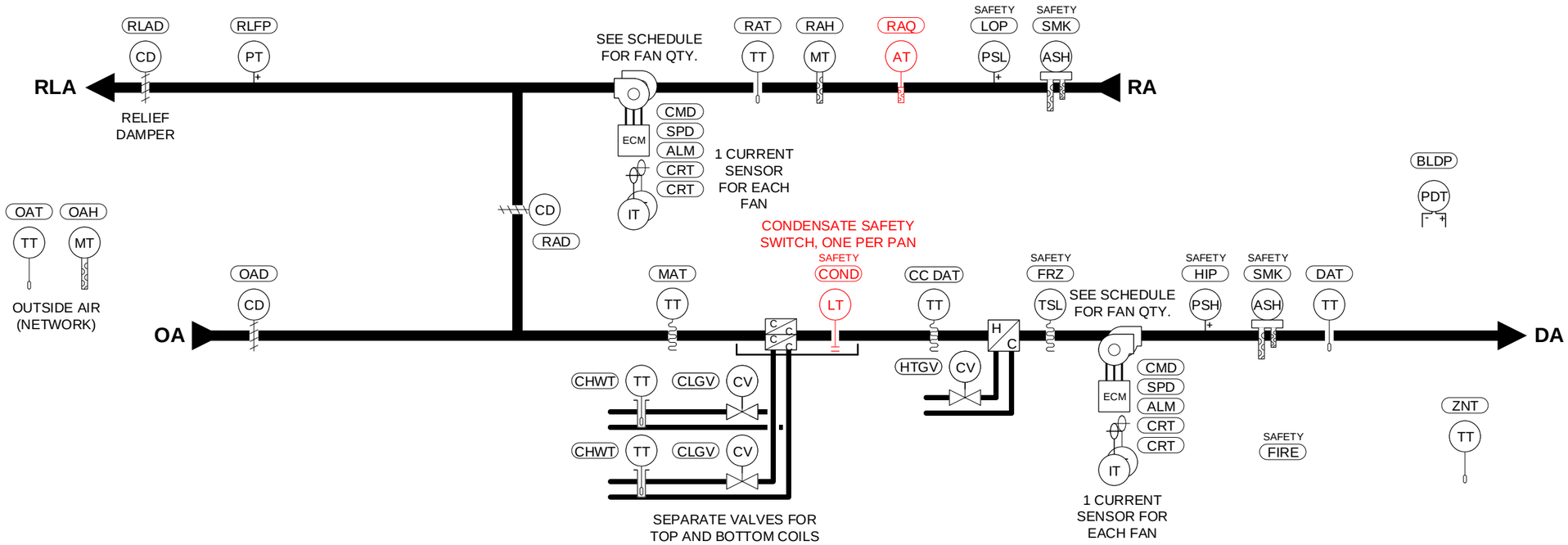
2. When dehumidification is active as described in COOLING CONTROL paragraph, the heating coil valve shall modulate to maintain the discharge temperature at the minimum setpoint.

3. When supply fan is on and unit is not in heating or dehumidification mode, heating valve shall be closed.

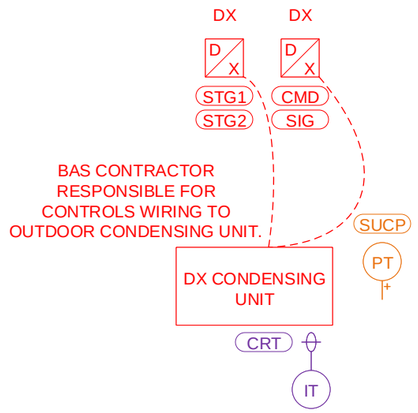
4. Whenever supply fan is off and the outside air temperature is greater than 40°F (adj.), the heating coil valve shall be closed. When the outside air temperature is less than 40°F (adj.), the heating coil valve shall modulate to heat the interior of the unit as follows:
    a. The heating coil valve shall modulate to maintain the minimum of the mixed air temperature and discharge air temperature at a setpoint of 50°F (adj.).
    b. As a back-up measure, if the mixed air temperature ever falls below 40°F, the heating coil valve shall be commanded fully open and remain open until mixed air temperature reaches 55°F.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Heating Valve Signal		1					Open	
Mixed Air Temperature	1							
Discharge Air Temperature	1							
Outside Air Temperature						1		A

Notes:
A. Only one is needed for the building. Value shall be shared across systems.



SINGLE ZONE AIR HANDLING UNIT



INDUCTION DISPLACEMENT UNIT (IDU) AND CHILLED BEAM (CB) SEQUENCE

A. ADDITIONAL REFERENCE

1. Refer to Common Controls Notes for additional information related to this sequence.
2. See specifications sections 23 09 00 and 23 09 23 for additional information related to this sequence.

B. UNIT SCHEDULE CONTROL

1. Refer to Common Controls Notes for details on unit scheduling and optimized start.
2. Provide a graphic showing a summary table of all IDU/CB units. Each IDU/CB zone shall be represented by a separate row within the table. The columns shall represent the following data points for each IDU/CB unit: equipment tag, areas served, time schedule selection, current schedule status, zone temperature, occupied cooling setpoint, occupied heating setpoint, target airflow setpoint, airflow, damper position, reheat valve position, discharge air temperature, radiation valve position.
3. Zone controller shall generate network outputs to parent equipment to communicate zone temperature and humidity. These values shall be used for system level control including optimized start and unoccupied operation.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Zone Temperature						1		A
Zone Humidity						1		A

Notes:

A. Include point in AHU minimum, maximum, and average calculations.

C. ZONE SETPOINT CONTROL

1. Refer to Common Controls Notes for details on zone temperature setpoints.
2. All cfm setpoints, primary airflow duct areas, and other settings shall be individually programmed and adjustable for each zone served by IDU/CB units. Refer to equipment schedules.
3. Zone temperature local setpoint adjustment (if equipped), range shall be limited to +/- 2°F (adj). Adjustment value shall be added to all occupied heating and cooling setpoints such that the deadband shall still be active and shifted accordingly. Adjustment value shall have no effect on unoccupied setpoints.
4. Zone occupancy sensor (if equipped), shall transition IDU/CB unit to a standby state when motion is not detected for 15-minutes (adj.) during periods of scheduled occupancy. Setpoints shall relax in standby mode, and ventilation rate shall be reduced as indicated here.
    a. 5°F (adj) offset shall be added to occupied cooling setpoint.
    b. 5°F (adj) offset shall be subtracted from occupied heating setpoint.
    c. [Designer Note: The following section applies only to IDUs, and should be deleted for chilled beams] Since displacement principle is not required when spaces are unoccupied, heating valve limitations shall be ignored during standby state for IDUs only. Hot air shall be allowed to discharge from IDU as required.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Zone Air Temperature	1							
Zone Air Temp Local Spt Adj (if equipped)	1							
Zone Occupancy Sensor (if equipped)			1					

Notes:

D. DAMPER AND AIRFLOW CONTROL

1. While zone is unoccupied, primary air damper shall be closed and airflow setpoint shall be zero cfm.
2. Primary air damper shall modulate to maintain the active airflow setpoint. The active airflow setpoint shall be determined based on unit state as follows:
   a. During standby state, airflow setpoint shall be minimum airflow. Minimum cfm shall be 50% (adj.) of maximum airflow.
   b. All other states, airflow setpoint shall be kept at maximum cfm. Maximum cfm shall be equal to design ventilation rate.
3. Morning warm-up and unoccupied heating functionality
   a. Warm-up state is shared over network from AHU controller. During warm-up state, warm air, rather than cool air is supplied from the AHU. When zone temperature is less than the occupied heating setpoint, the IDU/CB primary air damper shall maintain maximum cfm. Available IDU/CB reheat and radiation valves shall continue to operate normally, during this state. [Designer Note: The following section applies only to IDUs, and should be deleted for chilled beams] However, IDU reheat valve shall not be limited during morning warm-up.
   b. When zone temperature reaches the heating setpoint during morning warm-up, the zone shall enter an unoccupied state.
4. Morning cool-down
   a. When AHU has started early as a result of optimized start logic for cooling, IDU/CB unit dampers shall function normally as described in section D.2 above.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Primary Airflow	1							
Primary Air Damper Signal		1						
Morning Warm Up Mode						1		
AHU Discharge Air Temperature						1		

Notes:

E. TEMPERATURE AND STATE CONTROL

1. When the zone temperature rises above the active cooling setpoint, the unit shall be in cooling state. Unit remains in this state until zone temperature drifts across the deadband and falls below active heating setpoint, when it shall be in heating state.
   a. The **Zone Cooling Demand** is defined as the overall control loop that modulates to maintain zone temperature at the cooling setpoint within each zone. While in cooling state, the **Zone Cooling Demand** shall modulate between 0-100%.
   b. The **Zone Heating Demand** is defined as the overall control loop that modulates to maintain zone temperature at the heating setpoint within each zone. While in heating state, the **Zone Heating Demand** shall modulate between 0-100%.
2. [Designer Note: Include the following only if IDUs/CBs are supplied by a dual temperature water loop] A point representing whether dual-temperature loop is in heating state, and actively circulating hot water shall be shared over network to each zone. If heating water is not available, dual-temperature heating valve shall be held closed. This is done to prevent overcooling when heating water is not available.
3. [Designer Note: Include the following only if IDUs/CBs are supplied by a dual temperature water loop] A point representing whether dual-temperature loop is in cooling state, and actively circulating chilled water shall be shared over network to each zone. If chilled water is not available, dual-temperature cooling valve shall be held closed. This is done to prevent overheating when chilled water is not available.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Zone Temperature	1							
Heating Valve Signal		1						
Cooling Valve Signal		1						
Dual-Temperature Valve Signal		#						
Dual Temp Loop State (Htg or Clg)						1		

Notes:

F. COOLING VALVE CONTROL

1. Cooling Valve
   a. Shall be the **first** component used to provide cooling. The cooling valve shall increase from 0% to 100% as the **Zone Cooling Demand** increases.
   b. Shall be closed immediately when zone dewpoint exceeds supply water temperature by 2°F (mod.) for 15 min (mod.) and remain closed until dewpoint drops below supply water temperature by 2°F (mod.).
   c. If pipe condensate switch indicates that pipe is too cold and will cause condensation, close the cooling valve and command the water loop to stop circulating.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Cooling Valve Signal		1						
Supply Water Temperature						1		
Zone Temperature Sensor	1					1		A
Zone Relative Humidity Sensor	1					1		A
Pipe Condensate Switch			1					B

Notes:
A. Temperature and Relative Humidity used to calculate zone dewpoint temperature. Include in system maximum dewpoint calculation.
B. Install condensate switch in locations and quantities per plans.

G. HEAT AND RADIATION (if equipped) VALVE CONTROL

1. The **Zone Heating Demand** value shall be used to modulate the various output devices in a specific order when adding heat to the zone as described here.
   a. Radiation valve (if equipped)
      i. Shall be the **first** component used to provide heating. The radiation valve shall modulate open from 0% to 100% as the **Zone Heating Demand** resets linearly from [0% to 50%] (adj). The radiation valve shall be disabled and held closed whenever outside air temperature is greater than 65°F (adj) or in 2-pipe applications when dual temperature loop is supplying cold water.
   b. Heating valve
      i. [Designer Note: The following section applies only to chilled beams, and should be deleted for IDUs] Shall be the **second** component used to provide heating. The heating valve shall increase from 0% to 100% (adj) as the **Zone Heating Demand** resets linearly from [50% to 100%] (adj).
      ii. [Designer Note: The following section applies only to IDUs, and should be deleted for chilled beams] The heating valve shall not be limited during a standby or unoccupied state.
      iii. [Designer Note: The following section applies only to IDUs, and should be deleted for chilled beams] The heating valve shall be held closed during occupied states.

iv. Modulating open for heating purposes shall not be allowed in 2-pipe applications when dual temperature loop is supplying cold water.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Outside Air Temperature						1	LAST	A
Heating Valve Signal		1						
Radiation Valve Signal (if equipped)		1						
Dual Temp Loop State (Htg or Clg)						1		

Notes:
A. Only one sensor required for building, value to be shared over network. Upon network failure, last value shall be held.

H. ZONE DEMAND RESET REQUESTS

1. Zone controller shall generate network outputs to parent equipment based on zone demands. These values shall be utilized by the parent equipment for system level control.
   a. A Zone Cooling Request (r) shall be generated when the **Zone Cooling Demand** rises above 95%. This shall be used by the AHU discharge temperature reset.
   b. A Zone Pressure Request (r) shall be generated when the primary air damper rises above 95%. This shall be used by the AHU discharge static pressure reset.
   c. A Zone Heating Call or Zone Cooling Call shall be generated when the Zone Heating Demand or Zone Cooling Demand rises above 50%. This shall be used by the dual temperature loop system for state control.
   d. A Zone Heating Request (r) shall be generated when the **Zone Heating Demand** rises above 95%. This shall be used by the heating loop differential press. setpoint.
   e. Zone reheat signal shall be used by central heating system to calculate system differential pressure setpoint.
2. All requests shall be multiplied by the zone importance multiplier, set to 1 (adj.) by default, before being shared to the parent equipment.
3. Controller shall also totalize the amount of time a request has been active. See ASHRAE Guideline 36 Section 5.1.14 for more information.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Primary Air Damper Signal		1						
Zone Cooling Demand						1		B
Zone Cooling Request (r)						1		A
Zone Pressure Request (r)						1		A
Zone Heating Demand						1		B
Zone Heating Call						1		
Zone Cooling Call						1		
Zone Heating Request (r)						1		A

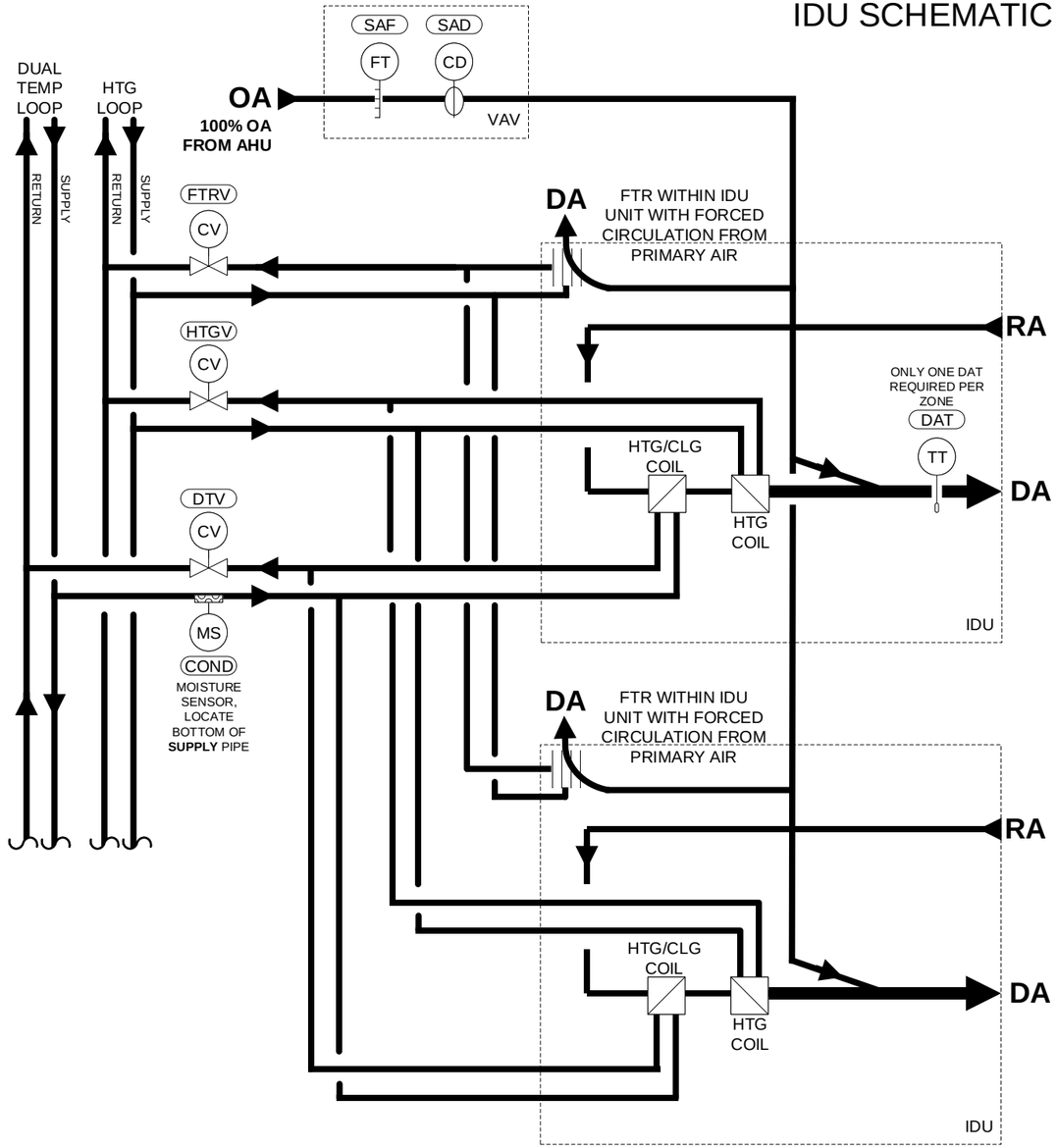
Notes:
A. Point to be multiplied by zone multiplier for inclusion in Trim and Respond logic.
B. Include point in system minimum, maximum, and average calculations.

I. OVERRIDE CONTROL POINTS

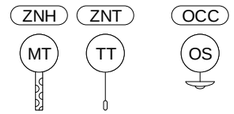
1. Provide override points for the following functionality for each system of AHU and IDU/CB units.
   a. Force all IDU/CB heating, cooling, and radiation valves fully open at the request of the mechanical contractor and TAB contractor to support the hydronic pipe flushing and balancing efforts.

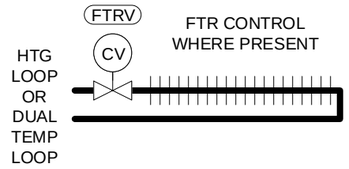
b. Force all IDU/CB primary air dampers to hold the maximum cfm setpoints at the request of the TAB contractor to support the balancing effort.
c. Force all IDU/CB primary air dampers to hold the minimum cfm setpoints at the request of the TAB contractor to support the balancing effort.

IDU SCHEMATIC 1



OCC SENSOR, IF EQUIPPED, EITHER INTEGRAL TO SPACE TEMP SENSOR OR PROVIDED BY OTHERS FOR LIGHTING SYSTEM.





DESIGNER NOTES:

1) SUPPLY AIR FROM AHU RANGES FROM 55 TO 65 DEG F. MUST RESET LOWER AS ZONE HUMIDITY RISES OR IF DUAL TEMP LOOP IS IN HEATING MODE AND COOLING AT ZONE IS REQUIRED. OTHERWISE IT CAN RESET HIGHER.

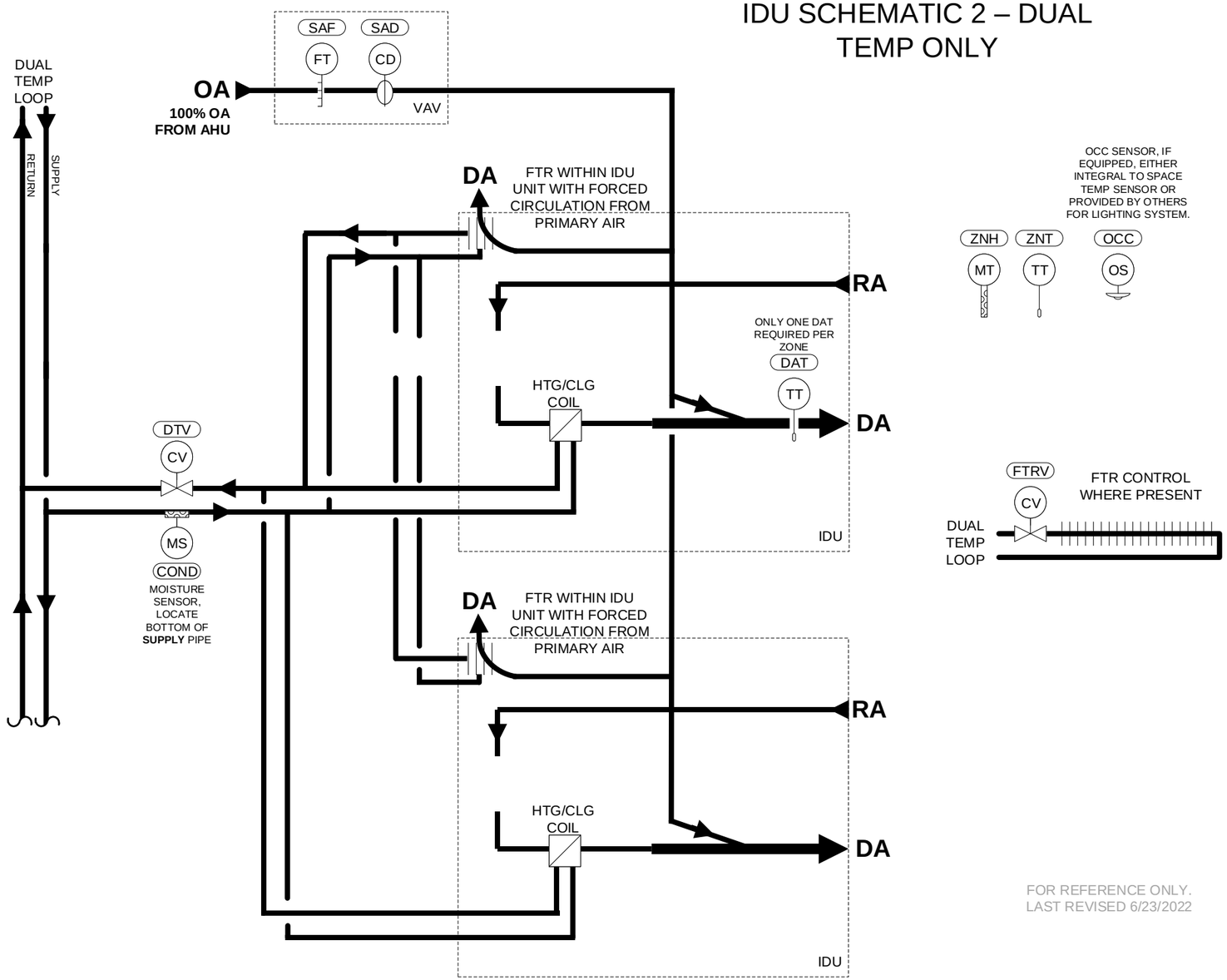
2) AIRFLOW MUST NOT DROP BELOW 50% OF DESIGN VOLUME TO ENSURE DISPLACEMENT WORKS PROPERLY.

3) IDU DAT MUST ALWAYS BE COOLER THAN ZONE TEMP WHEN PEOPLE ARE PRESENT, YEAR-ROUND, TO ENSURE DISPLACEMENT WORKS PROPERLY. RANGE IS FROM 62 TO 68 DEG F. ZONE TEMP CONTROL IS ADEQUATE, NOT REQUIRED TO MODULATE VALVE TO MAINTAIN IDU DISCHARGE AIR TEMPERATURE. IN FACT, IDU DISCHARGE AIR TEMPERATURE SENSOR IS NOT IDEAL LOCATION AND IS ONLY SUITABLE TO INDICATE WHETHER VALVE APPEARS TO BE WORKING OR NOT.

4) TO PROVIDE HEATING TO SPACE, HOT AIR CAN DISCHARGE FROM IDU BEFORE PEOPLE ARE PRESENT (MORNING WARM UP). FTR CAN DISCHARGE MUCH WARMER AIR AT ANY TIME.

5) DUAL TEMP LOOP, WHILE IN COOLING, SHALL ALWAYS BE ABOVE INTERNAL BUILDING DEWPOINT TEMPERATURE. INTERNAL BUILDING DEWPOINT TEMPERATURE SHALL CONTINUOUSLY BE CALCULATED FROM SEVERAL STRATEGICALLY PLACED RELATIVE HUMIDITY/TEMPERATURE SENSORS.

IDU SCHEMATIC 2 – DUAL TEMP ONLY



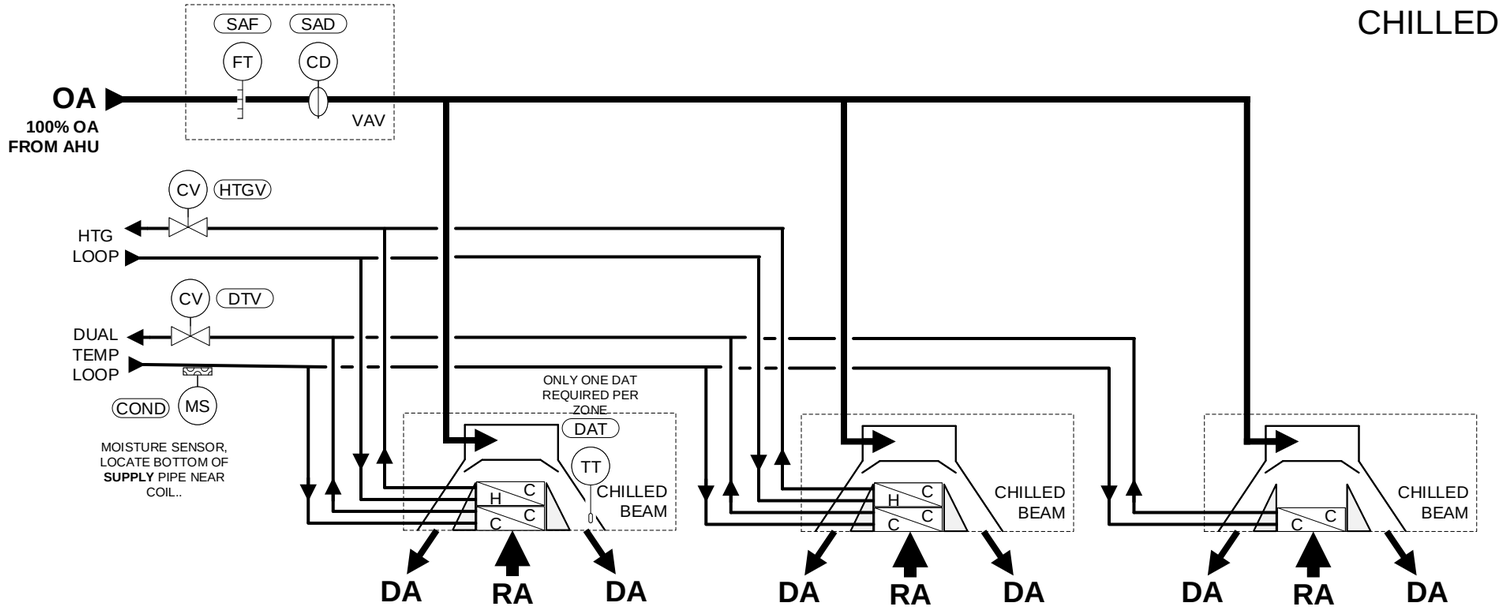
OCC SENSOR, IF EQUIPPED, EITHER INTEGRAL TO SPACE TEMP SENSOR OR PROVIDED BY OTHERS FOR LIGHTING SYSTEM.

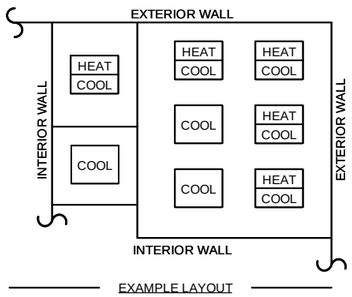
FOR REFERENCE ONLY.
LAST REVISED 6/23/2022

DESIGNER NOTES:

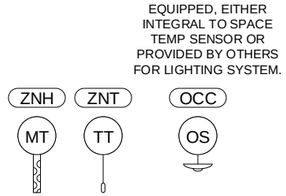
1) SUPPLY AIR FROM AHU RANGES FROM 55 TO 65 DEG F. MUST RESET LOWER AS ZONE HUMIDITY RISES OR IF DUAL TEMP LOOP IS IN HEATING MODE AND COOLING AT ZONE IS REQUIRED. OTHERWISE IT CAN RESET HIGHER.
2) AIRFLOW MUST NOT DROP BELOW 50%OF DESIGN VOLUME TO ENSURE DISPLACEMENT WORKS PROPERLY.
3) IDU DAT MUST ALWAYS BE COOLER THAN ZONE TEMP WHEN PEOPLE ARE PRESENT, ALL SEASONS TO ENSURE DISPLACEMENT WORKS PROPERLY. RANGE IS FROM 62 TO 68 DEG F. ZONE TEMP CONTROL IS ADEQUATE, NOT REQUIRED TO MODULATE VALVE TO MAINTAIN IDU DISCHARGE AIR TEMPERATURE. IN FACT, IDU DISCHARGE AIR TEMPERATURE SENSOR IS NOT IDEAL LOCATION AND IS REALLY ONLY SUITABLE TO INDICATE WHETHER VALVE APPEARS TO BE WORKING OR NOT.
4) TO PROVIDE HEATING TO SPACE, HOT AIR CAN DISCHARGE FROM IDU BEFORE PEOPLE ARE PRESENT, MORNING WARM UP. FTR CAN DISCHARGE MUCH WARMER AIR AT ANY TIME.
5) DUAL TEMP LOOP WHILE IN COOLING SHALL ALWAYS BE ABOVE INTERNAL BUILDING DEWPOINT TEMPERATURE. INTERNAL BUILDING DEWPOINT TEMPERATURE SHALL CONTINUOUSLY BE CALCULATED FROM SEVERAL STRATEGICALLY PLACED RELATIVE HUMIDITY/TEMPERATURE SENSORS.

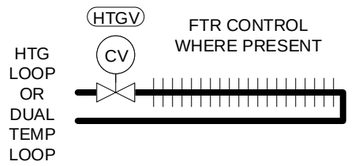
CHILLED BEAM SCHEMATIC 1





EXAMPLE LAYOUT



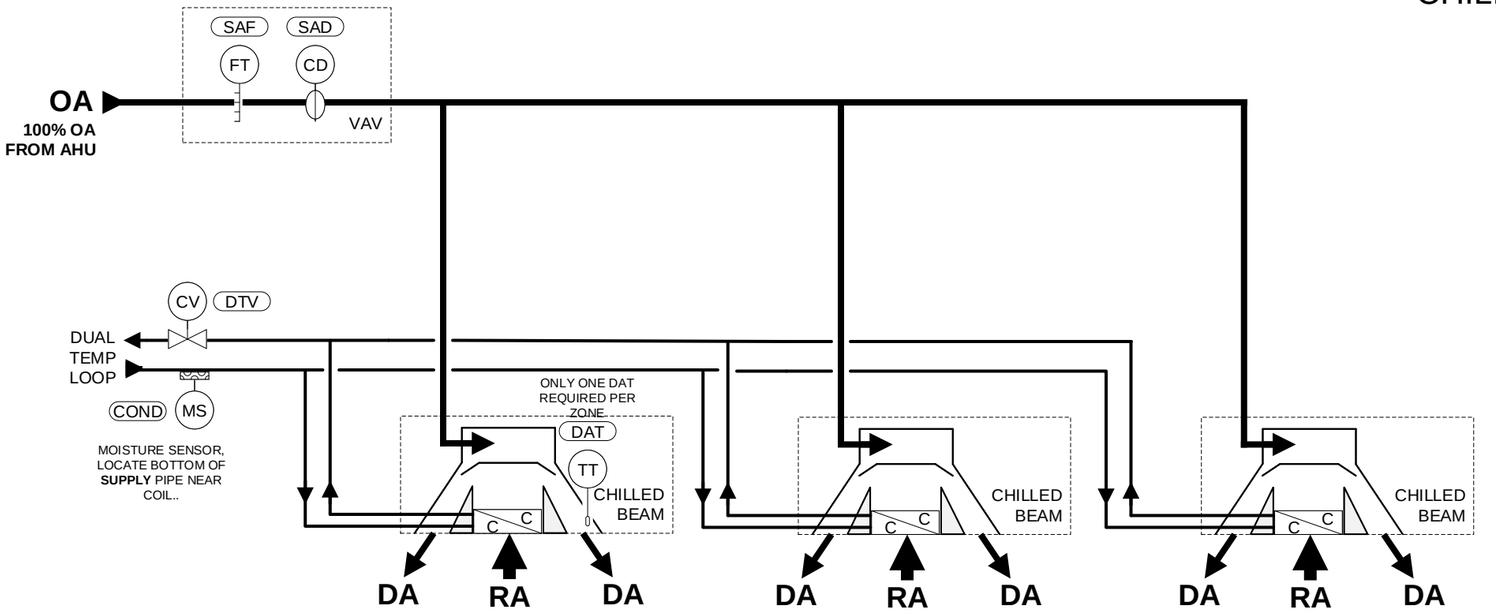


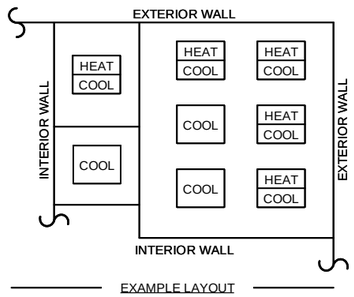
FOR REFERENCE ONLY.
LAST REVISED 6/23/2022

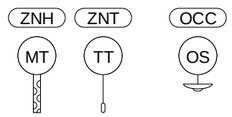
DESIGNER NOTES:

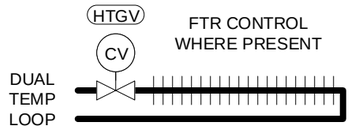
1) SUPPLY AIR FROM AHU RANGES FROM 55 TO 65 DEG F. MUST RESET LOWER AS ZONE HUMIDITY RISES OR IF DUAL TEMP LOOP IS IN HEATING MODE AND COOLING AT ZONE IS REQUIRED. OTHERWISE IT CAN RESET HIGHER.
2) AIRFLOW MUST NOT DROP BELOW 50%OF DESIGN VOLUME TO ENSURE RETURN AIRFLOW IS BEING INDUCED. NOT A DISPLACEMENT PRINCIPAL CONCERN, JUST AN AIR MOVEMENT CONCERN. THIS IS A DIFFERENCE FROM IDU.
3) CHILLED BEAM DIFFERS FROM IDU BECAUSE IT DOES NOT WORK ON DISPLACEMENT PRINCIPLES. THEREFORE, DELIVERY TEMPERATURE RESTRICTIONS ARE NOT REQUIRED. IT IS FINE TO BLOW HOT AIR WHEN PEOPLE ARE PRESENT.
4) BEAM DISCHARGE AIR TEMPERATURE SENSOR IS NOT IDEAL LOCATION AND IS REALLY ONLY SUITABLE TO INDICATE WHETHER VALVE APPEARS TO BE WORKING OR NOT.
5) TO PROVIDE HEATING TO SPACE, HOT AIR CAN DISCHARGE FROM BEAM ANY TIME. FTR CAN DISCHARGE MUCH WARMER AIR AT ANY TIME.
6) DUAL TEMP LOOP WHILE IN COOLING SHALL ALWAYS BE ABOVE INTERNAL BUILDING DEWPOINT TEMPERATURE. INTERNAL BUILDING DEWPOINT TEMPERATURE SHALL CONTINUOUSLY BE CALCULATED FROM SEVERAL STRATEGICALLY PLACED RELATIVE HUMIDITY/TEMPERATURE SENSORS.

CHILLED BEAM SCHEMATIC 2 – DUAL TEMP ONLY









FOR REFERENCE ONLY.
LAST REVISED 6/23/2022

DESIGNER NOTES:

1) SUPPLY AIR FROM AHU RANGES FROM 55 TO 65 DEG F. MUST RESET LOWER AS ZONE HUMIDITY RISES OR IF DUAL TEMP LOOP IS IN HEATING MODE AND COOLING AT ZONE IS REQUIRED. OTHERWISE IT CAN RESET HIGHER.
2) AIRFLOW MUST NOT DROP BELOW 50%OF DESIGN VOLUME TO ENSURE RETURN AIRFLOW IS BEING INDUCED. NOT A DISPLACEMENT PRINCIPAL CONCERN, JUST AN AIR MOVEMENT CONCERN. THIS IS A DIFFERENCE FROM IDU.
3) CHILLED BEAM DIFFERS FROM IDU BECAUSE IT DOES NOT WORK ON DISPLACEMENT PRINCIPLES. THEREFORE, DELIVERY TEMPERATURE RESTRICTIONS ARE NOT REQUIRED. IT IS FINE TO BLOW HOT AIR WHEN PEOPLE ARE PRESENT.
4) BEAM DISCHARGE AIR TEMPERATURE SENSOR IS NOT IDEAL LOCATION AND IS REALLY ONLY SUITABLE TO INDICATE WHETHER VALVE APPEARS TO BE WORKING OR NOT.
5) TO PROVIDE HEATING TO SPACE, HOT AIR CAN DISCHARGE FROM BEAM ANY TIME. FTR CAN DISCHARGE MUCH WARMER AIR AT ANY TIME.
6) DUAL TEMP LOOP WHILE IN COOLING SHALL ALWAYS BE ABOVE INTERNAL BUILDING DEWPOINT TEMPERATURE. INTERNAL BUILDING DEWPOINT TEMPERATURE SHALL CONTINUOUSLY BE CALCULATED FROM SEVERAL STRATEGICALLY PLACED RELATIVE HUMIDITY/TEMPERATURE SENSORS.

VARIABLE AIR VOLUME (VAV) BOX – SINGLE DUCT SEQUENCE

A. ADDITIONAL REFERENCE

1. Refer to Common Controls Notes for additional information related to this sequence.
2. Refer to specification sections 23 09 00 and 23 09 23 for additional information related to this sequence.

B. UNIT SCHEDULE CONTROL

1. Refer to Common Controls Notes for details on unit scheduling and optimized start.
2. Provide a graphic showing a summary table of all VAV units. Each VAV unit shall be represented by a separate row within the table. The columns shall represent the following data points for each VAV unit: equipment tag, area served, time schedule selection, current schedule status, zone temperature, occupied cooling setpoint, occupied heating setpoint, airflow setpoint, airflow, damper position, reheat signal, discharge air temperature, and radiation signal.
3. VAV controller shall generate network outputs to parent equipment to communicate zone temperature. These values shall be used for system level control including optimized start and unoccupied operation.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Zone Temperature						1		A

Notes:

A. Include point in AHU minimum, maximum, and average calculations.

C. ZONE SETPOINT CONTROL

1. Refer to Common Controls Notes for details on zone temperature setpoints.
2. All airflow setpoints, primary airflow duct areas, k-factors, and other settings shall be individually programmed and adjustable for each VAV box. Refer to equipment schedules.
3. Wherever multiple VAV boxes serve a common area as shown on drawings, VAV controllers shall operate in unison, coordinating operating states, and temperature setpoints.
4. Minimum airflow setpoint shall be 0 cfm during unoccupied mode.
5. Zone temperature local setpoint adjustment (if equipped) range shall be limited to +/- 2°F (adj.). This adjustment range limit shall be made available on graphic screen. Adjustment value shall be added to all occupied and standby heating and cooling setpoints such that the deadband shall still be active and shifted accordingly. Adjustment value shall have no effect on unoccupied setpoints.
6. Zone occupancy sensor (if equipped), shall transition VAV box to a standby mode when motion is not detected for 15-minutes (adj.) during periods of schedule occupancy.
    a. Temperature setpoints shall relax as indicated in the Common Controls Notes.
    b. Minimum airflow setpoint shall reduce to 25% of normally scheduled minimum, or to match makeup air requirements, whichever is greater.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Zone Temperature	1							
Zone Temp Setpoint Adjust (if equipped)	1							
Zone Occupancy Sensor			1					

Notes:

D. DAMPER AND AIRFLOW CONTROL

1. Minimum airflow setpoint shall vary based on operational mode as described in previous paragraph. Active airflow setpoint is calculated as described below.

2. Primary air damper control loop shall modulate between 0-100% to maintain primary airflow at the active airflow setpoint.
3. Normal cooling airflow functionality, not during morning warm-up mode:
    a. **Zone Cooling Demand** control loop shall modulate between 0-100% to maintain zone temperature at active cooling setpoint, increasing as zone temperature rises above setpoint. 0-100% value shall correspond to active airflow setpoint resetting between active minimum and cooling maximum.
4. Warm-up mode shall be triggered when the associated AHU has entered that mode, or when the air temperature being supplied to the VAV box is greater than the zone temperature.
    a. During warm-up mode when zone temperature is less than the heating setpoint, the VAV airflow setpoint shall be forced to the cooling maximum. Available VAV reheat and radiation shall continue to operate normally during this mode. When zone temperature is greater than the heating setpoint, the VAV airflow setpoint shall be 0 cfm.
    b. During warm-up mode when zone temperature is less than the heating setpoint, the VAV airflow setpoint shall operate as described below. When zone temperature is greater than the heating setpoint, the VAV airflow setpoint shall be the active minimum.
5. Morning cool-down
    a. When AHU has started early as a result of optimized start logic for cooling, VAV unit dampers shall function normally as described in section D.2 above.
6. Heating airflow functionality
    a. Refer to the heating control portion of the sequence below.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Morning Warm-Up Mode						1	Off	
AHU Discharge Air Temperature						1	55°F	
Zone Temperature	1							
Primary Airflow	1							A
Primary Air Damper Signal		1						

Notes:
A. Include point in a summing program to display total system supply airflow on the AHU graphic.

E. HEATING CONTROL

1. **Zone Heating Demand** control loop shall modulate between 0-100% to maintain zone temperature at active heating setpoint, increasing as zone temperature falls below setpoint. **Zone Heating Demand** shall sequence the available devices, in the order described, to add heat to zone.
    a. Radiation (if equipped)
        i. When outside air temperature is less than 60°F (adj.), including a 2°F differential, radiation shall be first device to modulate in response to **Zone Heating Demand.** Radiation shall reset from 0% to 100% as the maximum between **Zone Heating Demand,** and reheat signal, increase from 0-30% (adj.).
        ii. Staged radiation shall enable when **Zone Heating Demand** reaches 30% (adj.) or when the reheat is on and disable when **Zone Heating Demand** falls below 5% or when the reheat is off.
        iii. When outside air is greater than setpoint, radiation shall not be utilized.
    b. Reheat
        i. Reheat signal shall increase from 0% to 100% as **Zone Heating Demand** increases.

ii. Provide discharge air temperature control loop for reheat to prevent excessively hot air. VAV discharge air temperature setpoint shall reset from AHU discharge temperature setpoint to 95°F (adj.) as **Zone Heating Demand** increases from 0-50%.

c. Primary Air Damper

i. Primary air damper shall utilize the upper span of **Zone Heating Demand.** 50-100% value shall correspond to active airflow setpoint resetting between active minimum and heating maximum.

ii. Primary air damper shall not be allowed to increase above minimum setting if discharge air temperature is not greater than zone temperature plus 5°F.

2. A point indicating when central heating plant is active shall be made available via network from central heating plant controller to all VAV boxes with hot water reheat. If heating water is not available, reheat signal shall be kept at 0%.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Outside Air Temperature						1	0°F	
Radiation Signal (if equipped)		1						
Reheat Signal		1						
VAV Discharge Air Temperature	1							
AHU Discharge Air Temperature Setpoint						1	55°F	
Central HW Available						1	LAST	

Notes:

E. ZONE DEMAND RESET REQUESTS

1. VAV controller shall generate network outputs to parent equipment based on zone demands. These values shall be utilized by the parent equipment for system level control.
   a. A Zone Cooling Request (r) shall be generated when the **Zone Cooling Demand** rises above 95%. This shall be used by the AHU discharge temperature reset.
   b. A Zone Pressure Request (r) shall be generated when the primary air damper rises above 95%. This shall be used by the AHU discharge static pressure reset.
   c. A Zone Heating Request (r) shall be generated when the reheat signal rises above 95%. This shall be used by the central heating system differential pressure setpoint.
   d. Zone reheat signal shall be used by central heating system to calculate system differential pressure setpoint.
2. All requests shall be multiplied by the zone importance multiplier, set to 1 (adj.) by default, before being shared to the parent equipment.
3. Controller shall also totalize the amount of time a request has been active. See ASHRAE Guideline 36 Section 5.1.14 for more information.

HARDWARE POINTS	AI	AO	DI	DO	INT	NET	FAIL POS	NOTES
Primary Air Damper Signal		1				1		B
Reheat Signal		1						B
Zone Cooling Demand						1		B
Zone Cooling Request (r)						1		A
Zone Pressure Request (r)						1		A
Zone Heating Demand						1		B
Zone Heating Request (r)						1		A

Notes:

A. Point to be multiplied by zone multiplier for inclusion in Trim and Respond logic.

B. Include point in system minimum, maximum, and average calculations.

F. OVERRIDE CONTROL POINTS

1. Provide override points for the following functionality for each system of AHU and VAV boxes.
    a. Force all VAV reheat and radiation valves fully open at the request of the mechanical contractor and TAB contractor to support the hydronic pipe flushing and balancing efforts.
    b. Force all VAV primary air dampers to hold the maximum cooling airflow setpoints at the request of the TAB contractor to support the balancing effort.
    c. Force all VAV primary air dampers to hold the maximum heating airflow setpoints at the request of the TAB contractor to support the balancing effort.
    d. Force all VAV primary air dampers to hold the minimum airflow setpoints at the request of the TAB contractor to support the balancing effort.