25 90 00 GUIDE SEQUENCES OF OPERATION

Delete the associated previous linked document (Rev 3 dated 11/2008) in its entirety and its associated date from the table.

Air-Handling Units - Variable Air Volume January 2008

In the table, replace with new link to new Document (Rev 4 dated November 2010) inserted below, and update the associated Version Date. The Description shall remain unchanged.

25 90 00
AHU-VAV-REV4.docx

Air-Handling Units - Variable Air Volume November 2010

In the table, immediately below the word document, add the following associated AutoCAD and PDF files, current date, and description.

(AutoCad) vav-ahu-4pipe-blowthru-relief_fan.dwg **(PDF)** vav-ahu-4pipe-blowthru-relief_fan.pdf	November 2010	Control Schematic for typical central station VAV Air Handling Units: with 4-pipe, blow-through supply fan, relief fan configuration.
(AutoCad) vav-ahu-4pipe-blowthru-ret_fan.dwg **(PDF)** vav-ahu-4pipe-blowthru-ret_fan.pdf	November 2010	Control Schematic for typical central station VAV Air Handling Units: with 4-pipe, blow-through supply fan, return fan configuration.
(AutoCad) vav-ahu-4pipe-drawthru-relief_fan.dwg **(PDF)**	November 2010	Control Schematic for typical central station VAV Air Handling Units: with 4-pipe, draw-through supply fan, relief fan configuration.

vav-ahu-4pipe-drawthru-relief_fan.pdf		
(AutoCad) vav-ahu-4pipe-drawthru-ret_fan.dwg **(PDF)** vav-ahu-4pipe-drawthru-ret_fan.pdf	November 2010	Control Schematic for typical central station VAV Air Handling Units: with 4-pipe, draw-through supply fan, return fan configuration.

The new electronic documents to link shall follow (separately).

END of revision

Update Commentary:

Section was updated primarily for the following reasons:

1) Upgrades to technical sequences, point list, and schematic drawings for improved operation, energy savings and monitoring/alarming.
    a. Fan Tracking control
    b. Requires independent outside air, return air and relief damper actuation.
2) Added general clarifications and notes to design/construction teams.
3) Corrections of typographical errors

The changes between Rev 3 and Rev 4 are so extensive that the document is being replaced in its entirety rather than showing individual revisions throughout the body of the text. A "changes tracked" version, which has viewing modes that can be user selected, can be made available upon request.

F:\EVERYONE\Design and Construction Standards - PSU_OPP_Revisions_In Progress-By Division\Div 25 - Integrated Automation (BAS)\3 - Final Revew\25 90 00 AHU VAV - Rev Instructions.docx

PENNSTATE

Office of Physical Plant
Energy and Engineering Division
Engineering Services

The Pennsylvania State University
Physical Plant Building
University Park, PA 16802-1118

SEQUENCE OF OPERATION GUIDELINE

AIR HANDLING UNITS- VARIABLE AIR VOLUME

Revision: 4

Notes:

1. *This sequence is intended to provide the Design Professional with a basic guideline of minimum requirements for typical VAV Air Handling Units. Sequence, point list, and generic schematics shall be carefully reviewed and edited with respect to application-specific project requirements and proposed modifications shall be reviewed with OPP Staff. OPP has standard programming logic corresponding to this guide sequence. Clearly indicate all deviations from written sequence so that intended modifications can be made in the program. Finalized versions shall be included on the project DRAWINGS.*

2. *The intent is for this section to be inserted into the Part 4, "Sequence of Operation" section of the BAS Specification.*

3. *Sequence schematic drawings include both Blow-Thru and Draw-Thru configurations. The Design Professional shall develop project specific criteria and analysis for appropriate application and review with PSU-OPP during initial stages of design. Poor OA/RA mixing and resultant stratification and freezestat tripping continues to be a serious operational problem for OPP. Blow-throw arrangements have an advantage of inherently mix the air prior to the coils. Also fan heat is added prior to the cooling coil, which reduces the cooling load needed to subcool/dehumidify the air to achieve the desired discharge air temperature setpoint. The disadvantage is the requirement for a means to diffuse the air to achieve even velocity across the coils.*

4. *Design Professional shall evaluate and select basic fan configuration of each AHU system (whether relief damper, relief fan, or return fan) for best balance of energy optimization and reliable control function. Follow industry recommendations and review with OPP Engineering Services early in the design process. The following are general OPP application guidelines:*

    a. *Relief damper: These are the simplest and least expensive but can be used only for air distribution systems with few individual spaces and little or no return ductwork (negligible return external static pressure requirements – less than approximately 0.10"). Relief dampers (low-leakage type) shall be sized to limit pressure loss to 0.08-0.10"*
    b. *Relief Fan: Recommended for systems that require forced relief beyond that provided by separate general exhaust for proper outdoor air/economizer and space pressurization control and that have low return duct static pressure requirements – between approximately 0.10-0.30".*
    c. *Return fan: These configurations are the most expensive and most complicated to install, control and operate. Therefore they should only be used to meet high pressure return*

requirements – greater than approximately 0.3 inches of water (per ASHRAE HVAC Systems and Equipment Handbook, Chapter 2, Air Handling Unit Components).

4.x Air Handling Units - Variable Air Volume (VAV)

A. RUN CONDITIONS

1. Unit shall be automatically or manually enabled to run in Occupied or Unoccupied mode as follows:
   a. Automatic operation in Occupied/Unoccupied modes shall be as defined below in the VAV Zone Terminal Unit Interface, Fan Control and Outdoor Air Control Sections.
   b. OR Manually selected by user from graphic interface.
   c. When the unit is stopped (manually, automatically in unoccupied, or from safety functions), the fans shall be de-energized, the minimum and economizer outside air (OA) dampers shall close, the exhaust air (EA) damper shall close and return air (RA) dampers shall open, the CHW valve shall close completely (except as described elsewhere during freezestat activation) and the preheat valve shall be controlled as described in preheat section.
2. AHU Optimal Start: During this warm-up/cool-down mode, the unit air mixing dampers shall operate as described in the Unoccupied mode
   a. Mulitple space VAV air terminal unit application (typical): The AHU shall be started upon request from any of its associated air terminal unit controllers with Zone level optimal start.
   b. Single zone VAV AHU application (i.e. large assembly space): An adaptive optimal start algorithm shall be used to minimize the energy required and warm-up or cool-down time during the unoccupied period, necessary to achieve zone occupied temperature setpoints by the start of scheduled occupied period. The learning adaptive algorithm shall compare the zone temperature to its setpoint at beginning of scheduled occupied period and shall automatically adapt the heating or cooling response time for the next unoccupied period.
3. Emergency Demand Limiting: **Refer to current revision of the** Enterprise Utility Management System (EUMS) Equipment Control Strategies **in Division 25,** 25 90 00 GUIDE SEQUENCES OF OPERATION **on the Standards web page for specific requirements. Apply portions associated with VAV air handling units.**
4. Safety Shutdowns:
   a. Freeze Protection: The unit shall shut down as described above and generate an alarm upon receiving a freezestat status on leaving side of preheat coil. Manual restart required.
   b. High and Low Static Shutdown: The unit shall shut down and generate an alarm upon receiving either a hard-wired high or low static shutdown signal. Final setting shall be adjusted in the field, based on approximately 30% safety factory beyond normal maximum operating conditions to avoid nuisance trips, but not too exceed duct construction pressure class for each system.
      1) High Static Shutdown located at supply and return fan discharge,
      2) Low Static Shutdown located at supply and return fan suction.
   c. General Fire Alarm: The unit shall shut down and generate an alarm upon receiving a general alarm from Fire Alarm system. **[Edit per project specific requirements – coordinate with project Fire Alarm Control Requirements]**
   d. Return Air Smoke Detection: The unit shall shut down and generate an alarm upon receiving a return air smoke detector status. **[Edit per project specific requirements – coordinate with project Fire Alarm Control Requirements]**
   e. Supply Air Smoke Detection: The unit shall shut down and generate an alarm upon receiving a supply air smoke detector status. **[Edit per project specific requirements – coordinate with project Fire Alarm Control Requirements]**

f. Smoke or Isolation Damper End Switch: The unit shall shut down and generate an alarm upon receiving a closed status from an associated primary isolation or smoke control damper. **[Edit per project specific requirements]**

5. Fan Status monitoring and alarms shall be provided as follows:
   a. Fan Failure (supply, return/relief): Commanded on, but the status is off.
   b. Fan in Hand (supply, return/relief): Commanded off, but the status is on.
   c. Fan VFD Fault (supply, return/relief)
   d. Fan runtime exceeded (supply, return/relief): Status runtime exceeds a user definable limit (adj.). **[The controller shall have this logic included, but the default setting shall be disabled. It shall be enabled only by user if/when needed.]**

B. ZONE VAV AIR TERMINAL UNIT INTERFACE

1. At a minimum, all VAV terminal units served by an AHU shall be linked with associated VAV AHU controller to perform the following functions.
   a. Zone occupancy schedule (user defined from graphic interface) shall normally automatically select the Occupied or Unoccupied operating mode of air handling unit.
      1) Activation of timed override switch on zone thermostats (if present) shall only reset zone heating and cooling setpoints to "occupied" values, but shall not affect otherwise scheduled Unoccupied operating mode of air handling unit.
   b. Duct static pressure reset as described in Fan Control section.
   c. Discharge air temperature setpoint –optimized as described in the Discharge Temperature Control section.
   d. When AHU is in economizer mode (if furnished), minimum occupied airflow setpoint on VAV terminals shall be automatically reset based on percentage of outside air above design minimum.
      1) As percentage of OA increases at AHU (with minimum OA damper at 100% and as economizer PID output increases from 0-100%), minimum airflow setpoint at terminal units shall proportionately reset lower to maintain required minimum fresh air ventilation.
      2) Resetting shall occur based on increments of 10% change of value of economizer PID output.
   e. Demand Based Ventilation Control (if present): During occupied mode, Demand Ventilation controls shall monitor and satisfy zone ventilation requests. The Demand Ventilation Controls shall first increase zone minimum airflow to satisfy ventilation requirements, and then increase the outdoor air rate at the air handler. Coordinate with the associated section in the most current revision of the VAV terminal unit sequence for multiple zone systems and network the zone ventilation requests to the AHU controller.
   f. VAV Terminal Minimum Reset for pressure relief: If a majority of VAV terminal units on a fan system have the ability to reset to full shutoff during normal occupied periods (such as in "Standby" mode), then if the actual duct static pressure exceeds the maximum static pressure setpoint with fan at minimum speed, then disable resetting VAV terminal unit airflow minimums to 0 and maintain at normal minimum occupied airflow.

C. FAN CONTROL

1. General: The supply fan speed shall be modulated to maintain the duct static pressure setpoint which shall be automatically reset to meet zone airflow demands. Relief or return fans shall be controlled via airflow tracking to maintain an airflow differential to provide indirect building pressure control. The outside air, return and relief dampers also must be integrated with the fan tracking to ensure minimum ventilation air and to maintain proper pressure relationships within the system, depending on the type of return/relief system. The damper controls are discussed in the minimum OA and Economizer control section.
2. Occupied mode:
   a. Supply fan:

1) Shall be enabled to run continuously, unless shutdown on safeties.
2) Supply Fan Speed Control via Air Duct Static Pressure Control – Optimized: The controller shall measure duct static pressure and modulate the supply fan VFD speed to maintain an optimized duct static pressure setpoint.
   a) The initial duct static pressure setpoint shall be **[0.75]** in H_2O (adj.).
   b) Each AHU controller shall be networked with all associated VAV terminal units to obtain airflow requests. The static pressure setpoint shall be reset based on zone airflow requests, derived from damper position and meeting airflow and space temperature requirements as described below.
   c) When there are no zone airflow requests, (when all zone dampers are throttling closed **-** below 90% open and actual/setpoint airflow ratio is greater than 95%), the duct static pressure setpoint shall be incrementally reset down by 0.10" at a frequency of 10 minutes to a minimum of **[0.30]** in H_2O (adj.) or the supply fan VFD has reached its lowest operating speed limit.
   d) As airflow requests increase, when at least one zone damper is greater than 99% open and actual/setpoint airflow ratio is less than 90% and space temperature is not satisfied, the reverse shall occur and the duct static pressure setpoint shall incrementally reset up at same rate as above to a maximum of **[1.25]** in H_2O (adj.).

Note to Designer: For VAV systems that for whatever reason do not have airflow measuring capabilities at each terminal, substituting static pressure reset based on critical zone terminal damper position and space temperature cooling requests as described below in lieu of airflow measurement is an acceptable alternative.

   e) When the CZ is less than 90% open and cooling request (space temperature) is satisfied, the setpoint shall be incrementally reset down by 0.10" at a frequency of 10 minutes to a minimum of **[0.30]** in H_2O (adj.) or the supply fan VFD has reached its lowest operating speed limit.
   f) When the CZ is greater than 95% open and cooling request (space temperature) is not satisfied, the reverse shall occur and the setpoint shall incrementally reset up to a maximum of [1.25] in H_2O (adj.).

   g) The supply fan VFD <u>minimum</u> speed setting within the VFD itself shall be optimized in the field during system balancing and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.
   h) An airflow measuring station shall continuously monitor the total supply air fan volume in CFM and send output to the BAS.

b. Relief Air Fan Control: (When used) The Relief fan shall be enabled only as needed <u>independently from supply fan</u>, and speed shall be controlled in sequence along with mixing dampers to maintain building supply/return airflow (cfm) tracking offset to keep the building area served at the desired airflow/pressure relationship with respect to ambient and adjacent zones.
   1) An airflow measuring station shall continuously monitor the total system return volume in CFM and send output to the BAS.
   2) Airflow Tracking Control: Offset shall be maintained as calculated per section following.
   3) Refer to Minimum OA and Economizer control sequence for coordinated mixing damper and relief fan control sequence.
   4) The relief fan VFD <u>minimum</u> speed setting within the VFD itself shall be optimized in the field during system balancing and commissioning to be as low as possible while avoiding

inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

Designer Note:
Select above or below based on project specific applications (see general note 4 at the beginning of this guide).

c. Return Air Fan Control (when used): The RA fan shall be enabled in unison with the supply fan and its speed shall be controlled in sequence along with mixing dampers to maintain building supply/return cfm tracking offset to keep the building area served at the desired airflow/pressure relationship with respect to ambient and adjacent zones; and the return/relief air plenum always slightly positive with respect to mixed air (OA/RA) plenum AND to ambient.
   1) An airflow measuring station shall continuously monitor the total system return volume in CFM and send output to the BAS.
   2) Airflow Tracking Control: Offset shall be maintained as calculated per section following.
   3) Refer to Minimum OA and Economizer control sequence for coordinated mixing damper and relief fan control sequence.
   4) The relief fan VFD minimum speed setting within the VFD itself shall be optimized in the field during system balancing and commissioning to be as low as possible while avoiding inertial stalling of fan, approximately 5% above the field observed stall speed of the fan operating in the system.

3. Unoccupied mode:
   a. Mulitple space VAV air terminal unit application (typical): The unit shall normally be off and be enabled as necessary to satisfy a user definable minimum number of zone heating or cooling requests. The SA fan shall operate under normal fan control; the return or relief fans shall track the supply air with a differential as determined per the equation below. The fans shall run for a minimum of 30 minutes (adj.) or until there are no zone heating/cooling requests as defined at the VAV TU control level.
   b. Single zone VAV AHU application (i.e. large assembly space): refer to Unoccupied Mode in the TEMPERATURE AND HUMIDITY CONTROL SECTION, **Single zone VAV AHU application - Zone Temperature Control** later in this sequence.

4. Airflow Tracking Control: Total system return air shall continuously track supply air cfm according to the following relationship. RAcfm=SAcfm-(EAcfm+PAcfm+TAcfm)
   1) Supply Airflow (SAcfm) is measured continuously by air flow measuring station.
   2) Exhaust Airflow (EAcfm):
      a) Occupied period: sum of exhaust fan scheduled cfm with ON status operating in building or portion of building served by associated AHU.
      b) Unoccupied period: 0 default (adj.)
   3) Pressurization Air / Exfiltration (PAcfm)
      Designer Note:
      Rule of thumb. Exfiltration to maintain a mild pressurization (approximately between 0.03" to 0.08" above ambient) in a typical commercial building can be assumed to be approximately 0.05 to 0.15 cfm/sq.ft. of area served by AHU.
      a) Occupied period: initially determined as the absolute minimum OA required based on room area ventilation rate per current ASHRAE 62.1 – (2007).
      b) Unoccupied period: 0 default (adj.) **[Discuss]**
   4) Transfer Air (TAcfm): a design quantity of air that is intentionally transferred to adjacent area(s) of building. For instance, a recirculating air system that is adjacent to a negatively pressurized lab space in which the lab space depends on transferring air from the adjacent system. This is not necessarily used in every AHU application.

5. Fan speed control and pressure monitoring alarms shall be provided as follows:
   a. High Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) greater than maximum limit of the DP setpoint.
   b. Low Supply Air Static Pressure: If the supply air static pressure is 25% (adj.) less than effective reset setpoint.

NOTE: THE CONTROL BANDS, SETPOINT INCREMENT VALUES, SETPOINT DECREMENT VALUES AND ADJUSTMENT FREQUENCIES SHALL BE ADJUSTED AND TUNED TO MAINTAIN MAXIMUM STATIC PRESSURE OPTIMIZATION WITH STABLE SYSTEM CONTROL AND MAXIMUM COMFORT CONTROL.

D. MINIMUM OUTSIDE AIR / DEMAND BASED VENTILATION CONTROL

1. General: When in occupied mode, the minimum outside air shall be measured and controlled to maintain ventilation and pressurization requirements.
   a. Provide separate modulating actuators and analog I/O for minimum OA damper, economizer damper, return damper, and relief damper.
   b. Minimum Outdoor, Economizer, Return, and Relief damper types and sizes shall be selected per ASHRAE Guideline 16.
      1) OA and Relief air dampers shall be opposed blade.
      2) Return damper shall be parallel blade.
   c. Minimum OA damper must be sized for a minimum of 200 fpm at absolute minimum OA flow rate for proper control.
   d. An airflow measuring station shall be provided to continuously monitor the minimum outside air volume in CFM and send output to the BAS to maintain OA cfm setpoint as system fans modulate. OA cfm input and output AND OA damper position feedback shall be monitored and graphically displayed in the BAS.

2. Startup sequence: Upon startup, open the return damper 100% and the minimum OA to absolute minimum position. Relief damper remains closed.

   a. When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), the outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period. When OAT is >40°F, there shall not be a delayed ramp open period.

   DESIGNER NOTE: Return and relief damper controls described below are based on measuring and maintaining very small pressure differentials in sections of the AHU with a bi-directional bleed sensor/transmitter. Refer to the following link and the OPP BAS Guide Spec for further specification details.

   AMD Silver 104 RS485 "BLEED" Sensor Data Sheet

3. Relief Fan System: Integrated Fan and Damper control:
   a. Upon startup, energize the supply fan. Control supply fan speed to maintain duct static pressure setpoint as described in fan control portion.

   b. Modulate minimum OA damper up to 100% open in attempt to achieve measured outside airflow setpoint. If setpoint is not achieved through this action alone, then modulate return air damper closed as needed to achieve outside airflow setpoint.

   c. When supply fan is operating and the relief fan is off, a positive return/relief plenum pressure (bleed flow greater than zero) relative to ambient as measured by a bleed airflow sensor installed across the relief damper bank shall signal the relief damper to open 100% to allow excess building pressure to be relieved.

d. When relief damper is open, and return airflow tracking offset cannot be maintained otherwise, energize relief fan, and modulate fan speed to maintain building supply/return airflow tracking offset. This applies in either minimum OA or economizer control (where present).

e. When relief fan is energized, reset the maximum open position of the return damper if the bleed airflow across the return air damper is less then zero (indicating reverse flow from OA/ mixing plenum being pulled back through relief fan).

Designer Note:
Select above or below based on project specific applications (see general note 4 at the beginning of this guide).

4. Return Fan System: Integrated Fan and Damper control:
   a. Energize the supply and return fans in unison. Control supply fan to maintain duct static pressure setpoint. Enable return fan airflow tracking to maintain building supply/return CFM offset as described in fan control portion.

   b. Modulate minimum OA damper up to 100% open in attempt to achieve measured outside airflow setpoint. If setpoint has not be achieved through this action alone, override pressure differential control (item 3 below) to modulate return air damper closed as needed to achieve outside airflow setpoint.

   c. If minimum OA setpoint cannot be achieved with minimum OA damper at maximum open position (above), begin to throttle return damper closed to obtain minimum OA setpoint.

   d. Continue to modulate return air damper closed as needed to always maintain a non-negative pressure in the relief plenum with respect to mixed air plenum (indirectly) and to ambient (directly), as sensed by bleed airflow sensor installed across relief air damper. This is intended to throttle return damper to prevent high suction pressure from supply fan effecting measured return airflow and causing return fan to inappropriately reduce its speed. Note: This function shall be disabled if return fan status is proven OFF (because without return fan running, the mixed air plenum would always be negative and return damper would try to go full shut, closing off any return flow). Relief damper still shall initially remain closed in minimum OA mode.

   e. Modulate relief damper open as needed to maintain no greater than 0.15” (adj.) maximum positive pressure differential setpoint relative to ambient as sensed by bleed airflow sensor installed across relief air damper. This applies in either minimum OA or economizer control (where present).

DESIGNER NOTE: Select only above for systems only if demand based ventilation is not a practical option. Otherwise also include demand based ventilation control as described below.

Locate sensors in the specific zones to have demand controlled ventilation. Locating sensors in common return ducts or plenums is not effective since sensor reading can be skewed by outdoor air leakage into the duct, mixing with return from other zones, and possible air short-circuiting from supply air diffusers to return air inlets.

CO2 setpoint is dependent on space occupancy type (coordinate with OPP).

As an alternate to individual CO2 zone sensors, a system that periodically samples air qualtity in multiple zones through a common air quality measurement device ("Aircuity" or equivalent) may be applied to achieve similar Demand Based Ventilation Control.

Definitions - The absolute minimum OA cfm shall be determined and scheduled based on current industry best practices (e.g. approximately 5-10% greater than the concurrent cumulative building exhaust required to keep the building positively pressurized or 0.15 cfm/sf times the occupied area served – to be confirmed). The normal design minimum OA cfm is the sum of the code minimums as if there were no demand based ventilation control.

Resources:

- **ASHRAE Standard 62.1-2007, 6.2.7 Dynamic Reset**
- **ASHRAE Applications Handbook, Design and Application of Controls, Air Systems, Dynamic Reset of Intake or Demand Controlled Ventilation**
- **Advanced Variable Air Volume System Design Guide, http://www.uccsuiouee.org/**
- **http://www.trane.com/Commercial/library/vol31_3/#intro**

5. When switching from unoccupied to occupied mode, the outside air damper shall initially open to obtain absolute minimum OA cfm setpoint. The failsafe operating condition for the demand based ventilation sequence shall maintain normal design minimum OA cfm setpoint as scheduled.

6. Single Zone Systems:
   a. When in the occupied mode, the controller shall monitor the space CO2 level and modulate the minimum outside air cfm (damper position) from absolute minimum cfm/position to design minimum cfm/position as CO2 ppm level increases from low to high range of its setpoint (adj.).
   b. Standby Mode (where applicable with zone occupancy sensors): During regularly scheduled occupied period, if the zone occupancy sensor does not sense actual occupancy, the unit shall operate similar as described in the occupied mode, with the following exceptions:
      1) Offset to standby temperature setpoints. Default settings as follows: Standby cooling = occupied cooling + 0°F (adj.); Standby heating = occupied heating - 3°F (adj.).
      2) Fans shall cycle to run on zone heating/cooling requests.
      3) Minimum OA damper shall reset to absolute minimum (for pressurization and minimum room area ventilation rate).
      4) At the start of each regularly scheduled occupied mode, the occupancy sensor/standby mode shall be inhibited for the first 60 minutes (adj). This shall enable the unit to maintain at least the minimum occupied airflow setpoint to provide a fresh ventilation air "flush" of the zone during that initial period.
      5) The occupancy sensor shall NOT revert to the zone terminal "occupied" mode if temporary occupancy is sensed during the regularly scheduled unoccupied period.
      6) Coordinate with Div 26 Electrical, Interior Lighting work to turn off lights when no occupancy is sensed during regularly scheduled occupied period and to turn lights on when occupancy is sensed during regularly scheduled unoccupied periods.
      7) Sensitivity and time delays on make/break settings shall be adjusted within the occupancy sensor itself. Refer to Section Div 25, Building Automation Systems (BAS), Part 2, SENSORS for sensor requirements.
   c. Point Alarms: The following point alarms shall be generated at the operator work station.

1) High Zone Carbon Dioxide Concentration: If the CO2 concentration is greater than 10% (adj.) above setpoint for more than 15 min (adj) with OA damper at design minimum.
2) CO2 setpoints at zone level are dependent on type of space use. If values are not scheduled or otherwise defined as part of the contract documents, control vendor shall submit an RFI to obtain these values and implement them prior to acceptance and turnover of system.

7. Mulitple Zone Systems: During occupied mode, Demand Ventilation controls shall monitor spaces with CO2 sensors. The Demand Ventilation Controls shall first increase zone minimum airflow to satisfy ventilation requirements, and then increase the outdoor air rate at the air handler as described in the following sequence.
   a. At the zone: Upon a rise in zone CO2 concentration above setpoint, the minimum occupied airflow setpoint at the zone VAV terminal shall first be reset from the design minimum up to a ventilation override maximum value (adj).
   b. At the Air Handler: Upon continued call for ventilation (based on continued rise in critical zone CO2 concentration with VAV terminal at ventilation override maximum setpoint, then increase the minimum outdoor air rate (or damper position) from absolute minimum to design minimum.
   c. Point Alarms: The following point alarms shall be generated at the operator work station.
      1) High Zone Carbon Dioxide Concentration: If the highest zone CO2 concentration is greater than 10% (adj.) above setpoint for more than 15 min (adj) with critical zone minimum airflow reset to max and OA damper at full design minimum.
      2) CO2 setpoints at zone level are dependent on type of space use. If values are not scheduled or otherwise defined as part of the contract documents, control vendor shall submit an RFI to obtain these values and implement them prior to acceptance and turnover of system.
8. The OA damper control shall include a high select between the minimum OA position, economizer position, and Zone CO2 control position. **[Review with OPP CCS]**
9. The mixed air temperature shall override CO2 control to limit the OA damper/and return damper positions to maintain a predetermined MAT minimum value (adj.).
10. In the Unoccupied mode, the return damper shall go full open, OA damper(s) and relief dampers shall remain closed, except for use of economizer operation (if present).
    a. Exception: if application requires absolute minimum OA for maintaining exfiltration or transfer airflow/pressure relationships during scheduled unoccupied periods. In which case the system shall revert to the absolute minimum OA control as described above.
11. Provide a manual override OA/Mixing damper control from graphic interface with indicator when in manual override mode.
12. **DESIGNER NOTE: Edit per Project requirements if risk of contaminating OA intake from generator exhaust.** During operation of the emergency generator the OA damper shall be fully closed.
13. During Optimal Start or when the unit runs during the unoccupied modes, the damper controls shall operate as described to maintain plenum pressure relationships, except that the outside air and relief dampers shall be closed, unless the unit is operating in economizer mode.

E. TEMPERATURE AND HUMIDITY CONTROL

1. General: The controller shall monitor the following temperature/humidity sensors and use as required for control functions as described in the sections following.
   a. Outside Air Temperature
      1) local
      2) networked (coordinate with University)
   b. Outside Air Relative Humidity (used as required for OA Enthalpy calculation)
      1) networked (coordinate with University)

c. Return Air Temperature:
   1) Alarms shall be provided as follows: only during the occupied period (not during the unoccupied/optimal start periods).
      a) High Return Air Temp: If the return air temperature is greater than 80°F (adj.) for more than 30 minutes (adj.).
      b) Low Return Air Temp: If the return air temperature is less than 65°F (adj.), for more than 30 minutes (adj.).

d. Return Air Humidity: The controller shall monitor the return air humidity and use as required (enthalpy calculation) for economizer control (if present).
   1) Alarms shall be provided as follows:
      a) High Return Air Humidity: If the return air humidity is greater than 10% RH (adj.) above dehumidification mode setpoint, or greater than upper limit of 70% (adj.).

e. Low Return Air Humidity: Refer to Humidification section (if present), otherwise none required.

f. Mixed Air Temperature: The controller shall monitor the mixed air temperature and use as required for economizer control (if present) or preheating control (if present).
   1) The low limit mixed air temperature sensor shall be an averaging type of sufficient length and properly arranged in furthest downstream section of mixed air plenum after air blending apparatus in order to compensate for incomplete mixing and temperature variations of the mixed air stream. The length of the sensor shall the greater of 20' minimum or 1' per 1 sq. ft. of preheat coil face area.
   2) Alarms shall be provided as follows:
      a) High Mixed Air Temp: Only when economizer is enabled If the mixed air temperature is greater than 5°F (adj.) above effective MAT setpoint or upper limit of 85°F (adj.).
      b) Low Mixed Air Temp: Only when economizer is enabled, if the mixed air temperature is less than 5°F (adj.) below effective MAT setpoint or lower limit of 40°F (adj.).

g. Preheat Leaving Air Temp: See Preheat Temperature Control

h. Cooling Coil Leaving Air Temp: See Cooling Temperature Control

i. Discharge Air Temperature:
   1) Alarms shall be provided as follows:
      a) High Discharge Air Temp: If greater than 5°F (adj.) above effective DAT setpoint or upper limit of 75°F (adj.) **[EDIT FOR ZONE TEMPERATURE CONTROL HEATING APPLICATIONS TO HAVE AN UPPER LIMIT OF 10 DEGREES ABOVE MAX. HEATING DAT SETPOINT)**
      b) Low Discharge Air Temp: If less than 5°F (adj.) below effective DAT setpoint or lower limit of 50 for recirc or 45°F (adj.) for 100%.

j. Chilled Water Return Temp: See Cooling Coil Control and Miscellaneous Alarms and System Diagnostics

2. AHU HW / CHW Requests **(used for pump DP optimized reset)**: shall be initially defined as follows:
   a. Any HW or CHW Control valve PID output must be greater than 99% (adj.) before requests are generated, with no more than 5% (adj.) hysteresis.
   b. Request analog value shall be calculated as the difference of the controlled temperature from its setpoint, multiplied by a sensitivity factor of 2 (adj.). Include an upper value limit of 10 (adj.) requests per individual control valve.

3. DAT Setpoint – Optimized: used for Mulitple space VAV air terminal unit application (typical): The controller shall monitor the discharge air temperature and shall reset the discharge air temperature setpoint based on outside air conditions and satisfying all zone cooling requirements.
   a. The initial DATspt shall be 57°F (adj).

Suggested DAT reset sequence for typical recirculation units

b. The DATspt shall incrementally reset between a high and low offset range as described below. As zone cooling demand increases, a minimum of 3 cooling requests (adj.), the setpoint shall incrementally reset down to a minimum of the low offset. With no cooling requests, the setpoint shall incrementally reset up to a maximum high offset.
   1) Cooling requests shall typically be determined at the terminal unit zone level. Refer to "VAV Zone Terminal Unit Interface".
   2) Increment shall be 0.2°F/minute (adj).
c. When outside air temperature is above 70°F (adj), The DAT setpoint shall range from high offset of +2°F (adj) to a low offset of -3°F (adj) .
d. When outside air dry bulb temperature is between 70 and 60°F (adj) and dewpoint is below 57°F (adj), proportionally vary low offset to 0°F (adj) and high offset to +10°F (adj), and maintain those offsets when the outside air temperature is 60°F (adj) and below.

Suggested DAT reset sequence for 100% OA units (with air to air heat recovery)

e. The DATspt shall reset between a maximum high (DATresetmax) and minimum low (DATresetmin) offset range as described below and shall be the output of a slow acting PID loop. As zone cooling demand increases, a minimum of 3 cooling requests (adj.), the setpoint shall incrementally reset down to a minimum of the low offset. With no cooling requests, the setpoint shall incrementally reset up to a maximum high offset.
f. When outside air dry bulb temperature is above 65°F (adj) AND outside air dewpoint temperature is ≤ 57°F (adj), The DAT setpoint shall range from 65 (high offset of +8°F (adj)) to 54 (a low offset of -3°F (adj)). When OA dry bulb is above 65 and OA dewpoint is ≥ 57, then DAT range shall be limited to 57 max. and 54 min.
g. When outside air temperature is between 65 and 50°F (adj) AND outside air dewpoint temperature is ≤ 57°F (adj), proportionally vary high offset so that DATresetmax = OAT. Maintain low offset as above until DATresetmin = OAT (54), then DATresetmin = OAT down to 50°F (adj). When OA dry bulb is between 65 and 57 and OA dewpoint is ≥ 57, then DAT range shall be limited to 57 max. and 54 min.
   1) Mechanical heating and cooling should be locked out when OAT is between 50 and 54 (DATresetmin)
h. Maintain DATspt at 50°F (adj) minimum when the outside air temperature is 50°F (adj) and below.

Include below for either recirculation or 100% OA option above.

i. Dehumidification Mode: A **[return or space – select and edit per project requirements]** RH sensor shall override the cooling sequence above to maintain a maximum of 60% RH (adj.) for the area served by the air handling unit.
   1) If return RH is greater than maximum setpoint and current reset DATspt is above initial, then reset to initial DATspt. If after 15 minutes (adj) RH is still greater than maximum setpoint with initial DATspt, then continue to incrementally reset down to minimum low offset.

Designer Note: Below is suggested DAT reset sequence and supply fan speed control for direct space temperature control of single zone VAV AHU application.

4. Single zone VAV AHU application - Zone Temperature Control (via sequenced DAT reset and fan speed control): The unit controller shall use zone temperature to automatically select heating or cooling mode. Heating and cooling demand shall be calculated through independent heating and cooling PID outputs. These PIDs shall have individually adjustable interval, bias, and proportional, integral and, derivative parameters carefully tuned in each application for slow action to avoid hunting, particularly of fan speed drives. The discharge air temperature shall first

be reset depending on zone heating or cooling demand with fan operating at minimum airflow/speed. Then supply air fan will modulate through its minimum and maximum CFM effective setpoint (or speed range for systems without airflow tracking) to maintain the zone temperature setpoint as described below. Relief or return fans (if present) shall track supply fan accordingly as otherwise described in FAN CONTROL section.

a. Heating Mode: When zone temperature drops below heating setpoint (with 0.5ºF (adj) hysteresis), unit control shall be indexed to Heating Mode and cooling shall be disabled.
   1) First Stage - Heating DAT reset: Heating PID output from 1- 20% (adj.) shall first reset DAT from Minimum 70F (adj.) to maximum of 95F (adj.) while supply air flow stays at minimum ventilation cfm / fan speed setpoint.
   2) Second stage – Increase Airflow: Upon continued zone temperature below setpoint, Heating PID output increasing from 21-100% shall increase supply airflow setpoint from min to max heating cfm (or max heating VFD speed (70% adj.)).
   3) Reverse shall occur as zone temperature rises above heating setpoint, with hysteresis.
b. Deadband: When zone temperature is within deadband (allowing for cooling and heating mode hysteresis), unit controls shall revert to demand based ventilation control mode to maintain minimum ventilation. DAT shall remain in control from last mode, and fan shall modulate down to minimum airflow setpoint/speed to achieve minimum ventilation / CO2 setpoint.
c. Cooling Mode: When zone temperature rises above cooling setpoint (with 0.5ºF (adj) hysteresis), unit control shall be indexed to Cooling Mode and heating shall be disabled.
   1) First Stage – Cooling DAT reset: Cooling PID output from 1 to 20% (adj.) shall first reset DAT from Minimum 75F (adj.) to maximum of 55F (adj.) while supply air flow stays at minimum ventilation cfm / fan speed setpoint.
   2) Second stage – Increase Airflow: Upon continued zone temperature above setpoint Cooling PID output increasing from 21-100%), increase supply airflow setpoint from min to max heating cfm (or max cooling VFD speed (100% adj.)).
   3) Reverse shall occur as zone temperature drops below cooling setpoint, with hysteresis.
   4) **[If OAT > RAT - 3, then revert unit control to minimum OA / Demand Based Ventilation Control. Designer Note: Edit. Apply only for units with economizer cooling only with no provisions for mechanical cooling]**
d. Unoccupied mode: Unit shall cycle between off- heat/cool modes during unoccupied periods while allowing for wider temperature offset ranges above and below unoccupied setpoints. The intent is to allow the associated air handling unit(s) not to have to run continuously during the normally unoccupied period but rather cycle only as needed to keep associated zone within an acceptable temperature range.
   1) Apply +/- 3 degree (adjustable) allowable "drift" from unoccupied heating and cooling setpoints as described below.
   2) Cooling: The zone would not generate a cooling request to run unit until the zone temperature drifts 3 degrees above its unoccupied setpoint. At that point, the unit shall be enabled and shall ramp up in sequence to 100% cooling demand as described above until space drifts 3 degrees below unoccupied space temperature setpoint. Then zone controller shall have no run request, reverse sequence and turn unit off until cycle repeats.
   3) Heating: Where it exists, perimeter radiant heating shall be used to maintain unoccupied heating septoints as much as possible. A zone would not generate a heating request to run unit until the zone temperature has drifted 3 degrees below its unoccupied setpoint. At that point, the unit shall be enabled and ramp up in sequence to 100% heating output as described above until space drifts 3 degrees above unoccupied space temperature setpoint. Then zone controller shall have no run request, reverse sequence and unit would return to off until cycle repeats.
   4) An inhibit feature on the timed override control shall be included which shall prevent sending cooling or heating requests and/or otherwise enabling associated AHU if zone

temperature is within +/-3°F (adj.) of last previous occupied cooling/heating setpoints respectively when local override button is activated.

Designer Note: Apply the following for units with economizer cooling only with no provisions for mechanical cooling

e. Provide "summer" unoccupied economizer pre-cooling sequence (review with OPP BAS group). During the user-defined hours of 3-5:30 am (adj)), whenever OAT is greater than 52ºF (adj) and at least 7ºF (adj) less than zone temperature, and zone temperature is greater than occupied heating setpoint, enable system to ramp up to maximum economizer cooling output to pre-cool space as low as possible, with lower limit of occupied heating setpoint or optional user-defined lower limit of 65ºF (adj.). The heating mode sequence and zone low temperature alarms shall be disabled during the first 5 hours (adj.) of the occupied period immediately following each pre-cool period and when OAT is greater than 52ºF (adj) to avoid reheating the space and nuisance alarms if zone temperature has been intentionally pre-cooled below the occupied heating setpoint.

F. PREHEAT TEMPERATURE CONTROL

1. When enabled, the controller shall modulate the PHC valve and face and Bypass damper (if present) to maintain the DAT heating setpoint, normally limited to 55°F (adj.). This heating setpoint shall be able to be user selectable to automatically linearly reset as follows:
   a. As OAT drops from 40°F (adj.) to 0°F (adj.), the DAT heating setpoint shall reset upwards from 55°F (adj.) to 55 default up to 65 max°F (adj.)
2. The preheating valve/damper shall be enabled whenever:
   a. Outside air temperature is less than 52°F (adj.).
   b. AND the supply fan status is on.
   c. AND the cooling (if present) is not active
   d. AND economizer is not active (OA damper is at minimum position and MAT is below DATsetpoint).
   e. Or the unit is off and OAT is below 40 degrees (see below).
3. PreHeat Discharge Air Temperature (PHDAT): The controller shall monitor the preheat coil leaving air temperature.
   a. When unit is stopped, and OAT is less than 40 degrees, controller shall maintain PHDAT at 40 degrees (adj.), with a low limit alarm at 35 degrees.
   b. PHDAT shall also be used for system diagnostic / commissioning alarms as described in Miscellaneous Alarm segment.

Note: The following options are for non-freeze preheat coils with a combination of face and bypass dampers and a steam heating valve as required by 23 70 00 CENTRAL HVAC EQUIPMENT, **.02 Central Station Air-Handling Units**

4. Steam Distributing (non-freeze type) Heating Coil with Face and Bypass and control valve:
   a. 100% OA applications:
      1) If the outside air temperature is less than 40°F (adj.), the steam valve shall go full open and the face and bypass dampers shall be modulated to maintain the preheat control setpoint.
      2) If the outside air temperature is greater than or equal to 40°F (adj.), the face and bypass will open to full face with the steam valve modulated to maintain the preheat control setpoint
   b. Recirculation applications with high percentages of minimum OA.

1) If the outside air temperature is less than 40°F (adj.), the steam valve position shall be proportionally reset based on outside air temperature. From 40 to 0°F (adj.) the steam valve shall open from a minimum of 10% open to a maximum of 100% open. The face and bypass dampers shall be modulated to maintain the preheat control setpoint.

[REVIEW AND EDIT THE FOLLOWING WITH PSU ENVIRONMENTAL SYSTEMS - The face and bypass PID output shall be added to the linear converter for the steam valve.]

2) If the outside air temperature is greater than or equal to 40°F (adj.), the face and bypass will open to full face with the steam valve modulated to maintain the preheat control setpoint

5. The PHC valve (and f&b dampers if present) shall fully open to coil for freeze protection whenever:
   a. Discharge air temperature drops from 45°F (adj.) to 40°F (adj.).
   b. Or on activation of the freezestat.
6. Alarms shall be provided as follows:
   a. Low Preheat Fault: If the preheat is enabled (economizer and cooling disabled), and DAT is 5°F (adj.) less than DAT heating setpoint for more than 5 minutes (adj.) continuous.
   b. High Temp alarm: If greater than 5°F (adj.) above effective PHDAT setpoint or upper limit of 75°F (adj.), but only when MAT is less than PHDAT setpoint.

G. ECONOMIZER MIXED AIR TEMPERATURE CONTROL **(IF PRESENT)**

Designer Note: For adequate turndown control of modulating minimum outdoor air and modulating 100% economizer functions, provide two separate control dampers, each sized for the range of airflow for each application.

1. The controller shall modulate the economizer, relief and return dampers in sequence to maintain the mixed air temperature setpoint 2°F (adj.) less than the discharge air temperature setpoint.

2. The economizer shall be enabled whenever:
   a. Outside air temperature is less than 68°F (adj.).
   b. AND the outside air enthalpy is less than the return air enthalpy.
   c. AND the supply fan status is on.
   d. The preheat control output has been off continuously for at least 10 minutes (adj.).
   e. When the unit is started in Occupied mode and outside air temperature is less than 40°F (adj.), the minimum outside air (OA) damper shall ramp open to its minimum setpoint over a 5 minute (adj.) period and the economizer PID calculation shall be disabled. Only after this period shall the economizer PID output start calculating. When OAT is >40°F, there shall not be a delayed ramp open period. This is to prevent the economizer damper from automatically driving open too quickly while trying to satisfy DAT setpoint and tripping and retripping the freezestat.

3. When economizer is enabled, the following operations shall be allowed to occur as needed and in the order listed in order achieve mixed air temperature setpoint:

   a. First, minimum OA damper shall modulate open beyond the position required for minimum ventilation air and up to fully open. (first 10% of economizer PID output shall drive minimum OA damper fully open if not already.)
   b. Then, economizer damper shall modulate from closed to fully open. 10-55% Economizer PID output shall open economizer damper from 0-100% open.

c. Then return air damper shall modulate to fully closed. 55-100% economizer PID output shall continue to reset return damper from its controlled modulated position to achieve minimum OA and plenum pressures to fully closed, 0% open.
d. Relief damper shall remain under control as defined in the Relief or Return Fan system minimum OA control sequence.

4. The Economizer damper and exhaust air dampers shall close and the return air damper shall open when:
   a. Mixed air temperature drops from 50°F (adj.) to 45°F (adj.).
   b. OR the freezestat is on
   c. OR loss of supply fan on status.
   d. OR if unit is commanded off.

H. COOLING COIL CONTROL
1. The controller shall monitor the unit Discharge Air Temperature sensor and use as required for cooling coil control.
2. The CHW valve shall modulate last in sequence to maintain the unit DAT setpoint. The cooling coil control shall be enabled whenever:
   a. DAT exceeds effective DAT setpoint (or general cooling request).
   b. AND outside air temperature is greater than either than the effective DATsetpoint - 2°F (adj.) offset for fan heat (for units with economizer), with a lower limit of 54 °F (adj.).
   c. [**EDIT** - OR a User adjustable lower limit of 35°F (adj.) (for units without economizer) - to be coordinated with central cooling plant operation].
   d. AND the economizer (if present) is either disabled or fully open.
   e. AND the supply fan status is on.
   f. AND the preheating is disabled.
   g. AND Cooling coil condensate overflow switch (if present) status is not in fault/alarm.
      1) Refer to International Mechanical Code, Section 307, Condensate Disposal, Auxiliary and secondary drain system for optional methods.
      2) Condensate Overflow Switch option (if selected): A water level detection device conforming to UL 508 shall be provided that will send an alarm and disable all mechanical cooling in the event that the primary drain is blocked. The device shall be installed in the overflow drain line, or in the equipment-supplied drain pan, located at a point higher than the primary drain line connection and below the overflow rim of such pan.
   h. **The CHW valve shall open to 50% on activation of the freezestat with fans off. (Review and edit per project requirements. Eliminate if antifreeze solution is used.)**
3. Cooling Coil Leaving Air Temperature (CCLAT): The controller shall also monitor the cooling coil leaving air temperature and use as required for diagnostics as described in Miscellaneous Alarms.
4. Cooling Coil Chilled Water Return Temperature (CCCHWRT): The controller shall also monitor and control the cooling coil chilled water return temperature as described below.
   a. Chilled Water Return Temperature Low Limit Override: While trying to maintain DAT setpoint, 2-way modulating chilled water control valve applications shall be overridden to maintain chilled water return at a lower limit of 54°F (adj.). Not applicable on 3-way valve control valves (which typically should be avoided).
   b. Dehumidification mode: If application does not have a means for independent cooling coil leaving air temperature sensor for resetting maximum cooling/dehumidification output, then the chilled water control valve shall be controlled to start out maintaining CHWRT at 58°F (adj.) and resetting down to a minimum of 54°F (adj.) in an increment of 1 degree every 15 minutes (adj.). Not applicable on 3-way valve control valves (which typically should be avoided).
   c. Use as required for diagnostic alarms as described in Miscellaneous Alarms.

I. (RE)HEATING COIL CONTROL (IF PRESENT)
1. The controller shall measure the discharge air temperature and modulate the heating coil valve to maintain its heating setpoint.
2. The heating shall be enabled whenever:
   a. Zone heating request (for single zone VAV application).
   b. AND the supply fan status is on.
   c. AND the cooling (if present) is not active,
   d. OR if due to special project requirements and/or single zone VAV applications, the dehumidification control sequence requires simultaneous cooling and reheating to maintain close maximum relative humidity control without overcooling conditioned space.
3. The heating coil valve shall open whenever:
   a. Discharge air temperature drops from 40°F to 35°F (adj.) (but only after preheat output is at 100%).
   b. OR the freezestat is on.
4. Alarms: see TEMPERATURE AND HUMIDITY CONTROL, General, Discharge Air Temperature, Alarms above.

J. HUMIDIFICATION **(IF PRESENT)**

Designer Note: Unless specific project requirements demand close humidity control, general humidification shall not be included. If humidification is required, reviewed and approved by OPP staff, then the following sequence shall be included and edited per project requirements. The following is based on direct steam injection type humidifiers.

1. The controller shall measure the return air humidity and modulate the humidifier to maintain a setpoint of **30**% RH (adj.), while limiting supply air RH to a maximum of 85% (adj.). The humidifier shall be enabled whenever:
   a. the supply fan status is on
   b. AND if OA <u>dew point</u> temperature is below 40 deg. F. (adj.- corresponding to the dew point of maintaining humidity at approximately 70 deg F and 30% RH), then open seasonal isolation valve to enable steam to steam jacketed type humidifier tubes (if present). Edit per project requirements.
   c. And if the temperature sensor (typically hard-wired with humidifier controls – not a BAS point) on the condensate return line at the steam trap draining the humidifier indicates that the humidifier jacket/manifold is hot (to prevent discharging condensate into airstream).
   d. And if the mechanical cooling output is 0% / CHW valve is closed. [MIGHT NOT BE APPLICABLE FOR SPECIAL APPLICATIONS WHERE CENTRAL HUMIDIFIERS ARE USED TO MAINTAIN HGH ZONE LEVELS OF RH AND COOLING IS REQUIRED TO REDUCE 100% OA SUPPLY AIR FOR COOLING BUT OA SUPPLY AIR HUMIDITY IS TOO LOW AND CENTRAL HUMIDIFIERS ARE INSTALLED AFTER COOLING COIL.]
2. The humidifier shall be disabled whenever:
   a. Supply air humidity rises above safety hi-limit cutout of 95% (adj.).
3. Alarms shall be provided as follows (only when humidifier is enabled/operating):
   a. High Supply Air Humidity: If the supply air humidity is greater than 90% rh (adj.), with +/-3% adj. hysteresis.
   b. Low Supply Air Humidity: If the supply air humidity is less than 30% rh (adj.) with +/-3% adj. hysteresis.
   c. Low Return Air Humidity: If the return air humidity is lower than 5% below humidification setpoint or a lower limit of 20% RH for 30 minutes.

K. MISCELLANEOUS ALARMS & SYSTEM DIAGNOSTICS
1. Miscellaneous Alarms shall be provided as follows:

a. Final Filter Differential Pressure Monitor:
   The controller shall monitor the differential pressure across the final filters (if present).
   1) Alarms shall be provided as follows: Filter Change Required: Filter differential pressure exceeds a user definable limit (adj.).
   2) Typically the University changes pre-filters on a scheduled basis so no pre-filter monitoring is required.

2. Commissioning Alarms: When the associated AHU fan status is on, the following monitoring and alarm functions shall initiate one of several primary categories of commissioning "CX" alarms displayed at the BAS workstation. At the equipment controller level, each alarm within each category shall be labeled independently for easy, diagnostic purposes. Primary Categories shall be as follows in bold:

a. **Fan Control Fault**
   1) Unstable PID loop: If any fan speed PID loop continues to cycle its output more than 40% of its range (adj.) 3 times (adj.) in any 60 minute internal.
   2) "Excessive Supply Fan Speed" Alarm: If the supply fan speed output remains above 95% for more than 8 hours (adj.) accumulated per occupied period for at least 3 (adj.) consecutive occupied periods.
   3) "Excessive Relief / Return Fan Speed" Alarm: If the relief or return fan speed output remains above 95% for more than 8 hours (adj.) accumulated per occupied period for at least 3 (adj.) consecutive occupied periods.
   4) Continuous Zone "Check Sizing" /airflow request Alarm: If one or more zone terminal unit controllers is in "Check Sizing" alarm mode for cooling (sending continuous airflow requests), and duct static pressure has reset to maximum setpoint, and the combined condition remains for more than 8 hours (adj.) continuously.
   5) Airflow signal out of range: if measured supply and/or return airflow varies significantly from the initial baseline fan/system non-linear operating curve.
      a) The initial baseline operating curve shall be determined empirically using properly calibrated and measured fan speed, cfm readings and static pressures during system balancing/commissioning and modeled in the controller between actual operating limits of minimum and maximum VFD speeds for each system in a maximum of 10% speed increments.
      b) When fan systems are enabled, compare the associated airflow output, the duct sp output, and the VFD speed output to the initial actual performance curve. A commissioning level alarm shall be sent when current operating conditions vary from baseline curve by more than 20% (adj.) for more than 4 hours (adj.) continuously.
   6) VFD left in local Manual Override: Network with VFD interface and alarm if VFD is locally left in manual speed control mode or if VFD speed output signal remains constant for more than 12 hours (adj.) continuously.

b. **Damper Control Fault**
   1) Unstable PID loop: If any damper PID loop continues to cycle its output more than 40% of its range (adj.) 3 times (adj.) in any 60 minute internal.
   2) Outdoor air damper close off failure: If mixed air temperature is either less than or greater than return air temperature by more than 3°F (adj.) when minimum OA damper output is at 0% output for a minimum 30 minutes (adj) continuously.
   3) Return Damper / Return Plenum Pressure Control Failure: In a return fan configuration only, if return/relief plenum side of return damper goes negative and remains for more than 60 minutes (adj.) continuously.
   4) Return Damper reverse flow: In a relief fan configuration only, if reverse airflow/pressure is detected across return damper for more than 60 minutes (adj.) continuously when relief fan is running.
   5) Excessive Demand Based Ventilation Demand: If due to demand based ventilation CO2 control, the minimum OA resets to design (maximum) minimum OA airflow setpoint and

remains in that condition for more than 8 hours (adj.) accumulated per occupied period for at least 3 (adj.) consecutive occupied periods.

c. **Heating/Cooling Fault**

1) Unstable PID loop: If any heating or cooling PID loop continues to cycle its output more than 40% of its range (adj.) 3 times (adj.) in any 60 minute internal.
2) Cooling valve close off failure: If cooling coil discharge temperature is less than associated AHU preheat discharge by more than 2°F (adj.) when cooling valve output is at 0% output for a minimum 30 minutes (adj) continuously. Provide and install an averaging sensor on leaving face of cooling coil for draw-thru supply fan configuration. Unit DAT sensor may be used for blow through applications.
3) Preheat valve close off failure: If preheat discharge temperature is greater than associated AHU MAT by more than 2°F (adj.) when preheat valve output is at 0% output for a minimum 30 minutes (adj) continuously.
4) Reheat valve close off failure: If discharge temperature is greater than associated AHU cooling coil discharge temperature by more than 2°F (adj.) when reheat valve output is at 0% output for a minimum 30 minutes (adj) continuously. Increase to 5°F to compensate for fan heat if fan is between cooling coil and reheat coil.
5) "Excessive Heating Demand":
   a) If preheat valve and/or face & bypass damper output remains above 95% for more than accumulated 8 hours (adj.) per occupied period for at least 3 (adj.) consecutive occupied periods.
   b) If reheat valve (if present) output remains above 95% for more than accumulated 8 hours (adj.) per occupied period for at least 3 (adj.) consecutive occupied periods
6) "Excessive Cooling Demand":
   a) If the DAT setpoint resets and remains at minimum (dehumidification mode) for more than 8 hours (adj.) accumulated per occupied period for at least 3 (adj.) consecutive occupied periods.
   b) Or if cooling valve output remains above 95% for more than accumulated 8 hours (adj.) per occupied period for at least 3 (adj.) consecutive occupied periods.
7) Low CHWR Temp: If chilled water return temperature sensor (strap on type) reads less than 54°F (adj.) for more than 4 hours continuously. This alarm is to indicate ineffective coil heat transfer that results in "low DeltaT" syndrome – which results in greater pumping energy and chilled water plant inefficiency and can cause the campus chilled water choke valve to start throttling closed to maintain campus chilled water return temperature at its typical setpoint of 54°F.
8) Check Cooling Coil fouling: If chilled water return temperature sensor (strap on type) reads less than 54°F (adj.) for more than 4 hours continuously AND DAT setpoint is not satisfied.
9) "Excessive Humidification Demand" (if present):
   a) If humidifier valve output remains above 85% for more than accumulated 8 hours (adj.) per occupied period for at least 3 (adj.) consecutive occupied periods.
10) Return RH sensor check:
   a) If the RA RH sensor continuously reads at least 10% (adj.) above maximum setpoint (thereby enabling dehumidification mode) and/or if OAT is less than minimum low DATspt for a minimum of 8 continuous hours (adj.).
   b) If the RA RH sensor reads at least 10% (adj.) below minimum setpoint (thereby enabling humidification mode) for a minimum of 4 continuous hours (adj.).
11) Temperature Sensor Calibration Diagnostic Run: Run unit at minimum fan speeds for a minimum of 20 minutes each Sunday at 3 a.m.in 100% recirculation mode, (RA damper 100% open, OA and Relief Dampers fully closed) and with all heating and cooling controls disabled and compare and trend all temperature sensors to each other. Alarm if RAT, MAT, PHDAT, CCDAT, RHDAT, DAT vary from each other by more than +/- 1°F after 15 minutes elapsed time (adj.). Include compensation factors for fan heat depending

on relative locations of sensors and fan arrangement. Coordinate with TAB agent to obtain those factors with fans running at minimum speed.

3. VFD Communications BAS Interface:
   a. The VFD interface shall be connected directly to the main BAS network trunk to monitor, display, trend and report the following minimum points. VFD interface shall not be networked indirectly to the main BAS through AHU controller:
      1) Speed output
      2) Hand/Auto selection indication
      3) Drive Amps
      4) kW (compare instantaneous value, the connected motor nampeplate HP/kW (constant) and the ratio)
      5) kWhrs (include calculated energy savings from baseline if motor kW at full speed kW ran continuously at full speed)
      6) Operating hours
      7) Warnings
      8) Faults

L. POINTS LIST
1. All hardware and software points shall be included to achieve the sequence of operation described above. At a minimum, the following hardware and software points shall be included:

	Hardware Points				Software Points					
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Run Conditions										
Auto - Zone run requests (if multiple zone)					×					×
Demand Response Level (EUMS) (1)					×			×		×
Optimum Start (if single zone)					×			×		×
Manual						×				×
Auto - Schedule (if single zone)							×			×
Supply Fan Start/Stop				×				×		×
Supply Fan VFD Fault			×						G	×
Supply Fan Status - CT			×					×		×
Supply Fan Failure						×			G or CR	×
Supply Fan in Hand						×			G	×
Supply Fan Runtime Exceeded					×				PM	×
Return or Relief Fan Start/Stop (1)				×				×		×
Return or Relief Fan VFD Fault (1)			×						G	
Return or Relief Fan Status - CT (1)			×					×	G	×
Return or Relief Fan Failure (1)						×			G or CR	×
Return or Relief Fan in Hand (1)						×			G	×

	Hardware Points				Software Points					
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Return or Relief Fan Runtime Exceeded (1)					×				PM	×
Safeties										
Freezestat			×					×	G or CR	×
Supply Fan High Static Shutdown			×					×	G or CR	×
Return/Relief High Static Shutdown (1)			×					×	G or CR	×
Fire Alarm Shutdown			×					×	G or CR	×
Return Air Smoke Detector (1)			×					×	G or CR	×
Supply Air Smoke Detector (1)			×					×	G or CR	×
Smoke or Isolation Damper End Switch			×					×	G or CR	×
Fan Speed Control										
Supply Air Duct Static Pressure	×							×		×
Zone Airflow Request (3)					×			×		×
Supply Air Static Pressure Setpoint (initial and effective)					×			×		×
High Supply Air Static Pressure					×				G	×
Low Supply Air Static Pressure					×				G	×
Supply Airflow	×							×		×
Supply Fan % Speed		×						×		×
Supply Fan VFD Network Interface points					×			×		×
Return Airflow	×							×		×
Exhaust Fan(s) Status (used to calculate return airflow offset)						×		×		×
Return Airflow Setpoint (effective)					×			×		×
Return or Relief Fan % Speed		×						×		×
Return or Relief Fan VFD Network Interface points (1)					×			×		×
Damper Control										
Minimum Outdoor Airflow	×							×		×
Minimum Outdoor Air Damper %		× (4)						×		×
Minimum Outside Airflow Setpoint (absolute min, design min, and effective)					×			×		×
Emergency Minimum OA override					×			×	D	×

	Hardware Points				Software Points					
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Demand Based Ventilation Requests					×			×		×
High Zone CO2 Concentration (1)					×			×	G	×
Return Damper "Bleed" Airflow Direction/Pressure Diff. (1)	×							×		×
Return Damper Airflow Direction/Pressure Diff. Setpoint					×					×
Return/Relief Plenum "Bleed" Airflow Direction/Pressure Diff.	×							×		×
Return/Relief Plenum Pressure Setpoint					×					×
Return Air Damper %		× (4)						×		×
Relief Air Damper %		× (4)						×		×
Economizer Outdoor Air Damper %		× (4)						×		×
Economizer PID % Output (1) (for resetting zone occupied min airflow)					×			×		
Temperature and Humidity Control										
Outdoor Air Temp	×							×		×
Outdoor Air Humidity/Enthalpy	×							×		×
Return Air Temp	×							×		×
Return Air Humidity/Enthalpy	×							×		×
Mixed Air Temp	×							×		×
PreHeat leaving air Temp	×							×		×
Cooling Coil leaving air Temp	×							×		×
Discharge Air Temp	×							×		×
Discharge Air Humidity (1)	×							×		×
PreHeating Valve		×						×		×
Preheating F&B damper (1)		×						×		×
Cooling Valve		×						×		×
ReHeating Valve (1)		×						×		×
Humidifier capacity control (1)		×						×		×
Cooling Coil Condensate Overflow Switch			×					×	G or CR	×
Humidifier Enable (1)				×				×		×
High Return Air Temp					×				G	×
Low Return Air Temp					×				G	×
Mixed Air Temp Economizer Setpoint (normal and low limit)					×			×		×
High Mixed Air Temp					×				G	×
Low Mixed Air Temp					×				G	×
PreHeating Temp (PHT) Setpoint					×			×		×

	Hardware Points				Software Points					
Point Name	AI	AO	BI	BO	AV	BV	Sched	Trend	Alarm	Show On Graphic
(off and on modes)										
Discharge Air Temp Setpoint (initial and effective)					×			×		×
High Discharge Air Temp					×				G	×
Low Discharge Air Temp					×				G	×
Zone Cooling Request (Temperature) (2 & 3)					×			×		×
Dehumidification Setpoint					×			×		×
High Return Air Humidity					×				G	×
Humidifier Setpoint (1)					×			×		×
Low Return Air Humidity (1 - only if humidifier present)					×				G	×
High Supply Air Humidity (1 - only if humidifier present)					×				G	×
Low Supply Air Humidity (1 - only if humidifier present)					×				G	×
Zone Heating Request (for HW pump DP optimized reset)					×			×		×
AHU HW Heating Coil Request (for HW pump DP optimized reset)					×			×		×
AHU CHW Cooling Coil Request (for CHW pump DP optimized reset)					×			×		×
Miscellaneous Alarms and Diagnostics										
Final filter Differential Pressure (1)	×							×		
Final filter Change Required (1)									PM	×
Commissioning										
Fan Control Fault									CX	×
Unstable PID (any fan speed output)								×	D	
Excessive Supply Fan Speed								×	D	
Excessive Relief / Return Fan Speed								×	D	
Continuous Zone “Check Sizing” /airflow request								×	D	
Supply Airflow out of allowable limits wrt system baseline operating curve								×	D	
Return Airflow out of allowable limits wrt system baseline operating curve								×	D	
Damper Control Fault									CX	×
Unstable PID (any damper)								×	D	

	Hardware Points				Software Points					
Point Name	**AI**	**AO**	**BI**	**BO**	**AV**	**BV**	**Sched**	**Trend**	**Alarm**	**Show On Graphic**
Minimum OA Damper Closeoff Failure								×	D	
Return/Relief Plenum Pressure								×	D	
Return Damper Airflow Direction/Pressure Diff.								×	D	
Excessive Demand Based Ventilation								×	D	
Temp/Humidity Control Fault									CX	×
Unstable PID (any heating/cooling output)								×	D	
Cooling Valve Closeoff Failure								×	D	
PreHeating Valve Closeoff Failure								×	D	
Reheating Valve Closeoff Failure (1)								×	D	
Excessive Heating Demand								×	D	
Excessive Cooling Demand								×	D	
Low CHWR Temp	×							×	D	
Check Cooling Coil fouling					×			×	D	
Return RH sensor check								×	D	
Totals										

Total Hardware (--) **Total Software (--)**

Notes:
(1) Only enable when present in specific application
(2) Required link for interface to associated zone air terminals for DAT reset
(3) Required link for interface to associated zone air terminals for supply s.p. reset
(4) AO preferred if/when unit controller selected to meet all other hardware/software requirements inherently has them available. If all other hardware/software requirements can be met, with the exception of having inadequate AO's but adequate spare DO's, then 3-point floating may be an acceptable option for points noted. (CSC shall review with OPP before final controls submission).

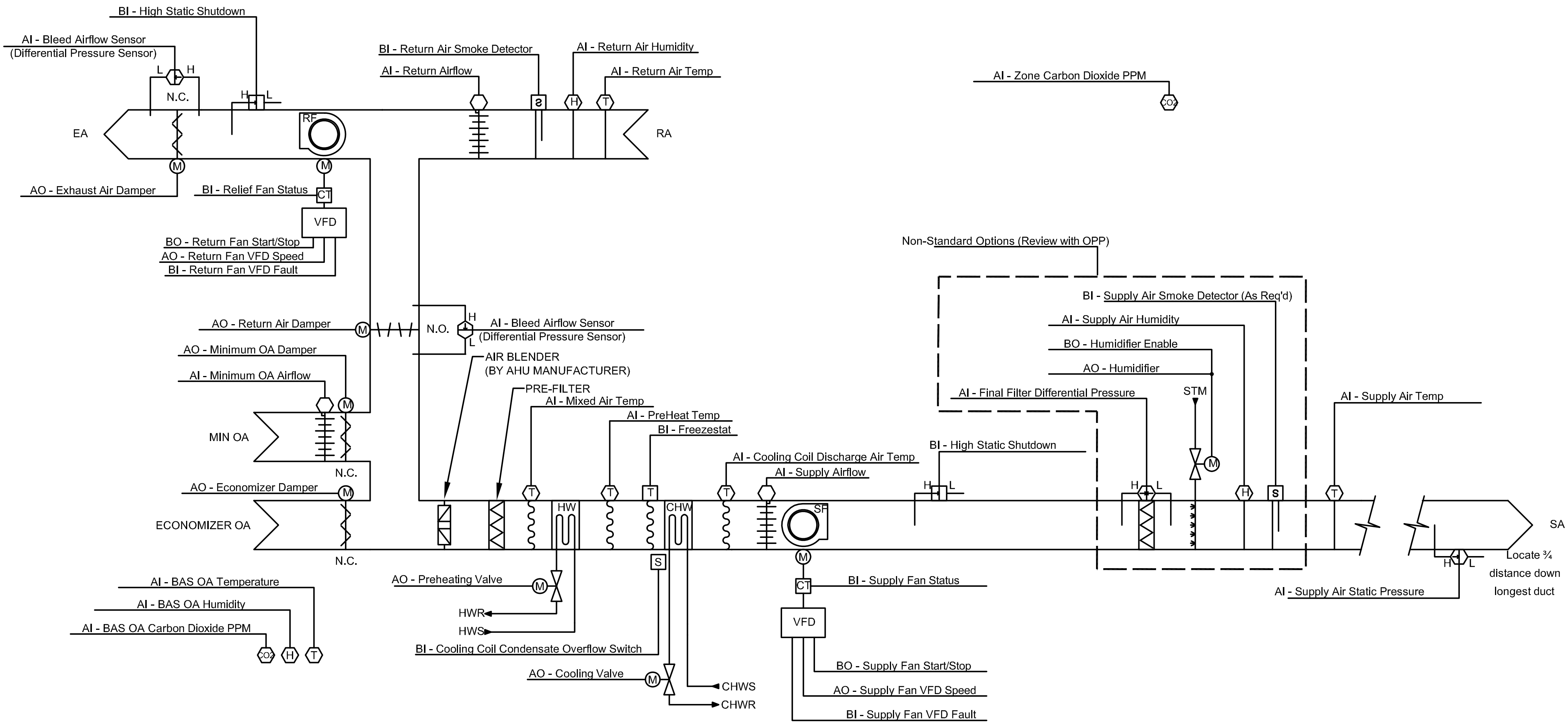
Alarm Notification Class: (Refer to Div 25, Building Automation Systems (BAS), "Alarms")
The following default alarm notification classes are suggested unless application warrants more critical level. Coordinate project specific requirements with OPP Environmental Services and implement them prior to acceptance and turnover of system.

- G General
- CR Critical (*If serving temperature sensitive, critical research space or areas with high risk of damage due to temperature extremes)
- PM Preventive Maintenance
- CX Commissioning
- D Diagnostic alarm point within controller (no external notification action)

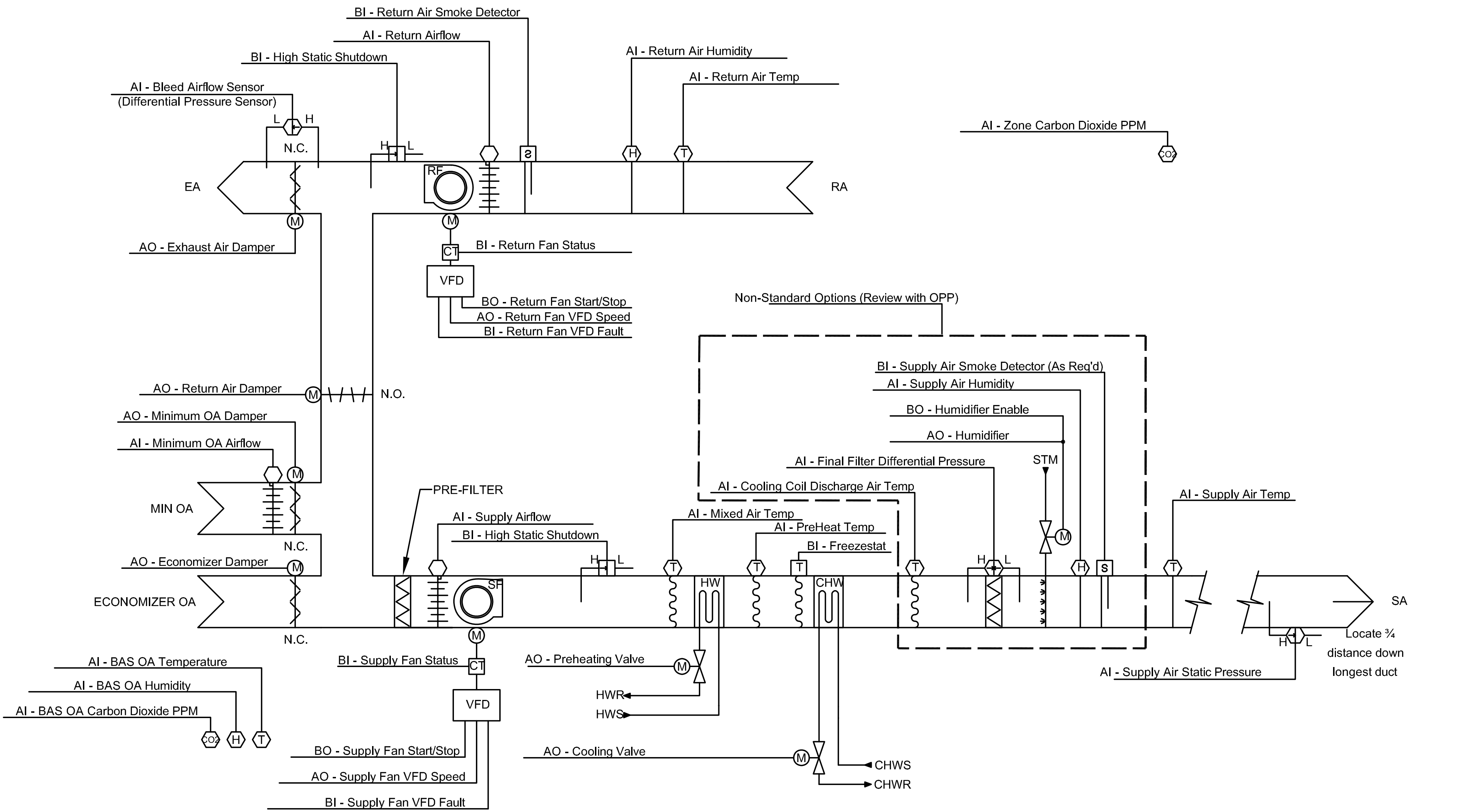
M. SCHEMATICS

1. Typical generic control schematics for various VAV air handling unit configurations are available (in either AutoCAD or PDF versions) in the table in section 25 90 00 GUIDE SEQUENCES OF OPERATION as described below:
   a. 4-pipe, blow-through supply fan, relief fan
   b. 4-pipe, blow-through supply fan, return fan
   c. 4-pipe, draw-through supply fan, relief fan
   d. 4-pipe, draw-through supply fan, return fan

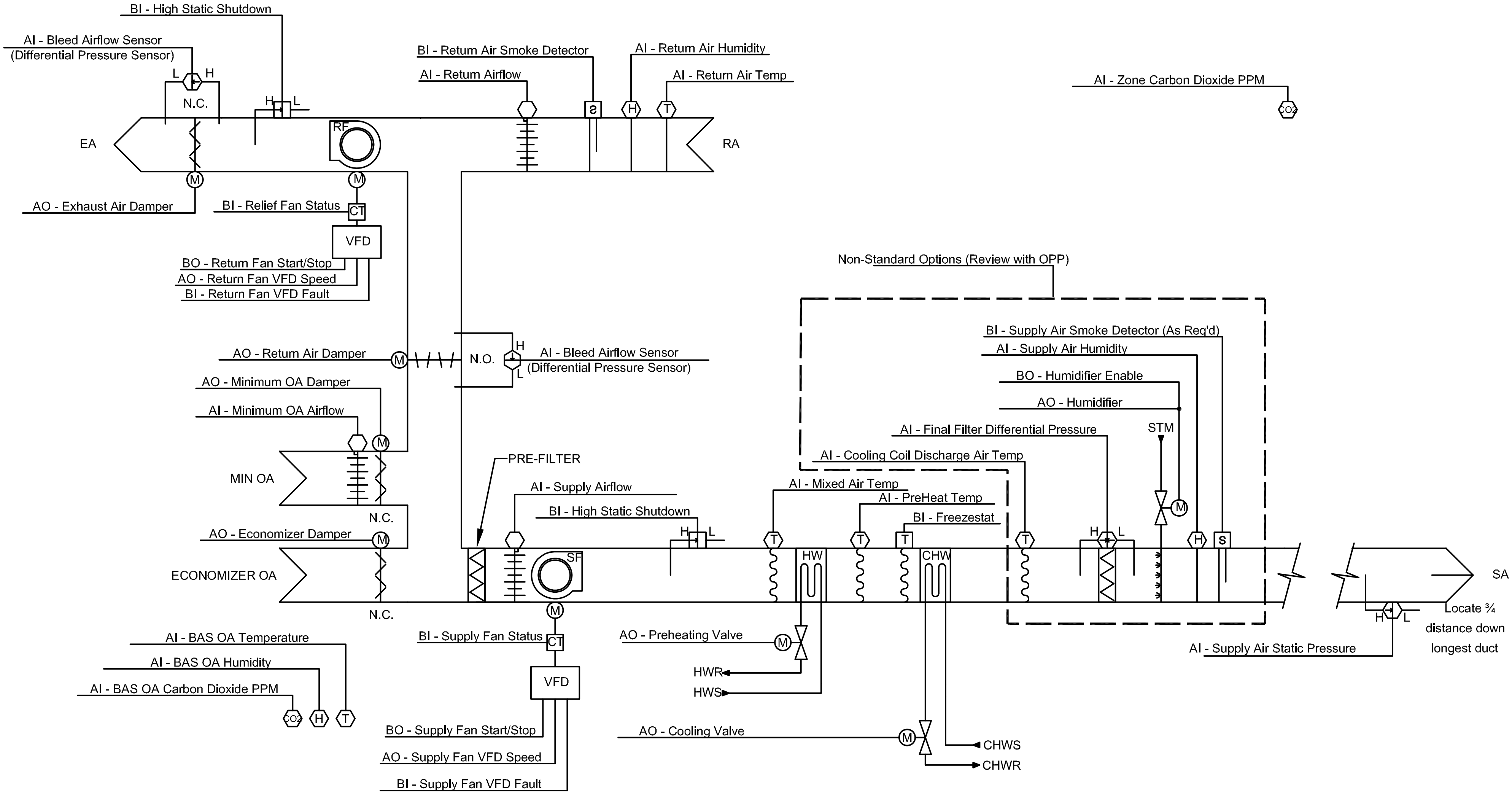
END



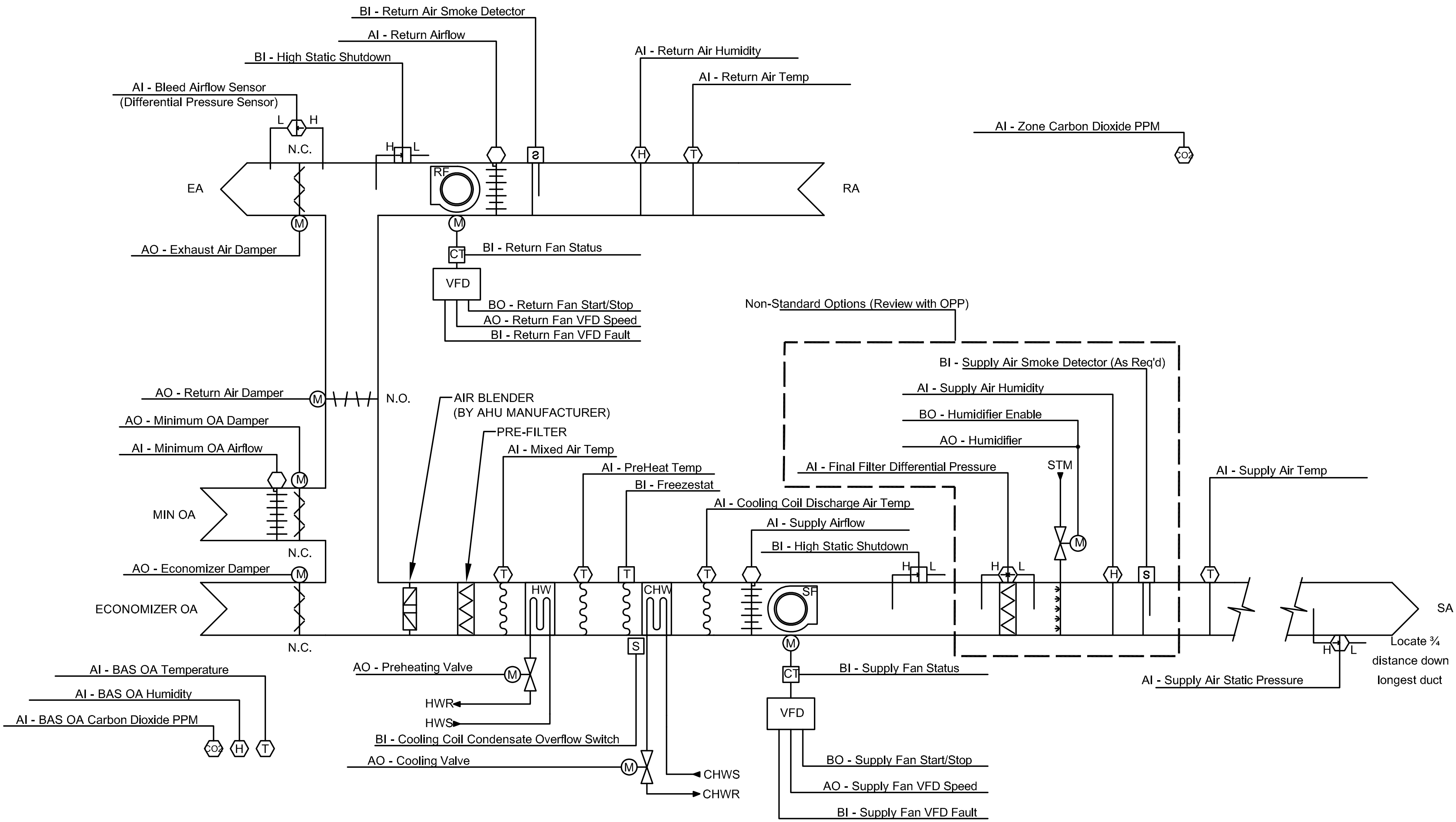
VAV AHU WITH RELIEF FAN, 4-PIPE, DRAW-THRU



VAV AHU WITH RETURN FAN, 4-PIPE, BLOW-THRU



VAV AHU WITH RELIEF FAN, 4-PIPE, BLOW-THRU



VAV AHU WITH RETURN FAN, 4-PIPE, DRAW-THRU