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1.1 List of Hard Wired Points

A. VAV Terminal Unit (Reheat Optional)

<table>
<thead>
<tr>
<th>Description</th>
<th>Type</th>
<th>Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAV Box Damper Position</td>
<td>AO or OR two DOs and one AI</td>
<td>Modulating actuator or Floating actuator w/position feedback</td>
</tr>
<tr>
<td>Heating Signal (reheat boxes only)</td>
<td>AO</td>
<td>Modulating valve or Modulating electric heating coil</td>
</tr>
<tr>
<td>Discharge Airflow</td>
<td>AI</td>
<td>Differential pressure transducer connected to flow sensor</td>
</tr>
<tr>
<td>Discharge Air Temperature</td>
<td>AI</td>
<td>Duct temperature sensor</td>
</tr>
<tr>
<td>Zone Temperature</td>
<td>AI</td>
<td>Room temperature sensor</td>
</tr>
<tr>
<td>Local Override (if applicable)</td>
<td>DI</td>
<td>Zone thermostat override switch</td>
</tr>
<tr>
<td>Occupancy Sensor (if applicable)</td>
<td>DI</td>
<td>Occupancy sensor</td>
</tr>
<tr>
<td>Window Switch (if applicable)</td>
<td>DI</td>
<td>Window switch</td>
</tr>
<tr>
<td>Zone Temperature Setpoint Adjustment (if applicable)</td>
<td>AI</td>
<td>Zone thermostat adjustment</td>
</tr>
<tr>
<td>Zone CO₂ Level (if applicable)</td>
<td>AI</td>
<td>Room CO₂ sensor</td>
</tr>
</tbody>
</table>

B. Fan Powered Terminal Unit (Series or Parallel, Constant or Variable Speed Fan)

<table>
<thead>
<tr>
<th>Description</th>
<th>Type</th>
<th>Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fan Speed Command (if applicable)</td>
<td>AO</td>
<td>Connect to ECM</td>
</tr>
<tr>
<td>Fan Start/Stop (if separate from fan speed point)</td>
<td>DO</td>
<td>Connect to ECM</td>
</tr>
<tr>
<td>Fan Status or Fan Speed Feedback</td>
<td>DI or AI</td>
<td>Connect to current switch or Connect to ECM</td>
</tr>
<tr>
<td>VAV Box Damper Position</td>
<td>AO or OR two DOs and one AI</td>
<td>Modulating actuator or Floating actuator w/position feedback</td>
</tr>
<tr>
<td>Heating Signal</td>
<td>AO</td>
<td>Modulating valve or Modulating electric heating coil</td>
</tr>
<tr>
<td>Primary Airflow</td>
<td>AI</td>
<td>Differential pressure transducer connected to flow sensor</td>
</tr>
<tr>
<td>Total Airflow (if applicable)</td>
<td>AI</td>
<td>Differential pressure transducer connected to flow sensor</td>
</tr>
</tbody>
</table>
### Dual Duct Terminal Unit with Inlet Sensors (Snap Acting or Cold Duct Minimum Control)

<table>
<thead>
<tr>
<th>Description</th>
<th>Type</th>
<th>Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Damper Position</td>
<td>AO OR</td>
<td>Modulating actuator</td>
</tr>
<tr>
<td></td>
<td>two DOs and one AI</td>
<td>Floating actuator w/position feedback</td>
</tr>
<tr>
<td>Heating Damper Position</td>
<td>AO OR</td>
<td>Modulating actuator</td>
</tr>
<tr>
<td></td>
<td>two DOs and one AI</td>
<td>Floating actuator w/position feedback</td>
</tr>
<tr>
<td>Cooling Airflow</td>
<td>AI</td>
<td>Differential pressure transducer connected to flow sensor</td>
</tr>
<tr>
<td>Heating Airflow</td>
<td>AI</td>
<td>Differential pressure transducer connected to flow sensor</td>
</tr>
<tr>
<td>Discharge Air Temperature</td>
<td>AI</td>
<td>Duct temperature sensor</td>
</tr>
<tr>
<td>Zone Temperature</td>
<td>AI</td>
<td>Room temperature sensor</td>
</tr>
<tr>
<td>Local Override (if applicable)</td>
<td>DI</td>
<td>Zone thermostat override switch</td>
</tr>
<tr>
<td>Occupancy Sensor (if applicable)</td>
<td>DI</td>
<td>Occupancy sensor</td>
</tr>
<tr>
<td>Window Switch (if applicable)</td>
<td>DI</td>
<td>Window switch</td>
</tr>
<tr>
<td>Zone Temperature Setpoint</td>
<td>AI</td>
<td>Zone thermostat adjustment</td>
</tr>
<tr>
<td>Adjustment (if applicable)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zone CO₂ Level (if applicable, cold duct minimum control only)</td>
<td>AI</td>
<td>Room CO₂ sensor</td>
</tr>
</tbody>
</table>

---

**ASHRAE RP-1455: Advanced Control Sequences for HVAC Systems**  
**Phase I, Air Distribution and Terminal Systems**

---

**Description**

**Type**

**Device**

- Discharge Air Temperature: AI  
  - Duct temperature sensor
- Zone Temperature: AI  
  - Room temperature sensor
- Local Override (if applicable): DI  
  - Zone thermostat override switch
- Occupancy Sensor (if applicable): DI  
  - Occupancy sensor
- Window Switch (if applicable): DI  
  - Window switch
- Zone Temperature Setpoint Adjustment (if applicable): AI  
  - Zone thermostat adjustment
- Zone CO₂ Level (if applicable): AI  
  - Room CO₂ sensor
### D. Dual Duct Terminal Unit with Discharge Sensor (Snap Acting or Mixing Control)

<table>
<thead>
<tr>
<th>Description</th>
<th>Type</th>
<th>Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Damper Position</td>
<td>AO OR two DOs and one AI</td>
<td>Modulating actuator OR Floating actuator w/position feedback</td>
</tr>
<tr>
<td>Heating Damper Position</td>
<td>AO OR two DOs and one AI</td>
<td>Modulating actuator OR Floating actuator w/position feedback</td>
</tr>
<tr>
<td>Discharge Airflow</td>
<td>AI</td>
<td>Differential pressure transducer connected to flow sensor</td>
</tr>
<tr>
<td>Discharge Air Temperature</td>
<td>AI</td>
<td>Duct temperature sensor</td>
</tr>
<tr>
<td>Zone Temperature</td>
<td>AI</td>
<td>Room temperature sensor</td>
</tr>
<tr>
<td>Local Override (if applicable)</td>
<td>DI</td>
<td>Zone thermostat override switch</td>
</tr>
<tr>
<td>Occupancy Sensor (if applicable)</td>
<td>DI</td>
<td>Occupancy sensor</td>
</tr>
<tr>
<td>Window Switch (if applicable)</td>
<td>DI</td>
<td>Window switch</td>
</tr>
<tr>
<td>Zone Temperature Setpoint Adjustment (if applicable)</td>
<td>AI</td>
<td>Zone thermostat adjustment</td>
</tr>
<tr>
<td>Zone CO(_2) Level (if applicable, mixing control only)</td>
<td>AI</td>
<td>Room CO(_2) sensor</td>
</tr>
<tr>
<td>Description</td>
<td>Type</td>
<td>Device</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
<td>-------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>For units with a common economizer/minimum OA damper, include the following points</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outdoor Airflow</td>
<td>AI</td>
<td>Airflow measurement station</td>
</tr>
<tr>
<td>For units with a separate minimum outdoor air damper, include the following points</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Outdoor Air Damper Open/Close</td>
<td>DO</td>
<td>Two position actuator</td>
</tr>
<tr>
<td>Minimum Outdoor Air Damper Differential Pressure</td>
<td>AI</td>
<td>Differential pressure transducer</td>
</tr>
<tr>
<td>OR</td>
<td></td>
<td>Airflow measurement station</td>
</tr>
<tr>
<td>Minimum Outdoor Airflow</td>
<td>AI</td>
<td></td>
</tr>
<tr>
<td>For units with actuated relief dampers but no relief fan, include the following points</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relief Damper Open/Close</td>
<td>AO</td>
<td>Modulating actuator</td>
</tr>
<tr>
<td>Building Static Pressure</td>
<td>AI</td>
<td>Differential pressure transducer between representative space and outdoors</td>
</tr>
<tr>
<td>For units with a relief fan, include the following points</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relief Fan Start/Stop</td>
<td>DO</td>
<td>Connect to VFD Run</td>
</tr>
<tr>
<td>Relief Fan Speed</td>
<td>AO</td>
<td>Connect to VFD Speed</td>
</tr>
<tr>
<td>Relief Damper Open/Close</td>
<td>DO</td>
<td>Two position actuator</td>
</tr>
<tr>
<td>Building Static Pressure</td>
<td>AI</td>
<td>Differential pressure transducer between representative space and outdoors</td>
</tr>
<tr>
<td>For units with a return fan, include the following points</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Return Fan Start/Stop</td>
<td>DO</td>
<td>Connect to VFD Run</td>
</tr>
<tr>
<td>Return Fan High Static Alarm Reset</td>
<td>DO</td>
<td>Dry contact to 120V or 24V control circuit</td>
</tr>
<tr>
<td>Return Fan Speed</td>
<td>AO</td>
<td>Connect to VFD Speed</td>
</tr>
<tr>
<td>Return Airflow (if applicable)</td>
<td>AI</td>
<td>Airflow measurement station at return fan</td>
</tr>
<tr>
<td>Return Fan Static Pressure</td>
<td>AI</td>
<td>Differential pressure transducer at fan</td>
</tr>
<tr>
<td>Exhaust Damper</td>
<td>AO</td>
<td>Modulating actuator</td>
</tr>
<tr>
<td>Building Static Pressure</td>
<td>AI</td>
<td>Differential pressure transducer between representative space and outdoors</td>
</tr>
</tbody>
</table>
1.2 Control Diagrams

A. VAV Terminal Unit with Reheat

B. Parallel Fan-Powered Terminal Unit, Constant Volume Fan
C. Parallel Fan-Powered Terminal Unit, Variable Volume Fan

D. Series Fan-Powered Terminal Unit
E. Dual Duct Terminal Unit with Inlet Sensors

F. Dual Duct Terminal Unit with Discharge Sensor
G. Multiple Zone VAV Air Handling Unit with Return Fan and OA Measurement Station
H. Multiple Zone VAV Air Handling Unit with Relief Fan and Differential Pressure OA Measurement
1.3 Sequences of Operation

A. General

1. Unless otherwise indicated, control loops shall be enabled and disabled based on the status of the system being controlled to prevent wind-up.

2. When a control loop is enabled, it and all its constituents (such as the proportional and integral terms) shall be set to a Neutral value.

3. A control loop in Neutral shall correspond to a condition which applies the minimum control effect, i.e. valves/dampers closed, VFDs at minimum speed, etc.

4. When there are multiple outdoor air temperature sensors, the system shall use the valid sensor which is physically closest to the equipment being controlled.
   a. Outdoor air temperature sensors at air handler outdoor air intakes shall be considered valid only when the supply fan is proven on and unit is in Occupied Mode (producing airflow across the sensor).
   b. The general TS-4 outdoor air temperature sensor shall be valid only if all outdoor air intake sensors are invalid.
   c. The outdoor air temperature used for graphics display, optimum start, plant OAT lockout, and other global sequences shall be the average of all valid sensor readings.

5. The term “proven” (i.e. “proven on”/“proven off”) shall mean that the equipment’s DI status point matches the state set by the equipment’s DO command point.

6. The term “control loop” or “loop” is used generically for all control loops. These will typically be PID loops, but proportional plus integral plus derivative gains are not required on all loops. Unless specifically indicated otherwise, the following guidelines shall be followed:
   - Use of proportional-only prevents integral windup.
     a. Use proportional only (P-only) loops for limiting loops (such as zone CO\textsubscript{2} control loops, etc.).
   - Derivative terms make loop tuning difficult in practice.
     b. Do not use the derivative term on any loops unless field tuning is not possible without it.

7. To avoid abrupt changes in equipment operation, the output of every control loop shall be limited to a maximum rate of change of 25\% per minute unless otherwise noted.

8. All setpoints, timers, deadbands, PID gains, etc. listed in sequences shall be capable of being adjusted by the operator through the normal EMCS user interface whether indicated as adjustable in sequences or not. Software (virtual) points shall be used for these variables. Fixed scalar numbers shall not be embedded in programs except for physical constants (e.g. conversion factors).
All hardware points, not just inputs, should be capable of being overridden for purposes of testing and commissioning. For example, the commissioning agent should be able to command damper positions, valve positions, fan speeds, etc directly through EMCS overrides. The following requirement to equate hardware points to software points is necessary for systems that do not allow overriding real input points. Application Specific Controllers (ASC) are excepted because, in our experience, it may not be cost effective or feasible for all points due to limitations of ASC hardware. However, some critical points (e.g. VAV box damper position) may need to have this capability; these are specifically addressed in subsequent sequences.

9. Values for all points, including real (hardware) points used in control sequences shall be capable of being overridden by the user (e.g. for testing and commissioning). If hardware design prevents this for hardware points, they shall be equated to a software point and the software point shall be used in all sequences. Exception: Not required for all ASC hardware points.

10. VFD Minimum Speed Setpoints

There needs to be corresponding instructions in the TAB specifications. For example:
- Start the fan or pump.
- Manually set speed to 6 Hz (10%) unless otherwise indicated in control sequences. For cooling towers with gear boxes, use 20% or whatever minimum speed is recommended by tower manufacturer.
- Observe fan/pump in field to ensure it is visibly rotating. If not, gradually increase speed until it is. The speed at this point shall be the minimum speed setpoint for this piece of equipment.

a. Minimum speed setpoints for all VFD-driven equipment shall be determined in accordance with the test and balance specifications.

The following prevents separate, potentially conflicting minimum speed setpoints from existing in the EMCS software and the drive firmware.

b. For each piece of equipment, the minimum speed shall be stored in a single software point. This value shall be mapped to the VFD’s minimum speed setpoint via the drive’s network interface; in the case of a hard-wired VFD interface, the minimum speed shall be the lowest speed command sent to the drive by the EMCS.

The following prohibits the practice of equating the minimum speed of a piece of equipment to a “zero” speed in the EMCS, which creates confusion during subsequent building recommissioning.

c. The minimum speed setpoint shall be stored as a positive percentage of full range. I.e. 0% speed shall correspond to fully stopped equipment, and the minimum speed shall be a value greater than 0%.
A Trim & Respond loop controls a setpoint for pressure, temperature, or other variables at an air handler or plant. It reduces the setpoint at a fixed rate, until a downstream zone is no longer satisfied and generates a request. When a sufficient number of requests are present, the setpoint is increased in response. The importance of each zone’s requests can be adjusted to ensure that critical zones are always satisfied. When a sufficient number of requests no longer exist, the setpoint resumes decreasing at its fixed rate. A running total of the requests generated by each zone is kept to identify zones which are driving the reset logic.

Trim and Respond logic is optimal for controlling a single variable which is subject to the requirements of multiple downstream zones (such as the static pressure setpoint for a VAV air handler). In this application, it is easier to tune than a conventional control loop, and provides for fast response without high frequency chatter or loss of control of the downstream devices. It typically does generate low frequency cyclic hunting, but this behavior is slow enough to be non-disruptive.

See the end of this section for an example of T&R implementation.

11. Trim & Respond Setpoint Reset Logic

   a. Trim & Respond setpoint reset logic and zone/system reset Requests where referenced in sequences shall be implemented as described below.

   b. A “Request” is a call to reset a static pressure or temperature setpoint, generated by downstream zones or air handling systems. These Requests are sent upstream to the plant or system that serves the zone or air handler which generated the Request.

   1) For each downstream zone or system, and for each type of setpoint reset Request listed for the zone/system, provide the following software points:

      Importance Multiplier is used to scale the number of requests the zone/system is generating. A value of zero causes the requests from that zone or system to be ignored. A value greater than one can be used to effectively increase the number of requests from the zone/system based on the critical nature of the spaces served.

      a) Importance Multiplier (default = 1)

      Request-Hours accumulates the integral of requests (prior to adjustment of Importance Multiplier) to help identify zones/systems that are driving the reset logic. Rogue zone identification is particularly critical in this context, since a single rogue zone can keep the Trim & Response loop at maximum, and prevent it from saving any energy.

      b) Request-Hours. Every x minutes (default 5 minutes), add x/60 times the current number of Requests to this request-hours accumulator point. The request-hours point is reset to zero upon a global command from the system/plant serving the zone/system – this global point simultaneously resets the request-hours point for all zones/systems served by this system/plant.

      c) Cumulative%-Request-Hours. This is the zone/system Request-Hours divided by the zone/system run-hours (the hours in any Mode other than Unoccupied Mode) since the last reset, expressed as a percentage.

      d) A Level 4 alarm is generated if the zone Importance Multiplier is greater than zero, the zone/system Cumulative%-Request-Hours exceeds 70%, and the total number of zone/system run-hours exceeds 40.

2) See zone and air handling system control sequences for logic to generate Requests.

3) Multiply the number of Requests determined from zone/system logic times the Importance Multiplier and send to the system/plant that serves the zone/system. See system/plant logic to see how Requests are used in Trim & Respond logic.
c. For each upstream system or plant setpoint being controlled by a T&R loop, define the following variables. All variables below shall be adjustable from a reset graphic accessible from a hyperlink on the associated system/plant graphic. Initial values are defined in system/plant sequences below. Values for trim, respond, time step, etc. shall be tuned to provide stable control.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>(SP_0)</td>
<td>Initial setpoint</td>
</tr>
<tr>
<td>(SP_{\text{min}})</td>
<td>Minimum setpoint</td>
</tr>
<tr>
<td>(SP_{\text{max}})</td>
<td>Maximum setpoint</td>
</tr>
<tr>
<td>(T_d)</td>
<td>Delay timer</td>
</tr>
<tr>
<td>(T)</td>
<td>Time step</td>
</tr>
<tr>
<td>(I)</td>
<td>Number of ignored Requests</td>
</tr>
<tr>
<td>(R)</td>
<td>Number of Requests from zones/systems</td>
</tr>
<tr>
<td>(SP_{\text{trim}})</td>
<td>Trim amount</td>
</tr>
<tr>
<td>(SP_{\text{res}})</td>
<td>Respond amount (must be opposite in sign to (SP_{\text{trim}}))</td>
</tr>
<tr>
<td>(SP_{\text{res-max}})</td>
<td>Maximum response per time interval (must be same sign as (SP_{\text{res}}))</td>
</tr>
</tbody>
</table>

d. Trim & Respond logic shall reset setpoint within the range \(SP_{\text{min}}\) to \(SP_{\text{max}}\). When the associated device (e.g. fan, pump) is off, the setpoint shall be \(SP_0\). The reset logic shall be active while the associated device is proven on, starting \(T_d\) after initial device start command. When active, every time step \(T\), trim the setpoint by \(SP_{\text{trim}}\). If there are more than \(I\) Requests, respond by changing the setpoint by \(SP_{\text{res}} \times (R-I)\), (i.e. the number of Requests minus the number of Ignored Requests), but no more than \(SP_{\text{res-max}}\). In other words, every time step \(T\):

  Change setpoint by \(SP_{\text{trim}}\)

  If \(R>I\), also change setpoint by \((R-I)\)\(SP_{\text{res}}\) but no larger than \(SP_{\text{res-max}}\)
The following is an example of a sequence which uses Trim & Respond to control the static pressure setpoint of a VAV AHU serving multiple downstream zones:

Static pressure setpoint shall be reset using trim and respond logic within the range 0.15 inches to 1.5 inches. When fan starts, setpoint is 0.5 inches. After fan is proven on for 5 minutes, every 2 minutes, decrease the setpoint by 0.04 inches. If there are more than two pressure requests, increase the setpoint by 0.06 for each request in excess of two, up to a maximum of 0.15. A pressure request is generated when any VAV damper served by the system is more than 95% open.

Note that it is recommended that \( |SP_{res}| > |SP_{trim}| \) so that one does not get stuck at a value, as can happen if \( SP_{res} \) and \( SP_{trim} \) are equal in absolute value.

This sequence defines the T&R variables as follows:

<table>
<thead>
<tr>
<th>SP_0</th>
<th>SP_min</th>
<th>SP_max</th>
<th>T_d</th>
<th>T</th>
<th>I</th>
<th>SP_trim</th>
<th>SP_res</th>
<th>SP_res-max</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.15</td>
<td>1.50</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>-0.04</td>
<td>0.06</td>
<td>0.15</td>
</tr>
</tbody>
</table>

(All zones are equal, e.g. an open plan office, so the Importance factor is not used.)

Description of general operation: The sequence will slowly reduce the AHU’s static pressure setpoint by 0.04” every 2 minutes. As static pressure drops, downstream VAV box dampers will open further for a given load. When the combination of reduced static pressure and changes in load drives more than two VAV boxes fully open, the system will respond by increasing static pressure setpoint. (In this example, if four boxes are all > 95%, the system will increase the pressure by 0.12”). The setpoint will continue to increase every 2 minutes until all but 2 VAV boxes (for ignore value of 2) are satisfied (damper position < 95%). Subsequently, the setpoint will continue to decrease by 0.04” every 2 minutes.

Example:

Initial Setpoint is 0.5”. System starts at 12:00.

At 12:02 (i.e. 1*T), there is one request (i.e. R=1). Setpoint is reduced by \( SP_{trim} \) which is 0.04; since \( R - I < 0 \), there is no response. Net result: Setpoint is 0.46”.

At 12:04 (i.e. 2*T), there are two requests (i.e. R=2): Setpoint is reduced by 0.04; since \( R - I = 0 \), there is no response. Net result: Setpoint is 0.42”.

At 12:06 (i.e. 3*T), there are three requests (i.e. R=3): Setpoint is reduced by 0.04; since \( R - I = 1 \), response increases Setpoint by 0.06 (i.e. 1 * \( SP_{res} \)). Net result: Setpoint is 0.44” (i.e. +0.02” net change).

At 12:08 (i.e. 4*T), there are four requests (i.e. R=4): Setpoint is reduced by 0.04; since \( R - I = 2 \), response increases Setpoint by 0.12 (i.e. 2 * \( SP_{res} \)). Net result: Setpoint is 0.52” (i.e. +0.08” net change).

At 12:10 (i.e. 5*T), there are six requests (i.e. R=6): Setpoint is reduced by 0.04; since \( R - I = 4 \) but \( SP_{res-max} = 0.15 \), response increases Setpoint by the maximum of 0.15 (i.e. \( not 4 * SP_{res} = 0.24 \)). Net result: Setpoint is 0.63” (i.e. +0.11” net change).

At 12:12 (i.e. 6*T), there are three requests (i.e. R=3): Setpoint is reduced by 0.04; since \( R - I = 1 \), response increases Setpoint by 0.06 (i.e. 1 * \( SP_{res} \)). Net result: Setpoint is 0.65”.

At 12:14 (i.e. 7*T), there are zero requests (i.e. R=0): Setpoint is reduced by 0.04; since \( R - I < 0 \), there is no response. Net result: Setpoint is 0.61”.
This is a trend graph of the example above, continued for a period of an hour:

The system will tend towards minimum static pressure (thus saving energy) but respond rapidly to increasing demand from the terminal units. This cyclic pattern is characteristic of a robust Trim & Respond loop – the setpoint is not expected to remain static except at its minimum and maximum values.

12. Equipment Staging and Rotation

The automatic even wear rotation presented in the following section is written using the basis of equipment run time to determine position in the queue for staging and is triggered only during a stage up or stage down event. These sequences will provide the most even run time across multiple pieces of equipment. The engineer may consider modifying this sequence to achieve other effects, such as:

- Providing a minimum run time before a piece of equipment is staged off to prevent the equipment from short cycling.
- Providing a maximum run time before a piece of equipment is staged off (this is useful for systems that operate continuously).

a. Automatic Even Wear Rotation

1) Lead/lag: Unless otherwise noted, parallel staged devices (such as pumps, towers) that are not redundant shall be lead/lag alternated when more than one is off or more than one is on so that the device with the most operating hours is made the later stage device and the one with the least number of hours is made the earlier stage device. For example, assuming there are three devices, if all three are off or all are on, the staging order will simply be based on run hours from lowest to highest. If two devices are on, the one with the most hours will be set to be stage 2 while the other is set to stage 1; this may be the reverse of the operating order when the devices were started. If two devices are off, the one with the most hours will be set to be stage 3 while the other is set to stage 2; this may be the reverse of the operating order when the devices were stopped.
2) Lead/standby: Unless otherwise noted, parallel devices (such as pumps, towers) that are 100% redundant shall be lead/standby alternated when more than one is off so that the device with the most operating hours is made the later stage device and the one with the least number of hours is made the earlier stage device. For example, assuming there are three devices, if all three are off, the staging order will be based on run hours from lowest to highest. If devices run continuously, lead/standby shall switch at an operator-specified runtime; standby device shall first be started and proven on before former lead device is changed to standby and shut off.

b. Exceptions

1) Operators shall be able to manually fix staging order via software points on graphics overriding the Even Wear or Periodic Rotation logic above, but not overriding the In Alarm or Hand Operation logic below.

The following sequence does not lock out a device that is in alarm. It moves all devices in alarm to the end of the rotation sequence such that they will be the last devices called to run. The sequence will only called for these devices in alarm if all of the devices not in alarm are already enabled and there is a call for a stage-up (e.g. due to loss of control). A device in alarm will respond if called to run, only if it is capable of doing so (e.g. not locked out on internal safety, locked out on an HOA switch at the starter or otherwise disabled). It is important to note that this staging does not override the devices internal safeties so it will not damage equipment.

Note some alarm conditions could be triggered when the underlying equipment is fully operable. For example a status point not matching the on/off command could be triggered by a faulty status signal. The same is true for a supervised HOA at a control panel, the operator might have been testing the equipment and simply forgot to turn the HOA back to AUTO.

2) In Alarm: If the lead device has a fault condition or has been manually switched off, a Level 2 alarm shall be generated and the device shall be set to the last stage position in the lead/lag order until alarm is reset by operator. Staging position of remaining devices shall follow the prevailing (Even Wear or Periodic Rotation) logic. A device in alarm can only automatically move up in the staging order if another device goes into alarm. Fault conditions include the following:

We are including pumps, chillers and boilers even though they are beyond the scope of RP-1455 in anticipation of TC-1.4 extending this work to such devices.

a) Variable Speed Fans and Pumps
   (1) VFD critical fault is ON
   (2) Status point not matching its on/off point for 15 seconds while the device is commanded on
   (3) Supervised HOA at control panel in OFF position
   (4) Loss of power (e.g. VFD DC Bus voltage = zero)

b) Constant Speed Fans and Pumps
   (1) Status point not matching its on/off point for 15 seconds while the device is commanded on
   (2) Supervised HOA at control panel in OFF position
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c) Chillers
   (1) Chiller alarm contact
   (2) Chiller is manually shut off as indicated by the status of the Local/Auto switch from chiller gateway
   (3) Chiller status remains off 5 minutes after command to start

d) Boilers
   (1) Boiler alarm point is ON
   (2) If its leaving water temperature remains 15°F below setpoint for 30 minutes.

Any condition in which a device appears to continue to run after being commanded off is considered a case of “hand operation”; in practice this condition may arise due to other circumstances (e.g. a bad current transducer).

3) Hand Operation: If a device is on in Hand (e.g. via an HOA switch or local control of VFD), the device shall be set to the lead device and a Level 4 alarm shall be generated. The device will remain as lead until the alarm is reset by the operator. Hand operation is determined by

a) Variable Speed Fans and Pumps
   (1) Status point not matching its on/off point for 15 seconds while the device is commanded off
   (2) VFD in local “hand” mode
   (3) Supervised HOA at control panel in ON position

b) Constant Speed Fans and Pumps
   (1) Status point not matching its on/off point for 15 seconds while the device is commanded off
   (2) Supervised HOA at control panel in ON position

c) Chillers: Chiller is manually turned on as indicated by the status of the local/auto switch from chiller gateway.
Defining the operator’s interface is outside of the scope of RP-1455, but effective use of alarms by building personnel require an effective user interface. We recommend including at least the following requirements in the specification for the EMCS graphical user interface:

- All alarms shall include a Time/Date Stamp using the standalone control module time and date.
- Each alarm can be configured in terms of criticality (Critical/Not Critical), operator acknowledgement (Requires Acknowledgement / Does Not Require Acknowledgement), and conditions required for an alarm to clear automatically (Requires Acknowledgement of a Return to Normal / Does Not Require Acknowledgement of a Return to Normal).
- An operator shall be able to sort alarms based on level, time/date, and current status.
- Alarms should be reported with the following information:
  - Date and time of the alarm
  - Level of the alarm
  - Description of the alarm
  - Equipment tags for the units in alarm
  - Possible causes of the alarm, if provided by the fault detection routines
  - The Source as defined in 1.3A.14.a.1) which serves the equipment in alarm

13. Alarms

a. There shall be 5 levels of alarm

1) Level 1: Critical/life safety
2) Level 2: Significant equipment failure
3) Level 3: Non-critical equipment failure/operation
4) Level 4: Energy conservation monitor
5) Level 5: Maintenance indication, notification

Hierarchical alarm suppression is described in a paper by Jeff Schein and Steve Bushby, published in HVAC&R Research January, 2006.

It is a technique for suppressing extraneous or nuisance alarms, based on the principle that if a fault occurs both at a source (e.g. AHU) and a load (e.g. VAV box), then the fault at the load is likely caused by the fault at the source and is at any rate of a lower priority than the source fault; as such, the alarm for the load fault is suppressed in favor of the alarm for the source fault, so that the operator’s attention is focused on the problem at the source. This principle can be extended up through the hierarchy: e.g. a fault at the chiller system would suppress faults at the AHUs that it serves, which would in turn suppress faults at the VAV boxes served by the suppressed AHUs.

Alarm suppression is based on the OK or fault state of upstream systems, rather than individual pieces of equipment. For example, in a plant with multiple redundant boilers, a single boiler failure would not necessarily impede the ability of the boiler plant to serve the load, so suppression of downstream alarms would not be appropriate in this case. It will necessarily be up to the designer to determine the appropriate threshold for setting a system fault based on the number of component faults (e.g. two out of three boilers must be off or in alarm before a system-level fault is set, triggering suppression of downstream alarms).

14. Hierarchical Alarm Suppression

a. For each piece of equipment or space controlled by the EMCS, define its relationship (if any) to other equipment in terms of “source”, “load”, or “system”.

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For equipment that participates in a Trim & Response loop, the equipment generating the requests will always be the load component, and the equipment receiving and responding to the requests will be a source component.

1) A component is a “source” if it provides resources to a downstream component, such as a chiller providing chilled water to an AHU.

2) A component is a “load” if it receives resources from an upstream component, such as an AHU that receives chilled water from a chiller.

3) The same component may be both a load (receiving resources from an upstream source) and a source (providing resources to a downstream load).

4) A set of components is a “system” if they share a load in common (i.e. collectively act as a source to downstream equipment, such as a set of chillers in a lead/lag relationship serving air handlers).

   a) If a single component acts as a source for downstream loads (e.g. an AHU as a source for its VAV boxes), then that single source component shall be defined as a “system” of one element.

   b) For equipment with associated pumps (chillers, boilers, cooling towers):
      
      (1) If the pumps are in a one-to-one relationship with equipment they serve, the pumps shall be treated as part of the system to which they are associated (i.e. they are not considered loads) since a pump failure will necessarily disable its associated equipment.
      
      (2) If the pumps are headered to the equipment they serve, then the pumps may be treated as a system, which is a load relative to the upstream equipment (e.g. chillers) and a source relative to downstream equipment (e.g. air handlers).

Example: Consider a building with four cooling tower cells, each with its own pump, two chillers with two CHW pumps in a headered arrangement, three air handlers, and 10 VAV boxes on each AHU, with each VAV box serving multiple rooms.

- The cooling towers together constitute a system, which is a source to the chillers.
- The chillers together constitute a system, which is a load to the cooling tower system and a source to the CHW pump system.
- The CHW pumps together constitute a system, which is a load to the chillers and a source to the air handlers.
- Each air handler constitutes its own separate system because they do not share a load in common. Each AHU is a load to the CHW pump system, and a source to its own VAV boxes.
- Each VAV box constitutes its own system because they do not share a load in common. Each VAV box is a load to its AHU (only: no relationship to the other AHUs), and a source to the rooms that it serves.
- Each interior space is a load to its associated VAV box.

b. For each system as defined above, there shall be a SystemOK flag, which is either true or false.

c. SystemOK shall be true when all of the following are true:

   1) The system is proven on.

   2) The system is achieving its temperature and/or pressure setpoint(s) for at least five minutes
3) The system is ready and able to serve its load

d. SystemOK shall be false while the system is starting up (i.e. before reaching setpoint) or when enough of the system’s components are unavailable (in alarm, disabled, or turned off) to disrupt the ability of the system to serve its load. This threshold shall be defined by the design engineer for each system.

1) By default, Level 1 through Level 3 component alarms (indicating equipment failure) shall inhibit SystemOK. Level 4 and Level 5 component alarms (maintenance and energy efficiency alarms) shall not affect SystemOK.

2) The operator shall have the ability to individually determine which component alarms may or may not inhibit SystemOK.

<table>
<thead>
<tr>
<th>Examples:</th>
</tr>
</thead>
<tbody>
<tr>
<td>If a boiler system consists of a pair of boilers sized for 100% of the design load, in a lead-standby relationship, then SystemOK is true if at least one boiler is operational and achieving setpoint.</td>
</tr>
<tr>
<td>If a chiller system consists of three chillers each sized for 50% of the design load, then SystemOK is true if at least two chillers are available to run. If only one chiller is available to run, then SystemOK will be false (even though the one remaining chiller may be sufficient to serve off-peak loads).</td>
</tr>
</tbody>
</table>

e. The EMCS shall selectively suppress (i.e. fail to report) alarms for load components if SystemOK is false for the source system which serves that load.

1) If SystemOK is false for a cooling water system (i.e. chiller, cooling tower, or associated pump) then only high temperature alarms from the loads shall be suppressed.

2) If SystemOK is false for a heating water system (i.e. boiler or associated pump) then only low temperature alarms from the loads shall be suppressed.

3) If SystemOK is false for an airside system (air handler, fan coil, VAV box, etc) then all alarms from the loads shall be suppressed.

f. This hierarchical suppression shall cascade through multiple levels of load-source relationship, such that alarms at downstream loads shall also be suppressed.
Example:
A building has a cooling tower system (towers and CDW pumps), a chiller system (chillers and CHW pumps), a boiler system (boilers and HHW pumps). These systems serve several air handlers (each considered its own system), and each air handler serves a series of VAV boxes.

If SystemOK is false for the cooling tower system, then high temperature alarms are suppressed for the chillers, the air handlers, the VAV boxes and zones, but not for the boilers. Low temperature alarms are not suppressed. (Note that in actuality, the hard-wired interlock between cooling tower and chiller would inhibit chiller operation if the cooling towers are off or locked out. The example is retained for illustrative purposes.)

If SystemOK is false for the chiller system, then high temperature alarms are suppressed for the air handlers and the VAV boxes, but not for the cooling towers or boilers. Low temperature alarms are not suppressed.

If SystemOK is false for the boiler system, then low temperature alarms are suppressed for the air handlers and the VAV boxes, but not for the cooling towers or chillers. High temperature alarms are not suppressed.

If SystemOK is false for one of the air handlers, then all alarms (low temperature, high temperature, and airflow) are suppressed for all VAV boxes served by that air handler only. Alarms are not suppressed for the cooling towers, chillers, boilers, or the other AHU or its VAV boxes.

If one VAV box is in alarm, then all alarms (e.g. zone temperature, CO\textsubscript{2}) are suppressed for all spaces served by that VAV box only. No other alarms are suppressed.

g. The following types of alarms will never be suppressed by this logic:

1) Life/safety and Level 1 alarms

2) Failure-to-start alarms (i.e. equipment is commanded on, but status point shows equipment to be off)

3) Failure-to-stop/hand alarms (i.e. equipment is commanded off, but status point shows equipment to be on)

B. Generic Thermal Zones

1. This section applies to all single zone systems and sub-zones of air handling systems, such as VAV boxes, fan-powered boxes, etc.

2. Minimum Outdoor Air

a. For every zone that requires mechanical ventilation, the zone minimum outdoor airflows and setpoints shall be calculated depending on the governing standard or code for outdoor air requirements. Zones that do not require mechanical ventilation may disregard this section.

b. For compliance with California Title 24, outdoor air setpoints shall be calculated as follows:

The following section describes ventilation logic which complies with California Title 24. If the project is to comply with Standard 62 ventilation requirements, delete subsection “b” and skip to subsection “c”.

b. For compliance with California Title 24, outdoor air setpoints shall be calculated as follows:
1) The following information shall be as scheduled on the plans or provided by the engineer of record for each ventilation zone:

a) Vocc-min: Zone minimum outdoor airflow for occupants, per Title 24 prescribed CFM-per-occupant requirements.

b) Varea-min: Zone minimum outdoor airflow for building area, per Title 24 prescribed CFM-per-ft² requirements.

Note that Vocc-min and Varea-min for Title 24 ventilation should not be confused with the area component and occupant component of minimum outdoor air as defined in Standard 62.1. For Title 24 compliance, Vocc-min and Varea-min should not be summed to establish the zone outdoor airflow.

2) For each zone, calculate the zone minimum outdoor air setpoints, which are used at the AHU level for minimum outdoor air control

a) Zone-Abs-OA-min is equal to
   (1) Varea-min if the zone has a CO₂ sensor.
   (2) Varea-min if the zone has an occupancy sensor and is unpopulated
   (3) Zero if the zone has a window switch and the window is open
   (4) Zone-Des-OA-min otherwise.

b) Zone-Des-OA-min is equal to the larger of Varea-min and Vocc-min.

3) Vocc-min, Varea-min, Zone-Abs-OA-min, and Zone-Des-OA-min shall be a fixed value for each zone.

The following section describes ventilation logic which complies with ASHRAE Standard 62. If the project is to comply with California Title 24 ventilation requirements, delete subsection “c” and use subsection “b”, above.

c. For compliance with the Ventilation Rate Procedure of ASHRAE Standard 62.1, outdoor air setpoints shall be calculated as follows:

   1) The following information shall be as scheduled on the plans or provided by the engineer of record for each ventilation zone:

   a) The area component of the breathing zone outdoor airflow V_{bz,A}
      (1) This is the zone floor area times the outdoor airflow rate per unit area, as given in Table 6-1 of Standards 62.1
      (2) i.e. V_{bz,A} = A_z * R_a

   b) The population component of the breathing zone outdoor airflow V_{bz,P}
      (1) This is the zone design population (without diversity) times the outdoor airflow rate per occupant, as given in Table 6-1 of Standards 62.1
      (2) i.e. V_{bz,P} = P_z * R_p

   c) Zone air distribution effectiveness E_{dH} in Heating
d) Zone air distribution effectiveness $E_{zc}$ in Cooling

Strictly speaking, Standard 62.1 requires only a single occupant diversity ratio $D$ for the entire system. If individual zone diversities are provided on plans, they may be used (see AHU sequences). Otherwise, a single system-wide diversity ratio should be used in calculations.

e) Occupant diversity ratio $D_i$ for each zone that is part of a multi-zone ventilation system. (Zones served by a dedicated single-zone unit do not require this value.)

2) For each zone, the breathing zone outdoor airflow shall be the sum of the area and the population components; i.e. $V_{bz} = V_{bz-A} + V_{bz-P}$

3) For each zone in Occupied Mode, the required zone outdoor airflow $V_{oz}$ shall be calculated as follows:

a) If the zone is populated, or if there is no occupancy sensor:
   (1) If discharge air temperature at the terminal unit is less than zone space temperature: $V_{oz} = V_{bz} / E_{zC}$
   (2) If discharge air temperature at the terminal unit is greater than zone space temperature: $V_{oz} = V_{bz} / E_{zH}$

b) If the zone has an occupancy sensor and is unpopulated:
   (1) If discharge air temperature at the terminal unit is less than zone space temperature: $V_{oz} = V_{bz-A} / E_{zC}$
   (2) If discharge air temperature at the terminal unit is greater than zone space temperature: $V_{oz} = V_{bz-A} / E_{zH}$

4) For each zone in Occupied Mode that is part of a multi-zone ventilation system, the zone primary outdoor air fraction $Z_{pz}$ shall be recalculated every 5 minutes as follows. (Zones served by a dedicated single-zone unit may disregard this calculation.):

a) $Z_{pz} = V_{oz} / V_{pz}$

b) Where $V_{pz}$ is the average zone primary airflow since the last recalculation of $Z_{pz}$, as measured by the zone airflow sensor

c) If a zone has an occupancy sensor and is unpopulated, set $Z_{pz}$ to zero.

$Z_{pz}$ is overridden to zero for an unpopulated zone in order to avoid the situation where an unpopulated zone (which has a low ventilation minimum, for area only) becomes the critical zone and drives up the outside air requirements for the entire system. Setting $Z_{pz}$ to zero effectively drops that zone out of the system level outdoor air calculation. The “right” way to avoid this issue is to dynamically reset the zone and system outdoor air setpoints by continuously recalculating the multiple spaces equation. If that function is added in the future, this clause should be removed.

d) This calculation is not required for zones that receive all their outdoor air from a single-zone air handler.
3. Setpoints

a. Each zone shall have separate occupied and unoccupied heating and cooling setpoints.

b. The active setpoints shall be determined by the operating Mode of the Zone Group [see 1.3C.7].
   1) The setpoints shall be the occupied setpoint during Occupied Mode, Warm-up Mode, and Cool-down Mode.
   2) The setpoints shall be unoccupied setpoints during Unoccupied Mode, Setback Mode, and Setup Mode.

c. Default set points shall be based on zone type:

<table>
<thead>
<tr>
<th>Zone Type</th>
<th>Occupied Heating</th>
<th>Occupied Cooling</th>
<th>Unoccupied Heating</th>
<th>Unoccupied Cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAV - Perimeter</td>
<td>70°F</td>
<td>74°F</td>
<td>60°F</td>
<td>90°F</td>
</tr>
<tr>
<td>VAV - Interior</td>
<td>70°F (or N/A)</td>
<td>73°F</td>
<td>60°F (or N/A)</td>
<td>90°F</td>
</tr>
<tr>
<td>Mech/Elec Rooms</td>
<td>65°F</td>
<td>85°F</td>
<td>65°F</td>
<td>85°F</td>
</tr>
<tr>
<td>Networking/Computer</td>
<td>65°F</td>
<td>75°F</td>
<td>65°F</td>
<td>75°F</td>
</tr>
</tbody>
</table>

d. The software shall prevent
   1) The heating setpoint from exceeding the cooling setpoint minus 1°F (i.e. the minimum difference between heating and cooling setpoints shall be 1°F)  
   2) The unoccupied heating setpoint from exceeding the occupied heating setpoint; and  
   3) The unoccupied cooling setpoint from being less than the occupied cooling setpoint.

e. Where the zone has a local setpoint adjustment knob/button
   1) The adjustment shall be capable of being limited in software.
      a) As a default, the active occupied cooling setpoint shall be limited between 72°F and 80°F.
      b) As a default, the active occupied heating setpoint shall be limited between 65°F and 72°F.
   2) The active heating and cooling setpoints shall be independently adjustable, respecting the limits and anti-overlap logic described above.
      If zone thermostat provides only a single setpoint adjustment, then the adjustment shall move both the active heating and cooling setpoint upwards or downwards by the same amount, within the limits described above.
   3) The adjustment shall only be effective in Occupied Mode, and shall be zero in all other modes.
   4) At the onset of demand limiting, the local setpoint adjustment value shall be frozen. Further adjustment of the setpoint by local controls shall be suspended for the duration of the demand limit event.

This are absolute limits imposed by programming, which are in addition to the range limits (e.g. ±4°F) of the thermostat adjustment device.
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5) If the window switch indicates the window is open, the local setpoint adjustment shall be set to zero. The local setpoint adjustment shall resume its previous value when the window switch indicates the window is closed.

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Demand limits can be triggered for different reasons including: utility shed events; exceeding of a predefined threshold; or to prevent excessive rates in a ratchet schedule. Additional logic (not provided here) is needed to define the Demand Limit Levels. 

For example:

- **Sliding Window**: The demand control function shall utilize a sliding window method selectable in increments of one minute, up to 60 minutes, 15 minute default.
- **Demand Levels**: Demand time periods shall be set up as per utility rate schedule. For each On-Peak or Partial-Peak period, three demand level limits can be defined. When the measured demand exceeds the limit, the Demand Limit Level switch for that level shall be set; when demand is less than 10% below the limit, the switch shall be reset. These levels are used at the zone level (see Zone Control sequences) to shed demand.

An override for critical zones like data centers or equipment rooms should be provided through the GUI. This override feature should require some level of supervision so that all zones don’t declare themselves “critical.”

---

f. Cooling Demand Limit Setpoint Adjustment: The active cooling setpoints for all zones shall be increased when a demand limit is imposed on the associated Zone Group. The operator shall have the ability to exempt individual zones from this adjustment through the normal EMCS user interface. Changes due to demand limits are not cumulative.

1) At Demand Limit Level 1, increase setpoint by 1°F.
2) At Demand Limit Level 2, increase setpoint by 2°F.
3) At Demand Limit Level 3, increase setpoint by 4°F.

---

Heating Demand Limits may be desirable in buildings with electric heat or heat pumps, or in regions with limited gas distribution infrastructure.

g. Heating Demand Limit Setpoint Adjustment: The active heating setpoints for all zones shall be decreased when a demand limit is imposed on the associated Zone Group. The operator shall have the ability to exempt individual zones from this adjustment through the normal EMCS user interface. Changes due to demand limits are not cumulative.

1) At Demand Limit Level 1, decrease setpoint by 1°F.
2) At Demand Limit Level 2, decrease setpoint by 2°F.
3) At Demand Limit Level 3, decrease setpoint by 4°F.

---

h. Window switches. For zones that have operable windows with indicator switches, when the window switch indicates the window is open, the heating setpoint shall be temporarily set to 40°F and the cooling setpoint shall be temporarily set to 120°F.

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i. Occupancy sensors. For zones that have an occupancy switch

1) When the switch indicates the space has been unpopulated for one minute continuously during the Occupied Mode, the active heating setpoint shall be decreased by 2°F and the cooling setpoint shall be increased by 2°F.
2) When the switch indicates that the space has been populated for one minute continuously, the active heating and cooling setpoints shall be restored to their previous values.

j. Hierarchy of Setpoint Adjustments: The following adjustment restrictions shall prevail in order from highest to lowest priority:

1) Setpoint overlap restriction (Section 1.3B.3.d.1)

2) Absolute limits on local setpoint adjustment (Section 1.3B.3.e.1)

3) Window switches

4) Demand limit

   a) Occupancy sensors: Change of setpoint by occupancy sensor is added to change of setpoint by any demand limits in effect.

   b) Local setpoint adjustment: Any changes to setpoint by local adjustment are frozen at the onset of the demand limiting event and remain fixed for the duration of the event. Additional local adjustments are ignored for the duration of the demand limiting event.

5) Scheduled setpoints based on Zone Group mode

The following will cause all zones in the Zone Group to operate in Occupied Mode to ensure that the system has adequate load to operate stably.

4. Local override: When thermostat override buttons are depressed, the call for Occupied Mode operation shall be sent up to the Zone Group control for 60 minutes.

5. Control Loops

   a. Two separate control loops shall operate to maintain space temperature at setpoint, the Cooling Loop and the Heating Loop.

      1) The Heating Loop shall be enabled whenever the space temperature is below the current zone temperature heating setpoint, and disabled otherwise.

      2) The Cooling Loop shall be enabled whenever the space temperature is above the current zone temperature cooling setpoint, and disabled otherwise.

   b. The Cooling Loop shall maintain the space temperature at the active cooling setpoint. The output of the loop shall be a virtual point ranging from 0% (no cooling) to 100% (full cooling).

   c. The Heating Loop shall maintain the space temperature at the active heating setpoint. The output of the loop shall be a virtual point ranging from 0% (no heating) to 100% (full heating).

   d. Loops shall be use proportional + integral logic or fuzzy logic. Proportional-only control is not acceptable, although the integral gain shall be small relative to the proportional gain. P and I gains shall be adjustable by the operator.

   e. See other sections for how the outputs from these loops are used.
6. Zone State
   a. Heating: when the output of the space heating control loop is nonzero and the output of the cooling loop is equal to zero.
   b. Cooling: when the output of the space cooling control loop is nonzero and the output of the heating loop is equal to zero.
   c. Deadband: when not in either Heating or Cooling.

7. Zone Alarms
   a. Zone temperature alarms

   Default time delay for zone temperature alarm (10 minutes) is intentionally long, to minimize nuisance alarms. For critical zones such as IT closets, consider reducing time delay or setting delay to zero.

   1) If the zone is 3°F above cooling or below heating setpoint for 10 minutes, generate Level 3 alarm.

   2) If the zone is 5°F above cooling or below heating setpoint for 10 minutes, generate Level 2 alarm.

   3) Suppress zone temperature alarms as follows:
      a) After zone setpoint is changed for a period of 10 minutes per degree of difference between the zone temperature at the time of the change and the new setpoint. This suppression period applies any time that the zone setpoint is changed.
         For example if setpoint changes from 68°F to 70°F and the zone temperature is 68.5°F at the time of the change, inhibit alarm for 1.5°F*10 minutes/°F = 15 minutes after the change.
         Note that this includes automatic changes in setpoint e.g. due to a window switch or occupancy status.
      b) While Zone Group is in Warm-up or Cool-down Modes.
         Zone alarms are not suppressed in Setup, Setback, or Unoccupied Modes so that you detect heating or cooling equipment or control failures which could result in excessive pull down or pick up loads and even freezing of pipes if left undetected.
      c) For zones with an Importance multiplier [see 1.3A.11.b.1a)] of zero for its static pressure reset, SAT reset, or HWST reset Trim & Response loops.

   b. For zones with CO₂ sensors:
      1) CO₂ sensors: If the CO₂ concentration is less than 300 ppm, or the zone is in Unoccupied Mode for more than 2 hours and zone CO₂ concentration exceeds 600 ppm, generate a Level 3 alarm. The alarm text shall identify the sensor and indicate that it may be out of calibration.
      2) If the CO₂ concentration exceeds setpoint plus 10% for more than 10 minutes generate a Level 3 alarm.
C. Zone Groups

1. Each system shall be broken into separate Zone Groups composed of a collection of one or more zones served by a single air handler.

2. Zones shall be assigned to Zone Groups as follows:
   a. Each zone served by a fan-coil or single-zone air handler shall be its own Zone Group.
   b. For air handlers serving multiple zones, zones shall be assigned to Zone Groups as specified by the designer, or as follows:
      1) All computer rooms, networking closets, mechanical and electrical rooms served by the air handler shall be a single Zone Group.
      2) A Zone Group shall not span floors.
      3) A Zone Group shall not exceed 25,000 square feet.
      4) If future occupancy patterns are known, a single Zone Group shall not include spaces belonging to more than one tenant.
   c. Assignment of zones to Zone Groups can be changed at the operator’s workstation.

3. Each Zone Group shall have separate occupancy schedules and operating modes from other Zone Groups.
   Note that, from the user’s point of view, schedules can be set for individual zones, or they can be set for an entire Zone Group, depending on how the user interface is implemented. From the point of view of the EMCS, individual zone schedules are superimposed to create a Zone Group schedule, which then drives system behavior.

4. All zones in each Zone Group shall be in the same operating mode at all times. If one zone in a Zone Group is placed in any mode other than Unoccupied Mode (due to override, sequence logic, or scheduled occupancy) all zones in that Zone Group shall enter that mode.

5. A Zone Group may be in only one mode at any given time.

   The Testing and Commissioning Overrides will be specified for each type of terminal unit and system in subsequent sequences. These overrides allow a commissioning agent to e.g. force a zone into cooling, or drive a valve all the way open or closed.

   Zone Group override switches allow a commissioning agent to apply a zone-level override to all zones in a Zone Group simultaneously. This greatly accelerates the testing and commissioning process.

6. For each Zone Group, provide a set of testing/commissioning software switches that override all zones served by the Zone Group. Provide a separate software switch for each of the zone-level override switches listed under “Testing and Commissioning Overrides” in terminal unit sequences. When the value of a Zone Group’s override switch is changed, the corresponding override switch for every zone in the
Zone Group shall change to the same value. Subsequently, the zone-level override switch at may be changed to a different value. The value of the zone-level switch has no effect on the value of the Zone Group switch, and the value of the Zone Group switch only affects the zone-level switches when the Zone Group switch is changed.

The modes presented in the following section are to enable different setpoints and ventilation requirements to be applied to Zone Groups based on their operating schedule, occupancy status, and deviation from current setpoint.

7. Zone Group Operating Modes: Each Zone Group shall have the following modes:

   a. Occupied Mode: A Zone Group is in the Occupied Mode when any of the following is true:

      1) The time of day is between the Zone Group’s scheduled occupied start and stop times.

      2) The schedules have been overridden by the Occupant Override System.

      Occipant Override System is a web-based system to allow individuals to modify the schedule of their zone. This is a best-in-class feature that will not be available on all projects.

      3) Any zone local override timer (initiated by local override button) is nonzero.

   b. Warm-Up Mode: For each zone, the EMCS shall calculate the required warm-up time based on the zone’s occupied heating setpoint, the current zone temperature, the outdoor air temperature, and a mass/capacity factor for each zone. Zones where the window switch indicates that a window is open shall be ignored. The mass factor shall be manually adjusted or self-tuned by the EMCS. If automatic, the tuning process shall be turned on or off by a software switch, to allow tuning to be stopped after the system has been trained. Warm-up Mode shall start based on the zone with the longest calculated warm-up time requirement, but no earlier than 3 hours before the start of the scheduled occupied period, and shall end at the scheduled Occupied start hour.

   c. Cool-Down Mode: For each zone, the EMCS shall calculate the required cool-down time based on the zone’s occupied cooling setpoint, the current zone temperature, the outdoor air temperature, and a mass/capacity factor for each zone. Zones where the window switch indicates that a window is open shall be ignored. The mass factor shall be manually adjusted or self-tuned by the EMCS. If automatic, the tuning process shall be turned on or off by a software switch, to allow tuning to be stopped after the system has been trained. Cool-down Mode shall start based on the zone with the longest calculated cool-down time requirement, but no earlier than 3 hours before the start of the scheduled occupied period, and shall end at the scheduled Occupied start hour.
Setback and Setup Modes are used to keep zone temperatures (and mass) from getting excessively far from occupied setpoints so that the Cool-Down and Warm-Up Modes can achieve setpoint when initiated. The minimum number of zones (set at 5 here) are to ensure that the central systems (fans, pumps, heating sources or cooling sources) can operate stably. Obviously the size of the zones and the characteristics of the central systems are a factor in choosing the correct number of zones in each group.

d. Setback Mode: During Unoccupied Mode, if any 5 zones (or all zones, if fewer than 5) in the Zone Group fall below their unoccupied heating setpoints, the Zone Group shall enter Setback Mode until all spaces in the Zone Group are 2\(^\circ\)F above their unoccupied setpoints.

e. Freeze Protection Setback Mode: During Unoccupied Mode, if any single zone falls below 38\(^\circ\)F, the Zone Group shall enter Setback Mode until all zones are above 42\(^\circ\)F, and a Level 3 alarm shall be set.

f. Setup Mode: During Unoccupied Mode, if any 5 zones (or all zones, if fewer than 5) in the Zone Group rise above their unoccupied cooling setpoints, the Zone Group shall enter Setup Mode until all spaces in the Zone Group are 2\(^\circ\)F below their unoccupied setpoints. Zones where the window switch indicates that a window is open shall be ignored.

g. Unoccupied Mode: When the Zone Group is not in any other mode.

If the minimum ventilation rate is more than 25% or so of the cooling maximum, or demand control ventilation is used, a reheat box is recommended to avoid overcooling. Demand control ventilation logic is not provided for cooling-only boxes.

D. VAV Cooling-Only Terminal Unit

1. See Generic Thermal Zones for setpoints, loops, control modes, alarms, etc.

2. Design airflow rates shall be as scheduled on plans:
   a. Zone maximum cooling airflow setpoint (Vcool-max)
   b. Zone minimum airflow setpoint (Vmin)

3. See 1.3B.2 for calculation of zone minimum outdoor airflow.

4. The occupied minimum airflow Vmin* shall be equal to Vmin except as follows:
   a. If the zone has an occupancy sensor, Vmin* shall be equal to Varea-min (if ventilation is according to California Title 24) or Voz (if ventilation is according to ASHRAE Standard 62.1) when the room is unpopulated.
   b. If the zone has a window switch, Vmin* shall be zero when the window is open.
   c. If Vmin is non-zero and less than the lowest possible airflow setpoint allowed by the controls (Vm), Vmin* shall be set equal to Vm. The minimum setpoint Vm shall be determined as follows:
      1) Determine the velocity pressure sensor reading \(V_P_m\) in inches H\(_2\)O that will give a reliable flow indication. If this information is not provided by the sensor manufacturer, determine the velocity pressure that will result in a digital reading from the transducer and A/D
2) Determine the minimum velocity $v_m$ for each VAV box size and model. If the VAV box manufacturer provides an amplification factor $F$ for the flow pickup, calculate the minimum velocity $v_m$ as

$$v_m = 4005 \frac{VP_m}{F}$$

Where $F$ is not known it can be calculated from the measured CFM at 1 inch signal from the VP sensor

$$F = \left( \frac{4005A}{CFM_{1''}} \right)^2$$

where $A$ is the nominal duct area ($\text{ft}^2$), equal to

$$A = \pi \left( \frac{D}{24} \right)^2$$

where $D$ is the nominal duct diameter (inches).

3) Calculate the minimum airflow setpoint allowed by the controls ($V_m$) for each VAV box size as

$$V_m = v_m A$$

5. Active maximum and minimum setpoints shall vary depending on the Mode of the Zone Group the zone is a part of:

<table>
<thead>
<tr>
<th>Setpoint</th>
<th>Occupied</th>
<th>Cool-down</th>
<th>Setup</th>
<th>Warm-up</th>
<th>Setback</th>
<th>Unoccupied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling maximum</td>
<td>V$_{cool-max}$</td>
<td>V$_{cool-max}$</td>
<td>V$_{cool-max}$</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minimum</td>
<td>V$_{min^*}$</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Heating maximum</td>
<td>V$_{min^*}$</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
6. Control logic is depicted schematically in the figure below and described in the following sections. Relative levels of various setpoints are depicted for Occupied Mode operation.

a. When the zone is in Cooling, the Cooling Loop output shall be mapped to the active airflow setpoint from the minimum to the cooling maximum airflow setpoints.

1) If supply air temperature from air handler is greater than room temperature, Cooling shall be locked out.

b. When the zone is in Deadband or Heating, the active airflow setpoint shall be the minimum airflow setpoint.

7. The VAV damper shall be modulated by a control loop to maintain the measured airflow at the active setpoint.

8. The following sequence applies to rooms with both VAV boxes and fan-coils where the VAV system was not designed to handle the IDF room loads – to save costs. VAV acts as primary while fan-coil acts as backup. The Importance multiplier is set to zero to prevent this zone from becoming a rogue zone and driving the resets.

a. If the static pressure setpoint of the system serving the VAV box is at the maximum of the reset range, limit the airflow to 15% of the zone maximum until the setpoint is 0.15” below the maximum setpoint.

b. This zone shall have an Importance Multiplier of 0 so that it does not generate any System Requests.
9. Alarms

a. Low airflow

1) If the measured airflow is less than 70% of setpoint for 5 minutes, generate a Level 3 alarm.

2) If the measured airflow is less than 50% of setpoint for 5 minutes, generate a Level 2 alarm.

3) If a zone has an Importance multiplier of 0 [see 1.3A.11.b.1)a)] for its static pressure reset Trim & Respond control loop, low airflow alarms shall be suppressed for that zone.

b. Airflow sensor calibration. If the fan serving the zone has been off for 10 minutes and airflow sensor reading is above 20 CFM, generate a Level 3 alarm.

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Per 1.3A.9, all hardware points can be overridden through the EMCS. Each of the following points is interlocked so that they can be overridden together at a Zone Group level, per 1.3C.6. E.g. The CxA can check for leaking dampers by forcing all VAV boxes in a Zone Group closed and then recording airflow at the AHU.

10. Testing/Commissioning Overrides: Provide software points that interlock to a system level point to

a. Force zone airflow setpoint to zero

b. Force zone airflow setpoint to Vcool-max.

c. Force zone airflow setpoint to Vmin

d. Force damper full closed/open

e. Reset request-hours accumulator point to zero (provide one point for each reset type listed below)

11. System Requests

a. Cooling SAT Reset Requests

1) If the Cooling Loop is less than 85%, send 0 Requests.

2) If the Cooling Loop is greater than 95%, send 1 Request.

3) If the zone temperature exceeds the zone’s cooling setpoint by 3°F for 2 minutes, send 2 Requests.

4) If the zone temperature exceeds the zone’s cooling setpoint by 5°F for 2 minutes, send 3 Requests.

b. Static Pressure Reset Requests

1) If the Damper Loop is less than 85%, send 0 Requests.

2) If the Damper Loop is greater than 95%, send 1 Request.

3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.

4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.
If the minimum ventilation rate is more than 25% or so of the cooling maximum, or demand controlled ventilation is used, a reheat box is recommended to avoid overcooling.

E. VAV Reheat Terminal Unit

1. See Generic Thermal Zones for setpoints, loops, control modes, alarms, etc.

2. Design airflow rates shall be as scheduled on plans:
   a. Zone maximum cooling airflow setpoint (Vcool-max)
   b. Zone minimum airflow setpoint (Vmin)
   c. Zone maximum heating airflow setpoint (Vheat-max)

3. See 1.3B.2 for calculation of zone minimum outdoor airflow.

4. The occupied minimum airflow Vmin* shall be equal to Vmin except as follows:
   a. If the zone has an occupancy sensor, Vmin* shall be equal to Varea-min (if ventilation is according to California Title 24) or $V_{oz}$ (if ventilation is according to ASHRAE Standard 62.1) when the room is unpopulated.
   b. If the zone has a window switch, Vmin* shall be zero when the window is open.
   c. If Vmin is non-zero and less than the lowest possible airflow setpoint allowed by the controls (Vm), Vmin* shall be set equal to Vm. The minimum setpoint Vm shall be determined in accordance with 1.3D.4.c above.
d. If the zone has a CO$_2$ sensor

1) During Occupied Mode, a P-only loop shall maintain CO$_2$ concentration at 1000 PPM; reset 0% at 800 PPM and 100% at 1,000 PPM of CO$_2$. The loop output from 0 to 50% shall reset the occupied minimum airflow setpoint (Vmin*) from the zone minimum airflow setpoint Vmin up to maximum cooling airflow setpoint Vcool-max, as shown below.

2) If ventilation outdoor airflow is controlled in accordance with California Title 24, the loop output from 50% to 100% will be used at the system level to reset outdoor air minimum; see AHU controls.

3) If ventilation outdoor airflow is controlled in accordance with ASHRAE Standard 62.1, the loop output from 50% to 100% shall be ignored.

4) Loop is disabled and output set to zero when the zone is not in Occupied Mode.

These sequences use different maximum airflow setpoints for heating and cooling. This “dual max” logic allows the minimum airflow setpoint to be lower than in a conventional sequence where the minimum airflow equals the heating airflow.

Heating is non-zero in Cool-down to allow for individual zones within a Zone Group which may need heating while the Zone Group is in Cool-down.

5. Active maximum and minimum setpoints shall vary depending on the Mode of the Zone Group the zone is a part of:

<table>
<thead>
<tr>
<th>Setpoint</th>
<th>Occupied</th>
<th>Cool-down</th>
<th>Setup</th>
<th>Warm-up</th>
<th>Setback</th>
<th>Unoccupied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling maximum</td>
<td>Vcool-max</td>
<td>Vcool-max</td>
<td>Vcool-max</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minimum</td>
<td>Vmin*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Heating maximum</td>
<td>Max(Vheat-max, Vmin*)</td>
<td>Vheat-max</td>
<td>0</td>
<td>Vcool-max</td>
<td>Vcool-max</td>
<td>0</td>
</tr>
</tbody>
</table>
6. Control logic is depicted schematically in the figure below and described in the following sections. Relative levels of various setpoints are depicted for Occupied Mode operation.

![Diagram of control logic](image)

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- a. When the zone is in Cooling, the Cooling Loop output shall be mapped to the airflow setpoint from the minimum to the cooling maximum airflow setpoints. Hot water valve is closed unless the supply air temperature is below the minimum setpoint [see 1.3E.6.e below].
  
  1) If supply air temperature from air handler is greater than room temperature, Cooling shall be locked out.

- b. When the zone is in Deadband, the active airflow setpoint shall be the minimum airflow setpoint. Hot water valve is closed unless the supply air temperature is below the minimum setpoint [see 1.3E.6.e below].

- c. When the zone is in Heating, the Heating Loop shall maintain space temperature at the heating setpoint as follows:

  "The purpose of the following heating sequence is to minimize the reheat energy consumption by first increasing the SAT while maintaining minimum flow, and only increasing the total airflow if needed to satisfy the zone. The design engineer should set Vheat-max such that the design heating load is met by Vheat-max CFM at 90°F."

  1) From 0-50%, the Heating Loop output shall reset the discharge temperature from the current AHU SAT setpoint to the lesser of 90°F or 20°F above space temperature.

  2) From 51%-100%, if heating is available (i.e. lead hot water pump, or electric heating coil, is enabled) the Heating Loop output shall reset the active airflow setpoint from the minimum airflow setpoint to the maximum heating airflow setpoint.
d. The hot water valve (or modulating electric heating coil) shall be modulated to maintain the discharge temperature at setpoint. (Directly controlling heating off the zone temperature control loop is not acceptable.)

This prevents excessively cold supply air temperatures if the AHU is providing high outdoor airflows and does not have a heating coil.

e. In any Mode except Unoccupied, the hot water valve (or modulating electric heating coil) shall be modulated to maintain a supply air temperature no lower than 50°F.

f. The VAV damper shall be modulated by a control loop to maintain the measured airflow at the active setpoint.

7. Alarms

a. Low airflow

1) If the measured airflow is less than 70% of setpoint for 5 minutes, generate a Level 3 alarm.

2) If the measured airflow is less than 50% of setpoint for 5 minutes, generate a Level 2 alarm.

3) If a zone has an Importance multiplier of 0 [see 1.3A.11.b.1a)] for its static pressure reset Trim & Respond control loop, low airflow alarms shall be suppressed for that zone.

b. Low supply air temperature

1) If boiler plant is proven on and the supply air temperature is 15°F less than setpoint for 10 minutes, generate a Level 3 alarm.

2) If boiler plant is proven on and the supply air temperature is 30°F less than setpoint for 10 minutes, generate a Level 2 alarm.

3) If a zone has an Importance multiplier of 0 [see 1.3A.11.b.1a)] for its HWST reset Trim & Respond control loop, low supply air temperature alarms shall be suppressed for that zone.

c. Airflow sensor calibration. If the fan serving the zone has been off for 10 minutes and airflow sensor reading is above 20 CFM, generate a Level 3 alarm.

Per 1.3A.9, all hardware points can be overridden through the EMCS. Each of the following points is interlocked so that they can be overridden together at a Zone Group level, per 1.3C.6.

E.g. The CxA can check for leaking dampers by forcing all VAV boxes in a Zone Group closed and then recording airflow at the AHU.

8. Testing/Commissioning Overrides: Provide software points that interlock to a system level point to

a. Force zone airflow setpoint to zero

b. Force zone airflow setpoint to Vcool-max

c. Force zone airflow setpoint to Vmin

d. Force zone airflow setpoint to Vheat-max

e. Force damper full closed/open
f. Force heating to off/closed

g. Reset request-hours accumulator point to zero (provide one point for each reset type listed below)

9. System Requests

a. Cooling SAT Reset Requests

1) If the Cooling Loop is less than 85%, send 0 Requests.

2) If the Cooling Loop is greater than 95%, send 1 Request.

3) If the zone temperature exceeds the zone’s cooling setpoint by 3°F for 2 minutes, send 2 Requests.

4) If the zone temperature exceeds the zone’s cooling setpoint by 5°F for 2 minutes, send 3 Requests.

b. Static Pressure Reset Requests

1) If the Damper Loop is less than 85%, send 0 Requests.

2) If the Damper Loop is greater than 95%, send 1 Request.

3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.

4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

c. If there is a hot water coil, heating HWST Reset Requests

1) If the HW valve is less than 85%, send 0 Requests.

2) If the HW valve is greater than 95%, send 1 Request.

3) If the supply air temperature is 15°F less than setpoint for 5 minutes, send 2 Requests.

4) If the supply air temperature is 30°F less than setpoint for 5 minutes, send 3 Requests.

d. If there is a hot water coil and a boiler plant, boiler Plant Requests. Send the boiler plant that serves the zone a Boiler Plant Request as follows:

1) If the HW valve is less than 10%, send 0 Requests.

2) If the HW valve is greater than 95%, send 1 Request.

F. Parallel Fan-Powered Terminal Unit, Constant Volume Fan

1. See Generic Thermal Zones for setpoints, loops, control modes, alarms, etc.

2. Design airflow rates shall be as scheduled on plans:

   a. Zone maximum cooling (primary) airflow setpoint (Vcool-max)
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b. Zone minimum primary airflow setpoint (Vmin)

If ventilation is controlled in accordance with California Title 24, Vmin may be less than OA-min, or even zero, if there is enough plenum air available for transfer from adjacent zones to provide minimum ventilation. If, on the other hand, each zone’s plenum is isolated (e.g. for acoustic reasons) or there are relatively few zones from which to draw plenum air, then Vmin must exceed OA-min.

3. See 1.3B.2 for calculation of zone minimum outdoor airflow.

4. The occupied primary airflow minimum Vmin* shall be equal to Vmin except as follows:

a. If the zone has an occupancy sensor, Vmin* shall be equal to Varea-min (if ventilation is according to California Title 24) or Vazz (if ventilation is according to ASHRAE Standard 62.1) when the room is unpopulated.

Zone minimum outside air Vazz is divided by system ventilation efficiency Ev to avoid a situation where the unpopulated zone drives the system outdoor air fraction to 100%. The “right” way to avoid this issue is to dynamically reset the system outdoor air setpoint by continuously recalculating the multiple spaces equation. If that function is added in the future, the Ev factor should be removed from this calculation.

b. If the zone has a window switch, Vmin* shall be zero when the window is open.

c. If Vmin is non-zero and less than the lowest possible airflow setpoint allowed by the controls (Vm), Vmin* shall be set equal to Vm. The minimum setpoint Vm shall be determined in accordance with 1.3D.4.c.

d. If the zone has a CO2 sensor

1) During Occupied Mode, a P-only loop shall maintain CO2 concentration at 1000 PPM; reset 0% at 800 PPM and 100% at 1,000 PPM of CO2. The loop output from 0 to 50% shall reset the occupied minimum airflow setpoint (Vmin*) from the zone minimum airflow setpoint Vmin up to maximum DCV airflow setpoint VCO2-max, as shown below.

a) When the zone is in Cooling, VCO2-max is equal to the maximum cooling airflow setpoint Vcool-max.

The following logic prevents the total supply airflow from exceeding Vcool-max, which could create diffuser noise problems.

b) When the zone is in Heating or Deadband, VCO2-max is equal to Vcool-max minus the parallel fan airflow.
2) If ventilation outdoor airflow is controlled in accordance with California Title 24, the loop output from 50% to 100% will be used at the system level to reset outdoor air minimum; see AHU controls.

3) If ventilation outdoor airflow is controlled in accordance with ASHRAE Standard 62.1, the loop output from 50% to 100% shall be ignored.

4) Loop is disabled and output set to zero when the zone is not in Occupied Mode.

5. Active maximum and minimum primary air setpoints shall vary depending on the Mode of the Zone Group the zone is a part of:

<table>
<thead>
<tr>
<th>Setpoint</th>
<th>Occupied</th>
<th>Cool-down</th>
<th>Setup</th>
<th>Warm-up</th>
<th>Setback</th>
<th>Unoccupied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling maximum</td>
<td>Vcool-max</td>
<td>Vcool-max</td>
<td>Vcool-max</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minimum</td>
<td>Vmin*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
6. Control logic is depicted schematically in the figure below and described in the following sections.

If OA-min > Vmin (assuming California Title 24 ventilation rules):

- When the zone is in Cooling, the Cooling Loop output shall be mapped to the primary airflow setpoint from the cooling maximum to the minimum airflow setpoints. Heating coil is off.

If OA-min < Vmin, or if Standard 62.1 ventilation rules are used:

- When the zone is in Cooling, the Cooling Loop output shall be mapped to the primary airflow setpoint from the cooling maximum to the minimum airflow setpoints. Heating coil is off.
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1) If supply air temperature from air handler is greater than room temperature, Cooling shall be locked out.

b. When the zone is in Deadband, the primary airflow setpoint shall be the minimum airflow setpoint. Heating coil is off.

c. When zone is in Heating

1) As the Heating Loop output increases from 0 to 100%, it shall reset the discharge temperature from the current AHU SAT setpoint to 90°F.

2) The hot water valve (or modulating electric heating coil) shall be modulated to maintain the discharge temperature at setpoint. (Directly controlling heat off zone temperature control loop is not acceptable.)

d. The VAV damper shall be modulated to maintain the measured primary airflow at setpoint.

e. Fan Control:

1) Fan shall run whenever zone is in Heating.

2) If ventilation is according to California Title 24, fan shall run in Deadband and Cooling when the primary supply air volume is less than OA-min for one minute, and shall shut off when primary air volume is above OA-min by 10% for 3 minutes.

3) If ventilation is according to ASHRAE Standard 62.1, the fan shall be off in Deadband and Cooling.

7. Alarms

a. Low Airflow

1) If the measured airflow is less than 70% of setpoint for 5 minutes, generate a Level 3 alarm.

2) If the measured airflow is less than 50% of setpoint for 5 minutes, generate a Level 2 alarm.

3) If a zone has an Importance multiplier of 0 [see 1.3A.11.b.1)a)] for its static pressure reset Trim & Respond control loop, low airflow alarms shall be suppressed for that zone.

b. Low Supply Air Temperature

1) If boiler plant is proven on and the supply air temperature is 15°F less than setpoint for 10 minutes, generate a Level 3 alarm.

2) If boiler plant is proven on and the supply air temperature is 30°F less than setpoint for 10 minutes, generate a Level 2 alarm.

3) If a zone has an Importance multiplier of 0 [see 1.3A.11.b.1)a)] for its HWST reset Trim & Respond control loop, low supply air temperature alarms shall be suppressed for that zone.

c. Fan alarm is indicated by the status input being different from the output command after a period of 15 seconds after a change in output status.

1) Commanded on, status off: Level 2
2) Commanded off, status on: Level 4

d. Airflow sensor calibration. If the fan serving the zone has been off for 10 minutes and airflow sensor reading is above 20 CFM, generate a Level 3 alarm.

Per 1.3A.9, all hardware points can be overridden through the EMCS. Each of the following points is interlocked so that they can be overridden together at a Zone Group level, per 1.3C.6. E.g. The CxA can check for leaking dampers by forcing all VAV boxes in a Zone Group closed and then recording airflow at the AHU.

8. Testing/Commissioning Overrides: Provide software points that interlock to a system level point to

a. Force zone airflow setpoint to zero

b. Force zone airflow setpoint to Vcool-max

c. Force zone airflow setpoint to Vmin

d. Force damper full closed/open

e. Force heating to off/closed

f. Turn fan on/off

g. Reset request-hours accumulator point to zero (provide one point for each reset type listed below)

9. System Requests

a. Cooling SAT Reset Requests

1) If the Cooling Loop is less than 85%, send 0 Requests.

2) If the Cooling Loop is greater than 95%, send 1 Request.

3) If the zone temperature exceeds the zone’s cooling setpoint by 3°F for 2 minutes, send 2 Requests.

4) If the zone temperature exceeds the zone’s cooling setpoint by 5°F for 2 minutes, send 3 Requests.

b. Static Pressure Reset Requests

1) If the Damper Loop is less than 85%, send 0 Requests.

2) If the Damper Loop is greater than 95%, send 1 Request.

3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.

4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

c. If there is a hot water coil, heating HWST Reset Requests

1) If the HW valve is less than 85%, send 0 Requests.
2) If the HW valve is greater than 95%, send 1 Request.

3) If the supply air temperature is 15°F less than setpoint for 5 minutes, send 2 Requests.

4) If the supply air temperature is 30°F less than setpoint for 5 minutes, send 3 Requests.

d. If there is a hot water coil and a boiler plant, boiler Plant Requests. Send the boiler plant that serves the zone a Boiler Plant Request as follows:

1) If the HW valve is less than 10%, send 0 Requests.

2) If the HW valve is greater than 95%, send 1 Request.

G. Parallel Fan-Powered Terminal Unit, Variable Volume Fan

1. See Generic Thermal Zones for setpoints, loops, control modes, alarms, etc.

2. Design airflow rates shall be as scheduled on plans:

   a. Zone maximum cooling (primary) airflow setpoint (Vcool-max)
   
   b. Zone minimum primary airflow setpoint (Vmin)

   | If ventilation is controlled in accordance with California Title 24, Vmin may be less than OA-min, or even zero, if there is enough plenum air available for transfer from adjacent zones to provide minimum ventilation. |
   | If, on the other hand, each zone’s plenum is isolated (e.g. for acoustic reasons) or there are relatively few zones from which to draw plenum air, then Vmin must exceed OA-min. |

   c. Parallel fan maximum airflow (Pfan-max)

   | ECM fan must be programmed with relationship between speed signal and airflow. ECMs can be programmed either for CFM (with fan curve mapped into logic) or torque (pressure dependent airflow). This is outside the scope of these sequences, but should be addressed by the design engineer. |

3. Pfan-z is the lowest rate the fan will operate at when it is turned on but has the lowest possible speed signal from the EMCS.

4. See 1.3B.2 for calculation of zone minimum outdoor airflow.

5. The occupied cooling minimum Vmin* shall be equal to Vmin except as follows:

   a. If the zone has an occupancy sensor, Vmin* shall be equal to Varea-min (if ventilation is according to California Title 24) or Voz (if ventilation is according to ASHRAE Standard 62.1) when the room is unpopulated.

   b. If the zone has a window switch, Vmin* shall be zero when the window is open.

   c. If Vmin is non-zero and less than the lowest possible airflow setpoint allowed by the controls (Vm), Vmin* shall be set equal to Vm. The minimum setpoint Vm shall be determined in accordance with 1.3D.4.c.
d. If the zone has a CO₂ sensor

1) During Occupied Mode, a P-only loop shall maintain CO₂ concentration at 1000 PPM; reset 0% at 800 PPM and 100% at 1,000 PPM of CO₂. The loop output from 0 to 50% shall reset the occupied minimum airflow setpoint (Vmin*) from the zone minimum airflow setpoint Vmin up to maximum DCV airflow setpoint VCO₂-max, as shown below.

a) When the zone is in Cooling, VCO₂-max is equal to the maximum cooling airflow setpoint Vcool-max.

```
The following logic prevents the total supply airflow from exceeding Vcool-max, which could create diffuser noise problems.
```

b) When the zone is in Heating or Deadband, VCO₂-max is equal to Vcool-max minus the parallel fan airflow.

2) If ventilation outdoor airflow is controlled in accordance with California Title 24, the loop output from 50% to 100% will be used at the system level to reset outdoor air minimum; see AHU controls.

3) If ventilation outdoor airflow is controlled in accordance with ASHRAE Standard 62.1, the loop output from 50% to 100% shall be ignored.

4) Loop is disabled and output set to zero when the zone is not in Occupied Mode.

6. Active maximum and minimum primary air setpoints shall vary depending on the Mode of the Zone Group the zone is a part of:

<table>
<thead>
<tr>
<th>Setpoint</th>
<th>Occupied</th>
<th>Cool-down</th>
<th>Setup</th>
<th>Warm-up</th>
<th>Setback</th>
<th>Unoccupied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling maximum</td>
<td>Vcool-max</td>
<td>Vcool-max</td>
<td>Vcool-max</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minimum</td>
<td>Vmin*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
7. Control logic is depicted schematically in the figure below and described in the following sections. Relative levels of various setpoints are depicted for Occupied Mode operation.

**Diagram Description:***

- **Pfan-max**: Maximum fan airflow setpoint.
- **OA-min (Title 24 ventilation)**: Minimum airflow setpoint as per Title 24 ventilation standards.
- **Minimum Airflow Setpoint**: Minimum airflow setpoint for parallel fan operation.
- **Discharge Air Temperature Setpoint**: Setpoint for discharge air temperature control.
- **Total CFM**: Total airflow rate.
- **Parallel fan CFM**: CFM for parallel fan operation.
- **Active Primary Airflow Setpoint**: Setpoint for active primary airflow.
- **Cooling Maximum**: Maximum cooling output.
- **Heating Loop Signal**: Signal for heating loop operation.
- **Cooling Loop Signal**: Signal for cooling loop operation.
- **Heating Loop Signal Deadband**: Deadband for heating loop operation.
- **Cooling Loop Signal Deadband**: Deadband for cooling loop operation.

**a. When the zone is in Cooling**

1) The Cooling Loop output shall be mapped to the airflow setpoint from the cooling maximum to the minimum airflow setpoints.
   
a) If supply air temperature from air handler is greater than room temperature, Cooling shall be locked out.

2) Heating coil is off

3) If ventilation is according to California Title 24: In Occupied Mode only, parallel fan starts when primary airflow drops below minimum outdoor airflow (OA-min) minus one half of Pfan-z and shuts off when primary airflow rises above OA-min. Fan airflow rate setpoint is equal to OA-min minus the current primary airflow setpoint.

4) If ventilation is according to ASHRAE Standard 62.1, parallel fan shall be off in Cooling.

**b. When the zone is in Deadband**

1) The airflow setpoint shall be the minimum airflow setpoint.

2) Heating coil is off.

3) If ventilation is according to California Title 24: In Occupied Mode only, parallel fan runs if primary airflow setpoint is below minimum outdoor airflow (OA-min). Fan airflow rate setpoint is equal to OA-min minus the current primary airflow setpoint.
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4) If ventilation is according to ASHRAE Standard 62.1, parallel fan shall be off in Deadband.

c. When zone is in Heating

1) Parallel fan shall run.

2) From 0-50%, the Heating Loop output shall reset the discharge temperature from the current AHU SAT setpoint to 90°F.

3) From 50%-100%, the Heating Loop output shall reset the parallel fan airflow setpoint from the airflow setpoint required in Deadband (see above; this is Pfan-z if Deadband setpoint is less than Pfan-z) proportionally up to the maximum airflow setpoint (Pfan-max).

4) The hot water valve (or modulating electric heating coil) shall be modulated to maintain the discharge temperature at setpoint. (Directly controlling heating off zone temperature control loop is not acceptable.)

d. The VAV damper shall be modulated to maintain the measured primary airflow at the primary airflow setpoint.

8. Alarms

a. Low Airflow

1) If the measured airflow is less than 70% of setpoint for 5 minutes, generate a Level 3 alarm.

2) If the measured airflow is less than 50% of setpoint for 5 minutes, generate a Level 2 alarm.

3) If a zone has an Importance multiplier of 0 [see 1.3A.11.b.1)a)] for its static pressure reset Trim & Respond control loop, low airflow alarms shall be suppressed for that zone.

b. Low Supply Air Temperature

1) If boiler plant is proven on and the supply air temperature is 15°F less than setpoint for 10 minutes, generate a Level 3 alarm.

2) If boiler plant is proven on and the supply air temperature is 30°F less than setpoint for 10 minutes, generate a Level 2 alarm.

3) If a zone has an Importance multiplier of 0 [see 1.3A.11.b.1)a)] for its HWST reset Trim & Respond control loop, low supply air temperature alarms shall be suppressed for that zone.

c. Fan alarm is indicated by the status input being different from the output command after a period of 15 seconds after a change in output status.

1) Commanded on, status off: Level 2

2) Commanded off, status on: Level 4

d. Airflow sensor calibration. If the fan serving the zone has been off for 10 minutes and airflow sensor reading is above 20 CFM, generate a Level 3 alarm.
9. Testing/Commissioning Overrides: Provide software points that interlock to a system level point to
   a. Force zone airflow setpoint to zero
   b. Force zone airflow setpoint to Vcool-max
   c. Force zone airflow setpoint to Vmin
   d. Force damper full closed/open
   e. Force heating to off/closed
   f. Turn fan on/off
   g. Reset request-hours accumulator point to zero (provide one point for each reset type listed below)

10. System Requests

   a. Cooling SAT Reset Requests
      1) If the Cooling Loop is less than 85%, send 0 Requests.
      2) If the Cooling Loop is greater than 95%, send 1 Request.
      3) If the zone temperature exceeds the zone’s cooling setpoint by 3°F for 2 minutes, send 2 Requests.
      4) If the zone temperature exceeds the zone’s cooling setpoint by 5°F for 2 minutes, send 3 Requests.

   b. Static Pressure Reset Requests
      1) If the Damper Loop is less than 85%, send 0 Requests.
      2) If the Damper Loop is greater than 95%, send 1 Request.
      3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.
      4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

   c. If there is a hot water coil, heating HWST Reset Requests
      1) If the HW valve is less than 85%, send 0 Requests.
      2) If the HW valve is greater than 95%, send 1 Request.
      3) If the supply air temperature is 15°F less than setpoint for 5 minutes, send 2 Requests.
      4) If the supply air temperature is 30°F less than setpoint for 5 minutes, send 3 Requests.
d. If there is a hot water coil and a boiler plant, boiler Plant Requests. Send the boiler plant that serves the zone a Boiler Plant Request as follows:

1) If the HW valve is less than 10%, send 0 Requests.

2) If the HW valve is greater than 95%, send 1 Request.

H. Series Fan-Powered Terminal Unit, Constant Volume Fan

1. See Generic Thermal Zones for setpoints, loops, control modes, alarms, etc.

2. Design airflow rates shall be as scheduled on plans:
   a. Zone maximum cooling airflow setpoint (Vcool-max)
   b. Zone minimum airflow setpoint (Vmin)

3. See 1.3B.2 for calculation of zone minimum outdoor airflow.

4. The occupied cooling minimum Vmin* shall be equal to Vmin except as follows:
   a. If the zone has an occupancy sensor, Vmin* shall be equal to Varea-min (if ventilation is according to California Title 24) or Vaz (if ventilation is according to ASHRAE Standard 62.1) when the room is unpopulated.
   b. If the zone has a window switch, Vmin* shall be zero when the window is open.
   c. If Vmin is non-zero and less than the lowest possible airflow setpoint allowed by the controls (Vm), Vmin* shall be set equal to Vm. The minimum setpoint Vm shall be determined in accordance with 1.3D.4.c.

   Note that DCV with series fan-powered boxes usually will not save energy since transfer air will almost always keep CO₂ levels low anyway.

   d. If the zone has a CO₂ sensor

      1) During Occupied Mode, a P-only loop shall maintain CO₂ concentration at 1000 PPM; reset 0% at 800 PPM and 100% at 1,000 PPM of CO₂. The loop output from 0 to 50% shall reset the occupied minimum airflow setpoint (Vmin*) from the zone minimum airflow setpoint Vmin up to maximum cooling airflow setpoint Vcool-max, as shown below.
2) If ventilation outdoor airflow is controlled in accordance with California Title 24, the loop output from 50% to 100% will be used at the system level to reset outdoor air minimum; see AHU controls.

3) If ventilation outdoor airflow is controlled in accordance with ASHRAE Standard 62.1, the loop output from 50% to 100% shall be ignored.

4) Loop is disabled and output set to zero when the zone is not in Occupied Mode.

5. Active maximum and minimum setpoints shall vary depending on the Mode of the Zone Group the zone is a part of:

<table>
<thead>
<tr>
<th>Setpoint</th>
<th>Occupied</th>
<th>Cool-down</th>
<th>Setup</th>
<th>Warm-up</th>
<th>Setback</th>
<th>Unoccupied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling maximum</td>
<td>Vcool-max</td>
<td>Vcool-max</td>
<td>Vcool-max</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minimum</td>
<td>Vmin*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
6. Control logic is depicted schematically in the figure below and described in the following sections.

a. When the zone is in Cooling, the Cooling Loop output shall be mapped to the primary airflow setpoint from the cooling maximum to the minimum airflow setpoints. Heating coil is off.

1) If supply air temperature from air handler is greater than room temperature, Cooling shall be locked out.

b. When the zone is in Deadband, the primary airflow setpoint shall be the minimum airflow setpoint. Heating coil is off.

c. When zone is in Heating

1) The Heating Loop shall reset the discharge temperature from the current AHU SAT setpoint to 90°F. Higher temperatures tend to cause air to stratify and bypass into the return air.

2) The hot water valve (or modulating electric heating coil) shall be modulated to maintain the discharge temperature at setpoint. (Directly controlling heating off zone temperature control loop is not acceptable.)

d. The VAV damper shall be modulated to maintain the measured airflow at setpoint.

e. Fan Control: Fan shall run whenever zone is in Occupied Mode. Prior to starting the fan, the damper is first driven fully closed to ensure that the fan is not rotating backwards. Once the fan is proven on for a fixed time delay (15 seconds), the damper override is released.
7. Alarms
   a. Low Airflow
      1) If the measured airflow is less than 70% of setpoint for 5 minutes, generate a Level 3 alarm.
      2) If the measured airflow is less than 50% of setpoint for 5 minutes, generate a Level 2 alarm.
      3) If a zone has an Importance multiplier of 0 [see 1.3A.11.b.1)(a)] for its static pressure reset Trim & Respond control loop, low airflow alarms shall be suppressed for that zone.
   b. Low Supply Air Temperature
      1) If boiler plant is proven on and the supply air temperature is 15°F less than setpoint for 10 minutes, generate a Level 3 alarm.
      2) If boiler plant is proven on and the supply air temperature is 30°F less than setpoint for 10 minutes, generate a Level 2 alarm.
      3) If a zone has an Importance multiplier of 0 [see 1.3A.11.b.1)(a)] for its HWST reset Trim & Respond control loop, low supply air temperature alarms shall be suppressed for that zone.
   c. Fan alarm is indicated by the status input being different from the output command after a period of 15 seconds after a change in output status.
      1) Commanded on, status off: Level 2
      2) Commanded off, status on: Level 4
   d. Airflow sensor calibration. If the fan serving the zone has been off for 10 minutes and airflow sensor reading is above 20 CFM, generate a Level 3 alarm.

8. Testing/Commissioning Overrides: Provide software points that interlock to a system level point to
   a. Force zone airflow setpoint to zero
   b. Force zone airflow setpoint to Vcool-max
   c. Force zone airflow setpoint to Vmin
   d. Force damper full closed/open
   e. Force heating to off/closed
   f. Turn fan on/off
   g. Reset request-hours accumulator point to zero (provide one point for each reset type listed below)

9. System Requests
   a. Cooling SAT Reset Requests
      1) If the Cooling Loop is less than 85%, send 0 Requests.
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2) If the Cooling Loop is greater than 95%, send 1 Request.

3) If the zone temperature exceeds the zone’s cooling setpoint by 3°F for 2 minutes, send 2 Requests.

4) If the zone temperature exceeds the zone’s cooling setpoint by 5°F for 2 minutes, send 3 Requests.

b. Static Pressure Reset Requests

1) If the Damper Loop is less than 85%, send 0 Requests.

2) If the Damper Loop is greater than 95%, send 1 Request.

3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.

4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

c. If there is a hot water coil, heating HWST Reset Requests

1) If the HW valve is less than 85%, send 0 Requests.

2) If the HW valve is greater than 95%, send 1 Request.

3) If the supply air temperature is 15°F less than setpoint for 5 minutes, send 2 Requests.

4) If the supply air temperature is 30°F less than setpoint for 5 minutes, send 3 Requests.

d. If there is a hot water coil and a boiler plant, boiler Plant Requests. Send the boiler plant that serves the zone a Boiler Plant Request as follows:

1) If the HW valve is less than 10%, send 0 Requests.

2) If the HW valve is greater than 95%, send 1 Request.
Snap Acting Control logic is the first choice among the various DD control schemes – it is the most efficient and does not require DD boxes with mixing sections which have a high pressure drop. It allows use of dual standard airflow sensors, one at each inlet, with standard pressure independent logic blocks; alternatively, a single discharge airflow sensor may be used.

However, snap acting logic is not ideal for CO\textsubscript{2} control because it can cause the zone to oscillate between Cooling and Heating. This occurs when the CO\textsubscript{2} control pushes the Vmin* up to Vcool-max; at that point temperature control is lost and if the space is overcooled, it will be pushed into Heating, where it will be overheated, then back again. If CO\textsubscript{2} demand controlled ventilation is required, the mixing logic described in the next section should be used. This logic assumes no ability to mix hot and cold air to prevent overly low supply air temperatures which may occur on systems with high outdoor airflow and no preheat coil. So a preheat coil is likely to be required on such systems if mixed air temperature can fall below 45°F or so in winter.

Note that snap acting logic can also be problematic for zones with high minimums, since the room itself is acting as the mixing box.

Because no cold duct air is supplied during heating mode, the heating system must include ventilation air either with direct outdoor air intake or indirectly via transfer air from over-ventilated spaces on the same system. Refer to Standard 62.1 and the Standard 62.1 User’s Manual.

I. Dual Duct VAV Terminal Unit – Snap Acting Control

1. See Generic Thermal Zones for setpoints, loops, control modes, alarms, etc.

2. Design airflow rates shall be as scheduled on plans:
   a. Zone maximum cooling airflow setpoint (Vcool-max)
   b. Zone minimum airflow setpoint (Vmin)
   c. Zone maximum heating airflow setpoint (Vheat-max)

3. See 1.3B.2 for calculation of zone minimum outdoor airflow.

4. The occupied cooling minimum Vmin* shall be equal to Vmin except as follows:
   a. If the zone has an occupancy sensor, Vmin* shall be equal to Varea-min (if ventilation is according to California Title 24) or \( V_{oz} \) (if ventilation is according to ASHRAE Standard 62.1) when the room is unpopulated.
   b. If the zone has a window switch, Vmin* shall be zero when the window is open.
   c. If Vmin is non-zero and less than the lowest possible airflow setpoint allowed by the controls (Vm), Vmin* shall be set equal to Vm. The minimum setpoint Vm shall be determined in accordance with 1.3D.4.c above.

5. Active maximum and minimum setpoints shall vary depending on the Mode of the Zone Group the zone is a part of:
Control logic is depicted schematically in the figures below and described in the following sections. Relative levels of various setpoints are depicted for Occupied Mode operation.
If the terminal unit is equipped with airflow sensors at both inlets, use paragraph a and delete paragraph b.

a. Temperature and Damper Control with dual inlet airflow sensors:

1) When the zone is in Cooling, the Cooling Loop output shall reset the cooling supply airflow setpoint from the minimum to cooling maximum setpoints. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at setpoint. The heating damper shall be closed.

   a) If cold deck supply air temperature from air handler is greater than room temperature, Cooling shall be locked out.

2) When the zone is in Heating, the Heating Loop output shall reset the heating supply airflow setpoint from the minimum to heating maximum setpoints. The heating damper shall be modulated by a control loop to maintain the measured heating airflow at setpoint. The cooling damper shall be closed.

   a) If hot deck supply air temperature from air handler is less than room temperature, Heating shall be locked out.

3) When the zone is in Deadband, the cooling and heating airflow setpoints shall be their last setpoints just before entering Deadband. In other words, when going from Cooling to Deadband, the cooling airflow setpoint is equal to the zone minimum and the cooling setpoint is zero. When going from Heating to Deadband, the heating airflow setpoint is equal to the zone minimum and the cooling setpoint is zero. This results in a snap-action switch in the damper setpoint as indicated in the figures above.
If the terminal unit is equipped with airflow sensors at both inlets, use paragraph b and delete paragraph a above.

b. Temperature and Damper Control with a single discharge airflow sensor:

1) When the zone is in Cooling, the Cooling Loop output shall reset the discharge airflow setpoint from the minimum to cooling maximum setpoints. The cooling damper shall be modulated by a control loop to maintain the measured discharge airflow at setpoint. The heating damper shall be closed.

2) When the zone is in Heating, the Heating Loop output shall reset the discharge airflow setpoint from the minimum to heating maximum setpoints. The heating damper shall be modulated by a control loop to maintain the measured discharge airflow at setpoint. The cooling damper shall be closed.

3) When the zone is in Deadband, the discharge airflow setpoint shall be the zone minimum, maintained by the damper that was operative just before entering Deadband. The other damper shall remain closed. In other words, when going from Cooling to Deadband, the cooling damper shall maintain the discharge airflow at the zone minimum setpoint and the heating damper shall be closed. When going from Heating to Deadband, the heating damper shall maintain the discharge airflow at the zone minimum setpoint and the cooling damper shall be closed. This results in a snap-action switch in the damper setpoint as indicated in the figures above.

7. Alarms

a. Low Airflow

1) If the measured airflow is less than 70% of setpoint for 5 minutes, generate a Level 3 alarm.

2) If the measured airflow is less than 50% of setpoint for 5 minutes, generate a Level 2 alarm.

3) If a zone has an Importance multiplier of 0 [see 1.3A.11.b.1a)] for its static pressure reset Trim & Respond control loop, low airflow alarms shall be suppressed for that zone.

b. Airflow sensor calibration. If the fan serving the zone has been off for 10 minutes and airflow sensor reading is above 20 CFM, generate a Level 3 alarm.

Per 1.3A.9, all hardware points can be overridden through the EMCS. Each of the following points is interlocked so that they can be overridden together at a Zone Group level, per 1.3C.6. E.g. The CxA can check for leaking dampers by forcing all VAV boxes in a Zone Group closed and then recording airflow at the AHU.

8. Testing/Commissioning Overrides: Provide software points that interlock to a system level point to

a. Force zone airflow setpoint to zero

b. Force zone airflow setpoint to Vcool-max

c. Force zone airflow setpoint to Vmin

d. Force zone airflow setpoint to Vheat-max

e. Force cooling damper full closed/open
9. System Requests

a. Cooling SAT Reset Requests
   1) If the Cooling Loop is less than 85%, send 0 Requests.
   2) If the Cooling Loop is greater than 95%, send 1 Request.
   3) If the zone temperature exceeds the zone’s cooling setpoint by 3°F for 2 minutes, send 2 Requests.
   4) If the zone temperature exceeds the zone’s cooling setpoint by 5°F for 2 minutes, send 3 Requests.

b. Cooling Static Pressure Reset Requests
   1) If the Damper Loop is less than 85%, send 0 Requests.
   2) If the Damper Loop is greater than 95%, send 1 Request.
   3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.
   4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

c. Heating SAT Reset Requests
   1) If the Heating Loop is less than 85%, send 0 Requests.
   2) If the Heating Loop is greater than 95%, send 1 Request.
   3) If the zone temperature falls below the zone’s heating setpoint by 3°F for 2 minutes, send 2 Requests.
   4) If the zone temperature falls below the zone’s heating setpoint by 5°F for 2 minutes, send 3 Requests.

d. Heating Static Pressure Reset Requests
   1) If the Damper Loop is less than 85%, send 0 Requests.
   2) If the Damper Loop is greater than 95%, send 1 Request.
   3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.
   4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

e. Heating Fan Requests. Send the heating fan that serves the zone a Heating Fan Request as follows:
   1) If the zone Heating Loop is less than 1%, send 0 Requests.
2) If the zone Heating Loop is greater than 15%, send 1 Request.

Mixing Control logic is the preferred option for use with demand control ventilation. If the box serves more than one room, it requires a DD box with mixing capability – a pair of single-duct boxes strapped together with a common plenum will not work because the discharge air will stratify rather than mix. However, if only a single room is served – as is typical for a zone using DCV – then the room becomes the mixing box and this issue can be disregarded. This sequence utilizes two airflow sensors, one at each inlet. This eliminates the need for a restriction at the discharge to facilitate flow measurement (and its associated pressure drop). A discharge restriction may still be required for mixing; see previous paragraph.

When the majority of the airflow is through one duct, the airflow velocity in the other duct may be too low to read and result in hunting at that damper. This is not a problem, because the absolute airflow in that duct will be too low for minor fluctuations to be detectable, while the airflow in the dominant duct is sufficient to provide a clear velocity signal.

Because no cold duct air is supplied during heating mode, the heating system must include ventilation air either with direct outdoor air intake or indirectly via transfer air from over-ventilated spaces on the same system. Refer to Standard 62.1 and the Standard 62.1 User’s Manual.

J. Dual Duct VAV Terminal Unit – Mixing Control with Inlet Airflow Sensors

1. See Generic Thermal Zones for setpoints, loops, control modes, alarms, etc.

2. Design airflow rates shall be as scheduled on plans:
   a. Zone maximum cooling airflow setpoint (Vcool-max)
   b. Zone minimum airflow setpoint (Vmin)
   c. Zone maximum heating airflow setpoint (Vheat-max)

3. See 1.3B.2 for calculation of zone minimum outdoor airflow.

4. The occupied cooling minimum Vmin* shall be equal to Vmin except as follows:
   a. If the zone has an occupancy sensor, Vmin* shall be equal to Varea-min (if ventilation is according to California Title 24) or Voz (if ventilation is according to ASHRAE Standard 62.1) when the room is unpopulated.
   b. If the zone has a window switch, Vmin* shall be zero when the window is open.
   c. If Vmin is non-zero and less than the lowest possible airflow setpoint allowed by the controls (Vm), Vmin* shall be set equal to Vm. The minimum setpoint Vm shall be determined in accordance with 1.3D.4.c above.
   d. If the zone has a CO2 sensor

1) During Occupied Mode, a P-only loop shall maintain CO2 concentration at 1000 PPM; reset 0% at 800 PPM and 100% at 1,000 PPM of CO2. The loop output from 0 to 50% shall reset the occupied minimum airflow setpoint (Vmin*) from the zone minimum airflow setpoint Vmin up to maximum cooling airflow setpoint Vcool-max, as shown below.
2) If ventilation outdoor airflow is controlled in accordance with California Title 24, the loop output from 50% to 100% will be used at the system level to reset outdoor air minimum; see AHU controls.

3) If ventilation outdoor airflow is controlled in accordance with ASHRAE Standard 62.1, the loop output from 50% to 100% shall be ignored.

4) Loop is disabled and output set to zero when the zone is not in Occupied Mode.

5. Active maximum and minimum setpoints shall vary depending on the Mode of the Zone Group the zone is a part of:

<table>
<thead>
<tr>
<th>Setpoint</th>
<th>Occupied</th>
<th>Cool-down</th>
<th>Setup</th>
<th>Warm-up</th>
<th>Setback</th>
<th>Unoccupied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling maximum</td>
<td>Vcool-max</td>
<td>Vcool-max</td>
<td>Vcool-max</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minimum</td>
<td>Vmin*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Heating maximum</td>
<td>Vheat-max</td>
<td>0</td>
<td>0</td>
<td>Vheat-max</td>
<td>Vheat-max</td>
<td>0</td>
</tr>
</tbody>
</table>
6. Control logic is depicted schematically in the figures below and described in the following sections. Relative levels of various setpoints are depicted for Occupied Mode operation.
a. Temperature Control

1) When the zone is in Heating, the Heating Loop output shall reset the heating supply airflow setpoint from zero to the maximum heating setpoint. The heating damper shall be modulated by a control loop to maintain the measured heating airflow at setpoint. The cooling damper shall be controlled to maintain minimum airflow, as described below.

   a) If hot deck supply air temperature from air handler is less than room temperature, Heating shall be locked out.

2) When the zone is in Cooling, the Cooling Loop output shall reset the cooling supply airflow setpoint from zero to the maximum cooling setpoint. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at setpoint. The heating damper shall be controlled to maintain minimum airflow, as described below.

   a) If cold deck supply air temperature from air handler is greater than room temperature, Cooling shall be locked out.

3) When the zone is in Deadband, the cooling and heating dampers are controlled to maintain minimum airflow, as described below.

b. Minimum Volume Control

1) In Heating, the cooling damper is modulated to maintain the sum of the measured inlet airflows at the minimum airflow setpoint.

2) In Cooling, the heating damper is modulated to maintain the sum of the measured inlet airflows at the minimum airflow setpoint.

3) In Deadband, the last damper that was used to maintain minimum airflow continues to do so (for example in transitioning from Heating into Deadband, the cooling damper would continue to maintain minimum airflow).

7. Alarms

a. Low Airflow

1) If the measured airflow is less than 70% of setpoint for 5 minutes, generate a Level 3 alarm.

2) If the measured airflow is less than 50% of setpoint for 5 minutes, generate a Level 2 alarm.

3) If a zone has an Importance multiplier of 0 [see 1.3A.11.b.1)a)] for its static pressure reset Trim & Respond control loop, low airflow alarms shall be suppressed for that zone.

b. Airflow sensor calibration. If the fan serving the zone has been off for 10 minutes and airflow sensor reading is above 20 CFM, generate a Level 3 alarm.
8. Testing/Commissioning Overrides: Provide software points that interlock to a system level point to
   a. Force zone airflow setpoint to zero
   b. Force zone airflow setpoint to $V_{cool\text{-max}}$
   c. Force zone airflow setpoint to $V_{min}$
   d. Force zone airflow setpoint to $V_{heat\text{-max}}$
   e. Force cooling damper full closed/open
   f. Force heating damper full closed/open
   g. Reset request-hours accumulator point to zero (provide one point for each reset type listed below)

9. System Requests
   a. Cooling SAT Reset Requests
      1) If the Cooling Loop is less than 85%, send 0 Requests.
      2) If the Cooling Loop is greater than 95%, send 1 Request.
      3) If the zone temperature exceeds the zone’s cooling setpoint by 3°F for 2 minutes, send 2 Requests.
      4) If the zone temperature exceeds the zone’s cooling setpoint by 5°F for 2 minutes, send 3 Requests.
   b. Cooling Static Pressure Reset Requests
      1) If the Damper Loop is less than 85%, send 0 Requests.
      2) If the Damper Loop is greater than 95%, send 1 Request.
      3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.
      4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.
   c. Heating SAT Reset Requests
      1) If the Heating Loop is less than 85%, send 0 Requests.
      2) If the Heating Loop is greater than 95%, send 1 Request.
      3) If the zone temperature falls below the zone’s heating setpoint by 3°F for 2 minutes, send 2 Requests.
4) If the zone temperature falls below the zone’s heating setpoint by 5°F for 2 minutes, send 3 Requests.

d. Heating Static Pressure Reset Requests

1) If the Damper Loop is less than 85%, send 0 Requests.

2) If the Damper Loop is greater than 95%, send 1 Request.

3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.

4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

e. Heating Fan Requests. Send the heating fan that serves the zone a Heating Fan Request as follows:

1) If the zone Heating Loop is less than 1%, send 0 Requests.

2) If the zone Heating Loop is greater than 15%, send 1 Request.

Mixing Control logic is the preferred option for use with demand control ventilation. If the box serves more than one room, it requires a DD box with mixing capability – a pair of single-duct boxes strapped together with a common plenum will not work because the discharge air will stratify rather than mix. However, if only a single room is served – as is typical for a zone using DCV – then the room becomes the mixing box and this issue can be disregarded. This sequence utilizes a single airflow sensor at the discharge outlet. This requires a restriction at the outlet to ensure that airflow velocity is high enough to measure, which adds extra pressure drop. It is somewhat a legacy approach, from when adding a second airflow sensor was much more expensive. As dual-airflow-sensor controllers are now more common, the next sequence (mixing control with inlet airflow sensors) is generally preferred. Because no cold duct air is supplied during heating mode, the heating system must include ventilation air either with direct outdoor air intake or indirectly via transfer air from over-ventilated spaces on the same system. Refer to Standard 62.1 and the Standard 62.1 User’s Manual.

K. Dual Duct VAV Terminal Unit – Mixing Control with Discharge Airflow Sensor

1. See Generic Thermal Zones for setpoints, loops, control modes, alarms, etc.

2. Design airflow rates shall be as scheduled on plans:

   a. Zone maximum cooling airflow setpoint (Vcool-max)

   b. Zone minimum airflow setpoint (Vmin)

   c. Zone maximum heating airflow setpoint (Vheat-max)

3. See 1.3B.2 for calculation of zone minimum outdoor airflow.

4. The occupied cooling minimum Vmin* shall be equal to Vmin except as follows:

   a. If the zone has an occupancy sensor, Vmin* shall be equal to Varea-min (if ventilation is according to California Title 24) or Voz (if ventilation is according to ASHRAE Standard 62.1) when the room is unpopulated.
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b. If the zone has a window switch, Vmin* shall be zero when the window is open.

c. If Vmin is non-zero and less than the lowest possible airflow setpoint allowed by the controls (Vm), Vmin* shall be set equal to Vm. The minimum setpoint Vm shall be determined in accordance with 1.3D.4.c above.

d. If the zone has a CO₂ sensor

1) During Occupied Mode, a P-only loop shall maintain CO₂ concentration at 1000 PPM; reset 0% at 800 PPM and 100% at 1,000 PPM of CO₂. The loop output from 0 to 50% shall reset the occupied minimum airflow setpoint (Vmin*) from the zone minimum airflow setpoint Vmin up to maximum cooling airflow setpoint Vcool-max, as shown below.

2) If ventilation outdoor airflow is controlled in accordance with California Title 24, the loop output from 50% to 100% will be used at the system level to reset outdoor air minimum; see AHU controls.

3) If ventilation outdoor airflow is controlled in accordance with ASHRAE Standard 62.1, the loop output from 50% to 100% shall be ignored.

4) Loop is disabled and output set to zero when the zone is not in Occupied Mode.

5. Active maximum and minimum setpoints shall vary depending on the Mode of the Zone Group the zone is a part of:

<table>
<thead>
<tr>
<th>Setpoint</th>
<th>Occupied</th>
<th>Cool-down</th>
<th>Setup</th>
<th>Warm-up</th>
<th>Setback</th>
<th>Unoccupied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling maximum</td>
<td>Vcool-max</td>
<td>Vcool-max</td>
<td>Vcool-max</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minimum</td>
<td>Vmin*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Heating maximum</td>
<td>Vheat-max</td>
<td>0</td>
<td>0</td>
<td>Vheat-max</td>
<td>Vheat-max</td>
<td>0</td>
</tr>
</tbody>
</table>
6. Control logic is depicted schematically in the figures below and described in the following sections. Relative levels of various setpoints are depicted for Occupied Mode operation.
Because there is only a single airflow sensor on the combined discharge, typical pressure-independent control will not work. Instead, the active (Heating or Cooling) damper position equals the active loop signal (i.e. pressure dependent control), with additional logic to ensure that minimum and maximum airflow volumes are met.

a. Temperature Control

1) When the zone is in Heating, the Heating Loop output shall be mapped to the heating damper position.
   a) If hot deck supply air temperature from air handler is less than room temperature, Heating shall be locked out.

2) When the zone is in Cooling, the Cooling Loop output shall be mapped to the cooling damper position.
   a) If cold deck supply air temperature from air handler is greater than room temperature, Cooling shall be locked out.

3) When the zone is in Deadband, the cooling and heating dampers are controlled to maintain minimum airflow, as described below.

b. Minimum Volume Control

1) In Heating, the cooling damper is modulated to maintain measured discharge airflow at the minimum airflow setpoint.

2) In Cooling, the heating damper is modulated to maintain measured discharge airflow at the minimum airflow setpoint.

3) In Deadband, the last damper that was used to maintain minimum airflow continues to do so (for example in transitioning from Heating into Deadband, the cooling damper would continue to maintain minimum airflow).

c. Maximum Volume Control

1) There shall be a Maximum Volume Control loop which is a reverse-acting P-only loop. The loop’s setpoint shall be the current maximum airflow volume, i.e. either Vcool-max or Vheat-max depending on whether the zone is in Cooling or Heating.

2) The output of the Maximum Volume Control loop shall be a damper position from 0% to 100%. This value shall be the maximum damper position of the currently-active damper, i.e. the maximum cooling damper position in Cooling; the maximum heating damper position in Heating.

7. Alarms

a. Low Airflow

1) If the measured airflow is less than 70% of setpoint for 5 minutes, generate a Level 3 alarm.

2) If the measured airflow is less than 50% of setpoint for 5 minutes, generate a Level 2 alarm.
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3) If a zone has an Importance multiplier of 0 [see 1.3A.11.b.1)a)] for its static pressure reset Trim & Respond control loop, low airflow alarms shall be suppressed for that zone.

b. Airflow sensor calibration. If the fan serving the zone has been off for 10 minutes and airflow sensor reading is above 20 CFM, generate a Level 3 alarm.

Per 1.3A.9, all hardware points can be overridden through the EMCS. Each of the following points is interlocked so that they can be overridden together at a Zone Group level, per 1.3C.6. E.g. The CxA can check for leaking dampers by forcing all VAV boxes in a Zone Group closed and then recording airflow at the AHU.

8. Testing/Commissioning Overrides: Provide software points that interlock to a system level point to

   a. Force zone airflow setpoint to zero
   b. Force zone airflow setpoint to Vcool-max
   c. Force zone airflow setpoint to Vmin
   d. Force zone airflow setpoint to Vheat-max
   e. Force cooling damper full closed/open
   f. Force heating damper full closed/open
   g. Reset request-hours accumulator point to zero (provide one point for each reset type listed below)

9. System Requests

   a. Cooling SAT Reset Requests

      1) If the Cooling Loop is less than 85%, send 0 Requests.
      2) If the Cooling Loop is greater than 95%, send 1 Request.
      3) If the zone temperature exceeds the zone’s cooling setpoint by 3°F for 2 minutes, send 2 Requests.
      4) If the zone temperature exceeds the zone’s cooling setpoint by 5°F for 2 minutes, send 3 Requests.

   b. Cooling Static Pressure Reset Requests

      1) If the Damper Loop is less than 85%, send 0 Requests.
      2) If the Damper Loop is greater than 95%, send 1 Request.
      3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.
      4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

   c. Heating SAT Reset Requests

      1) If the Heating Loop is less than 85%, send 0 Requests.
d. Heating Static Pressure Reset Requests

1) If the Damper Loop is less than 85%, send 0 Requests.
2) If the Damper Loop is greater than 95%, send 1 Request.
3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.
4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

e. Heating Fan Requests. Send the heating fan that serves the zone a Heating Fan Request as follows:

1) If the zone Heating Loop is less than 1%, send 0 Requests.
2) If the zone Heating Loop is greater than 15%, send 1 Request.

Cold Duct Minimum Control logic is the most conventional but least efficient dual duct control strategy. It assures ventilation rates without Standard 62.1 “generalized multiple spaces” considerations since only the cold duct has ventilation air with DFDD systems. This strategy utilizes dual airflow sensors, one at each inlet. It may be used with or without demand control ventilation. The designer must ensure that the cooling minimum and heating maximum sum to less than the cooling maximum to avoid over-supplying the diffusers.

L. Dual Duct VAV Terminal Unit – Cold Duct Minimum Control

1. See Generic Thermal Zones for setpoints, loops, control modes, alarms, etc.

2. Design airflow rates shall be as scheduled on plans:
   a. Zone maximum cooling airflow setpoint (Vcool-max)
   b. Zone minimum airflow setpoint (Vmin)
   c. Zone maximum heating airflow setpoint (Vheat-max)

3. See 1.3B.2 for calculation of zone minimum outdoor airflow.

4. The occupied cooling minimum Vmin* shall be equal to Vmin except as follows:
   a. If the zone has an occupancy sensor, Vmin* shall be equal to Varea-min (if ventilation is according to California Title 24) or V_{oc} (if ventilation is according to ASHRAE Standard 62.1) when the room is unpopulated.
b. If the zone has a window switch, Vmin* shall be zero when the window is open.

c. If Vmin is non-zero and less than the lowest possible airflow setpoint allowed by the controls (Vm), Vmin* shall be set equal to Vm. The minimum setpoint Vm shall be determined in accordance with 1.3D.4.c above.

d. If the zone has a CO₂ sensor

1) During Occupied Mode, a P-only loop shall maintain CO₂ concentration at 1000 PPM; reset 0% at 800 PPM and 100% at 1,000 PPM of CO₂. The loop output from 0 to 50% shall reset the occupied minimum airflow setpoint (Vmin*) from the zone minimum airflow setpoint Vmin up to maximum cooling airflow setpoint Vcool-max, as shown below.

2) If ventilation outdoor airflow is controlled in accordance with California Title 24, the loop output from 50% to 100% will be used at the system level to reset outdoor air minimum; see AHU controls.

3) If ventilation outdoor airflow is controlled in accordance with ASHRAE Standard 62.1, the loop output from 50% to 100% shall be ignored.

4) Loop is disabled and output set to zero when the zone is not in Occupied Mode.

5. Active maximum and minimum setpoints shall vary depending on the Mode of the Zone Group the zone is a part of:

<table>
<thead>
<tr>
<th>Setpoint</th>
<th>Occupied</th>
<th>Cool-down</th>
<th>Setup</th>
<th>Warm-up</th>
<th>Setback</th>
<th>Unoccupied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling maximum</td>
<td>Vcool-max</td>
<td>Vcool-max</td>
<td>Vcool-max</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Minimum</td>
<td>Vmin*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Heating maximum</td>
<td>Vheat-max</td>
<td>0</td>
<td>0</td>
<td>Vheat-max</td>
<td>Vheat-max</td>
<td>0</td>
</tr>
</tbody>
</table>
6. Control logic is depicted schematically in the figures below and described in the following sections. Relative levels of various setpoints are depicted for Occupied Mode operation.

a. Temperature and Damper Control:

1) When the zone is in Cooling, the Cooling Loop output shall reset the cooling supply airflow setpoint from the minimum to cooling maximum setpoints. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at setpoint. The heating damper shall be closed.

   a) If cold deck supply air temperature from air handler is greater than room temperature, Cooling shall be locked out.

2) When the zone is in Deadband, the cooling airflow setpoint shall be the minimum setpoint. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at setpoint. The heating damper shall be closed.

3) When the zone is in Heating,

   a) The Heating Loop output shall reset the heating supply airflow setpoint from zero to heating maximum setpoint. The heating damper shall be modulated by a control loop to maintain the measured heating airflow at setpoint.

   b) The cooling airflow setpoint shall be the minimum setpoint. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at setpoint.

   c) If hot deck supply air temperature from air handler is less than room temperature, Heating shall be locked out.
7. Alarms
   a. Low Airflow
      1) If the measured airflow is less than 70% of setpoint for 5 minutes, generate a Level 3 alarm.
      2) If the measured airflow is less than 50% of setpoint for 5 minutes, generate a Level 2 alarm.
      3) If a zone has an Importance multiplier of 0 [see 1.3A.11.b.1.a)] for its static pressure reset
         Trim & Respond control loop, low airflow alarms shall be suppressed for that zone.
   b. Airflow sensor calibration. If the fan serving the zone has been off for 10 minutes and airflow
      sensor reading is above 20 CFM, generate a Level 3 alarm.

   Per 1.3A.9, all hardware points can be overridden through the EMCS. Each of the following points is
   interlocked so that they can be overridden together at a Zone Group level, per 1.3C.6.
   E.g. The CxA can check for leaking dampers by forcing all VAV boxes in a Zone Group closed and then
   recording airflow at the AHU.

8. Testing/Commissioning Overrides: Provide software points that interlock to a system level point to
   a. Force zone airflow setpoint to zero
   b. Force zone airflow setpoint to Vcool-max
   c. Force zone airflow setpoint to Vmin
   d. Force zone airflow setpoint to Vheat-max
   e. Force cooling damper full closed/open
   f. Force heating damper full closed/open
   g. Reset request-hours accumulator point to zero (provide one point for each reset type listed below)

9. System Requests
   a. Cooling SAT Reset Requests
      1) If the Cooling Loop is less than 85%, send 0 Requests.
      2) If the Cooling Loop is greater than 95%, send 1 Request.
      3) If the zone temperature exceeds the zone’s cooling setpoint by 3°F for 2 minutes, send 2
         Requests.
      4) If the zone temperature exceeds the zone’s cooling setpoint by 5°F for 2 minutes, send 3
         Requests.
   b. Cooling Static Pressure Reset Requests
      1) If the Damper Loop is less than 85%, send 0 Requests.
      2) If the Damper Loop is greater than 95%, send 1 Request.
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3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.
4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

c. Heating SAT Reset Requests
1) If the Heating Loop is less than 85%, send 0 Requests.
2) If the Heating Loop is greater than 95%, send 1 Request.
3) If the zone temperature falls below the zone’s heating setpoint by 3°F for 2 minutes, send 2 Requests.
4) If the zone temperature falls below the zone’s heating setpoint by 5°F for 2 minutes, send 3 Requests.

d. Heating Static Pressure Reset Requests
1) If the Damper Loop is less than 85%, send 0 Requests.
2) If the Damper Loop is greater than 95%, send 1 Request.
3) If the measured airflow is less than 70% of setpoint for 1 minute, send 2 Requests.
4) If the measured airflow is less than 50% of setpoint for 1 minute, send 3 Requests.

e. Heating Fan Requests. Send the heating fan that serves the zone a Heating Fan Request as follows:
1) If the zone Heating Loop is less than 1%, send 0 Requests.
2) If the zone Heating Loop is greater than 15%, send 1 Request.

M. Multiple Zone VAV Air Handling Unit

1. AHU system Modes are the same as the Mode of the Zone Group served by the system. When Zone Group served by an air handling system are in different modes, the following hierarchy applies (highest one sets AHU mode).
   a. Occupied Mode
   b. Cool-down Mode
   c. Setup Mode
   d. Warm-up Mode
   e. Setback Mode
   f. Unoccupied Mode
2. Supply Fan Control
   
a. Supply Fan Start/Stop
   
1) Supply fan shall run when system is in the Cool-down Mode, Setup Mode, or Occupied Mode.

2) If there are any VAV-reheat boxes on perimeter zones, supply fan shall also run when system is in Setback Mode or Warmup Mode (i.e. all Modes except Unoccupied).

3) Totalize current airflow rate from VAV boxes and display on AHU graphic at discharge duct. If the AHU has an airflow measurement station, display the AFMS airflow rate adjacent to the sum-of-zone airflow rate.

b. Static Pressure Setpoint Reset

1) Static pressure setpoint: Setpoint shall be reset using Trim & Respond logic [see 1.3A.11]. The following parameters are suggested as a starting place, but they will require adjustment during the commissioning/tuning phase:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP₀</td>
<td>0.5 inches</td>
</tr>
<tr>
<td>SPₘᵟᵥ</td>
<td>0.1 inches</td>
</tr>
<tr>
<td>SPₘₐₓ</td>
<td>Per TAB report</td>
</tr>
<tr>
<td>T_d</td>
<td>10 minutes</td>
</tr>
<tr>
<td>T</td>
<td>2 minutes</td>
</tr>
<tr>
<td>I</td>
<td>2</td>
</tr>
<tr>
<td>R</td>
<td>Zone Static Pressure Reset Requests</td>
</tr>
<tr>
<td>SPₜᵢᵐᵥ</td>
<td>-0.05 inches</td>
</tr>
<tr>
<td>SPₙᵢᵉˢ</td>
<td>+0.06 inches</td>
</tr>
<tr>
<td>SPᵣₑₛ⁻ₓᵉₐₓ</td>
<td>+0.13 inches</td>
</tr>
</tbody>
</table>

   
c. Static Pressure Control
   
*High pressure trips may occur if all VAV boxes are closed (as in Unoccupied Mode) or if fire/smoke dampers are closed (in some FSD designs, the dampers are interlocked to the fan status rather than being controlled by smoke detectors).*

1) Supply fan speed is controlled to maintain duct static pressure at setpoint when the fan is proven on. See 1.3A.10 for minimum speed setpoint. Where the Zone Groups served by the system are small, provide multiple sets of gains that are used in the control loop as a function of a load indicator (such as supply fan airflow rate, the area of the Zone Groups that are occupied, etc.).
Delete the next paragraph if there is only one supply fan or if fan isolation is by barometric dampers.
The delay is to ensure fan is on before damper opens to prevent backflow from the other fan from back-wheeling the fan prior to startup.
Contractor should adjust rate of isolation damper closing and opening to prevent damage to plenum.

2) Loop output shall be mapped to the VFD speed from minimum VFD speed to 100% speed.
Start to open isolation damper (inlet cone) when fan reaches minimum speed. Close the damper when the fan status indicates fan is off.

3. Supply Air Temperature Control

a. Control loop is enabled when the supply air fan is proven on, and disabled and output set to Deadband (no heating, minimum economizer) otherwise.

The default range of outdoor air temperatures (70°F – 60°F) used to reset the Occupied Mode SAT setpoint was chosen to maximize economizer hours. It may be preferable to use a lower range of OATs (e.g. 65°F – 55°F) to minimize fan energy if:
• There is a 24/7 chiller plant that is running anyway
• Reheat is minimized, as in a VAV dual-fan, dual-duct system
• The climate severely limits the number of available economizer hours
If using this logic, the engineer should oversize interior zones and rooms with high cooling loads (design them to be satisfied by the warmest SAT) so these zones don’t drive the T&R block to the minimum SAT setpoint.

b. Supply Air Temperature Setpoint

1) During Occupied Mode: Setpoint shall be reset from T-min when the outdoor air temperature is 70°F and above, proportionally up to T-max when the outdoor air temperature is 60°F and below.

a) T-min shall be the design cooling coil leaving air temperature per coil schedule.

b) T-max shall be reset using Trim & Respond logic [see 1.3A.11] between SP_{min} (the design supply air temperature per the AHU schedule) and SP_{max}. The following parameters are suggested as a starting place, but they will require adjustment during the commissioning/tuning phase:

SP_{min} should equal the design supply air temperature.
SP_{max} may need to be less than 65°F for dehumidification in humid climates. It should not normally be greater than 65°F, as this may lead to excessive fan energy use.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP_{0}</td>
<td>SP_{max}</td>
</tr>
<tr>
<td>SP_{min}</td>
<td>Design SAT (55°F typ)</td>
</tr>
<tr>
<td>SP_{max}</td>
<td>65°F (or less for dehumidification)</td>
</tr>
<tr>
<td>T_d</td>
<td>10 minutes</td>
</tr>
<tr>
<td>T</td>
<td>2 minutes</td>
</tr>
<tr>
<td>R</td>
<td>Zone Cooling SAT Requests</td>
</tr>
</tbody>
</table>
The net result of this SAT reset strategy is depicted in the chart below:

### Variable | Value
--- | ---
$SP_{trim}$ | +0.2°F
$SP_{res}$ | -0.3°F
$SP_{res-max}$ | -1.0°F

2) During Setup or Cool-Down Modes: Setpoint shall be T-min.  

*The following will effectively lock out the economizer and cooling coil, which is desirable for warmup even if there is no heating coil at the AHU to meet the higher SAT. This does not apply in the case of a DFDD AHU, or if all the zones are equipped with fan-powered boxes such that the AHU is off in warmup and setback.*

3) During Warm-Up and Setback Modes: Setpoint shall be 95°F.
c. For units with a separate minimum outdoor air damper: Supply air temperature shall be controlled to setpoint using a control loop whose output is mapped to sequence the hot water valve or modulating electric heating coil (if applicable), economizer outdoor damper, return air damper, and chilled water valve as shown in the diagram below. Outdoor air and return air dampers are sequenced rather than complementary (as per most standard sequences) to reduce fan power at part loads.

1) The points of transition along the x-axis shown and described below are representative. Separate gains shall be used for each section of the control map (hot water, economizer, chilled water), which are determined by the Contractor to provide stable control. If this is not possible, Contractor shall adjust the precise value of the x-axis thresholds shown in the figure to provide stable control.
d. For units with a combined minimum outdoor air and economizer damper: Supply air temperature shall be controlled to setpoint using a control loop whose output is mapped to sequence the hot water valve or modulating electric heating coil (if applicable), outdoor air damper, return air damper, and chilled water valve as shown in the diagram below. Outdoor air and return air dampers are sequenced rather than complementary (as per most standard sequences) to reduce fan power at part loads. Outdoor air damper minimum (MinOA-P) and maximum (MaxOA-P) positions and return air damper maximum position (MaxRA-P) are limited for economizer lockout and to maintain minimum outdoor airflow rate as described in paragraphs 1.3M.6.d and 1.3M.7.d below.

1) The points of transition along the x-axis shown and described below are representative. Separate gains shall be used for each section of the control map (hot water, economizer, chilled water), which are determined by the Contractor to provide stable control. If this is not possible, Contractor shall adjust the precise value of the x-axis thresholds shown in the figure to provide stable control.

4. Minimum Outdoor Air Control with a separate minimum outdoor air damper and differential pressure control
   a. See 1.3B.2 for calculation of zone minimum outdoor airflow.
### The following section describes ventilation logic which complies with California Title 24. If the project is to comply with Standard 62 ventilation requirements, delete subsection “b” and skip to subsection “c”.

b. Outdoor airflow setpoint, for California Title 24 ventilation:

1) See zone CO₂ control logic under terminal unit sequences.

2) Outdoor air absolute minimum and design minimum setpoints are recalculated continuously based on the Mode of the zones being served.

   a) AbsMinOA* is the sum of Zone-Abs-OA-min for all zones in all Zone Groups that are in Occupied Mode, but shall be no larger than the absolute minimum outdoor airflow, AbsMinOA scheduled on Drawings.

   b) DesMinOA* is the sum of Zone-Des-OA-min for all zones in all Zone Groups that are in Occupied Mode, but shall be no larger than the design minimum outdoor airflow, DesMinOA scheduled on Drawings.

---

**Instructions for establishing MinDP are given in the Test And Balance Specification. For example:**

1) Open the minimum outdoor air damper and return air damper fully; close the economizer outdoor air damper.
2) Measure outdoor airflow.
3) If outdoor airflow rate is above design minimum, adjust damper linkage on minimum outdoor air damper so that intake is at minimum with damper fully stroked.
4) If outdoor airflow rate is below design minimum, temporarily adjust return air damper position via the EMCS until design outdoor airflow is achieved. This position shall be used for testing only and shall not limit the return air damper position during normal operation.
5) Note differential pressure across the outdoor air damper. This value becomes the design minimum outdoor air differential pressure setpoint in the EMCS. Convey this setpoint to EMCS installer and note on air balance report.
6) With the system at the minimum outdoor air position, reduce supply air fan speed until the outdoor airflow is equal to the absolute minimum outdoor airflow on AHU schedule.
7) Note differential pressure across the outdoor air damper. This value becomes the absolute minimum outdoor air differential pressure setpoint in the EMCS. Convey this setpoint to EMCS installer and note on air balance report.

---

3) DP Setpoint

   a) Determine in conjunction with air balancer the absolute minimum outdoor air damper differential pressure, AbsMinDP, that provides an outdoor airflow equal to the absolute minimum outdoor airflow, AbsMinOA, scheduled on drawings.

   b) Determine in conjunction with air balancer the design minimum outdoor air damper differential pressure, DesMinDP, that provides the design minimum outdoor airflow, DesMinOA, scheduled on drawings.
The following equation prevents excess outdoor air from being supplied during periods of partial occupancy.

4) The active minimum differential pressure setpoints, AbsDPsp* and DesDPsp*, shall be determined by the equations below:

\[
\text{AbsDPsp}^* = \text{AbsMinDP} \frac{\text{AbsMinOA}^*}{\text{AbsMinOA}} \\
\text{DesDPsp}^* = \text{DesMinDP} \frac{\text{DesMinOA}^*}{\text{DesMinOA}}
\]

5) OA DP Setpoint (MinDPsp). The minimum outdoor air DP setpoint (MinDPsp) shall be reset based on the highest zone CO\(_2\) PID loop signal from AbsDPsp* at 50% signal to DesDPsp* at 100% signal.

The following section describes ventilation logic which complies with ASHRAE Standard 62. If the project is to comply with California Title 24 ventilation requirements, delete subsection “c” and use subsection “b”, above.

c. Outdoor airflow setpoint, for ASRHAE Standard 62.1 ventilation:

1) CO\(_2\) signals from zones are disregarded at the air handler level.

2) Every 5 minutes, the EMCS shall calculate the uncorrected outdoor air intake \(V_{ou}\), based on the zone diversity \(D_i\) (or system diversity \(D\)) and the area and population components of \(V_{bz}\) for all zones in Occupied Mode, as follows:

\[
V_{ou} = \sum_{\text{all zones in Occupied Mode}} (D_i \times V_{bzP}) + \sum_{\text{all zones in Occupied Mode}} V_{bZA}
\]

a) For any zone with an occupancy sensor, \(D_i\) shall be set to zero when the occupancy sensor shows that the zone is unpopulated.

3) Every 5 minutes, the EMCS shall calculate the current system ventilation efficiency \(E_v\). This is the smallest value of the zone ventilation efficiency \(E_{vz}\) for any zone in Occupied Mode, calculated in accordance with Appendix A of Standard 62.1.

a) For single-supply systems: \(E_{vz} = 1 + \left( \frac{V_{ou}}{V_{ps}} \right) - Z_{pz}\)

b) Where \(Z_{pz}\) is the zone primary outdoor air fraction [see 1.3B.2.c.3] and \(V_{ps}\) is the system primary airflow at the air handler.

4) Every 5 minutes, the EMCS shall calculate the minimum outdoor air setpoint MinOAsp. This shall be the uncorrected outdoor air intake \(V_{ou}\) divided by the system ventilation efficiency \(E_v\), but shall be not be greater than “Des Min OA” as scheduled on the drawings:

\[
\text{MinOAsp} = \text{MINIMUM} \left( \frac{V_{ou}}{E_v} \right) \text{DesMinOA}
\]
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5) Design OA DP Setpoint: Determine in conjunction with air balancer the design minimum outdoor air damper differential pressure, DesMinDP, that provides the design minimum outdoor airflow, DesMinOA, scheduled on drawings.

6) OA DP Setpoint (MinDPsp): The minimum outdoor air DP setpoint MinDPsp shall be calculated

\[ \text{MinDPsp} = \text{DesMinDP} \left( \frac{\text{MinOAsp}}{\text{DesMinOA}} \right)^2 \]

d. Open minimum outdoor air damper when the supply air fan is proven on and the system is in Occupied Mode. Damper shall be closed otherwise.

e. Return Air Dampers: When the supply fan is proven on, the unit is in Occupied Mode, and economizer outdoor air damper is disabled due to the high temperature lockout, or the economizer outdoor air damper is less than 3% open for 5 minutes until it is above 5% open, the RA damper signal is modulated to maintain differential pressure across the minimum outdoor air damper at setpoint, MinDPsp.

The following section applies to air handlers with a separate minimum OA damper, an airflow measurement station, and DCV. It should be deleted if the unit has a common minimum OA and economizer damper.

5. Minimum Outdoor Air Control with a separate minimum outdoor air damper and airflow measurement

a. See 1.3B.2 for calculation of zone minimum outdoor airflow.

The following section describes ventilation logic which complies with California Title 24. If the project is to comply with Standard 62 ventilation requirements, delete subsection “b” and skip to subsection “c”.

b. Outdoor airflow setpoint, for California Title 24 ventilation:

1) See zone CO₂ control logic under terminal unit sequences.

2) Outdoor air absolute minimum and design minimum setpoints are recalculated continuously based on the Mode of the zones being served.

   a) AbsMinOA* is the sum of Zone-Abs-OA-min for all zones in all Zone Groups that are in Occupied Mode, but shall be no larger than the absolute minimum outdoor airflow, “Abs Min OA” scheduled on Drawings.

   b) DesMinOA* is the sum of Zone-Des-OA-min for all zones in all Zone Groups that are in Occupied Mode, but shall be no larger than the design minimum outdoor airflow, “Des Min OA” scheduled on Drawings.

3) OA Setpoint (MinOAsp)

   a) The minimum outdoor air setpoint MinOAsp shall be reset based on the highest zone CO₂ control loop signal from AbsMinOA* at 50% signal to DesMinOA* at 100% signal.
c. Outdoor airflow setpoint, for ASHRAE Standard 62.1 ventilation:

1) \( \text{CO}_2 \) signals from zones are disregarded at the air handler level.

2) Every 5 minutes, the EMCS shall calculate the uncorrected outdoor air intake \( V_{ou} \), based on the system diversity \( D \) and the area and population components of \( V_{bz} \) for all zones in Occupied Mode, as follows:

\[
V_{ou} = \sum_{all \text{ zones in Occupied Mode}} (D_i \times V_{bzP}) + \sum_{all \text{ zones in Occupied Mode}} V_{bzA}
\]

Strictly speaking, Standard 62.1 requires only a single occupant diversity ratio \( D \) for the entire system. If individual zone diversities are provided on plans, they may be used. Otherwise, a single system-wide diversity ratio should be used in this calculation.

a) For any zone with an occupancy sensor, \( D_i \) shall be set to zero when the occupancy sensor shows that the zone is unpopulated.

3) Every 5 minutes, the EMCS shall calculate the current system ventilation efficiency \( E_v \). This is the smallest value of the zone ventilation efficiency \( E_{vz} \) for any zone in Occupied Mode, calculated in accordance with Appendix A of Standard 62.1.

a) For single-supply systems: \( E_{vz} = 1 + \frac{V_{ou}}{V_{ps}} - Z_{pz} \)

b) Where \( Z_{pz} \) is the zone primary outdoor air fraction [see 1.3B.2.c.3] and \( V_{ps} \) is the system primary airflow at the air handler.

4) Every 5 minutes, the EMCS shall calculate the minimum outdoor air setpoint \( \text{MinOAsp} \). This shall be the uncorrected outdoor air intake \( V_{ou} \), divided by the system ventilation efficiency \( E_v \), but shall be not be greater than “Des Min OA” as scheduled on the drawings:

\[
\text{MinOAsp} = \text{MINIMUM}\left( \frac{V_{ou}}{E_v} \right) \text{ Des Min OA}
\]

d. Minimum Outdoor Air Control Loop

1) Minimum outdoor air control loop is enabled when the AHU is in Occupied Mode and disabled and output set to zero otherwise.

2) The outdoor airflow rate shall be maintained at the minimum outdoor air setpoint \( \text{MinOAsp} \) by a reverse-acting control loop whose output is mapped to the minimum outdoor air damper signal.

e. Return Air Dampers: When the supply fan is proven on, the unit is in Occupied Mode, and economizer outdoor air damper is disabled due to the high temperature lockout, or the economizer outdoor air damper is less than 3% open for 5 minutes until it is above 5% open, and the minimum outdoor air damper is fully open, the RA damper signal is modulated to maintain minimum outdoor airflow at setpoint, \( \text{MinOAsp} \), determined above.
The following section applies to air handlers with a common minimum OA and economizer damper (i.e. no separate minimum OA damper), an airflow measurement station, and DCV. It should be deleted if the unit has a separate minimum OA damper.

6. Minimum Outdoor Air Control with a single common damper for minimum outdoor air and economizer functions, and airflow measurement

   a. See 1.3B.2 for calculation of zone minimum outdoor airflow.

   The following section describes ventilation logic which complies with California Title 24. If the project is to comply with Standard 62 ventilation requirements, delete subsection “b” and skip to subsection “c”.

   b. Outdoor airflow setpoint, for California Title 24 ventilation:

      1) See zone CO₂ control logic under terminal unit sequences.

      2) Outdoor air absolute minimum and design minimum setpoints are recalculated continuously based on the Mode of the zones being served.

         a) AbsMinOA* is the sum of Zone-Abs-OA-min for all zones in all Zone Groups that are in Occupied Mode, but shall be no larger than the absolute minimum outdoor airflow, “Abs Min OA” scheduled on Drawings.

         b) DesMinOA* is the sum of Zone-Des-OA-min for all zones in all Zone Groups that are in Occupied Mode, but shall be no larger than the design minimum outdoor airflow, “Des Min OA” scheduled on Drawings.

      3) OA Setpoint (MinOAsp)

         a) The minimum outdoor air setpoint MinOAsp shall be reset based on the highest zone CO₂ control loop signal from AbsMinOA* at 50% signal to DesMinOA* at 100% signal.

   The following section describes ventilation logic which complies with ASHRAE Standard 62. If the project is to comply with California Title 24 ventilation requirements, delete subsection “c” and use subsection “b”, above.

   c. Outdoor airflow setpoint, for ASHRAE Standard 62.1 ventilation:

      1) CO₂ signals from zones are disregarded at the air handler level.

      2) Every 5 minutes, the EMCS shall calculate the uncorrected outdoor air intake \( V_{ou} \), based on the system diversity \( D \) and the area and population components of \( V_{bz} \) for all zones in Occupied Mode, as follows:

         \[
         V_{ou} = \sum_{\text{all zones in Occupied Mode}} (D_i \times V_{bzP}) + \sum_{\text{all zones in Occupied Mode}} V_{bzA}
         \]

         Strictly speaking, Standard 62.1 requires only a single occupant diversity ratio \( D \) for the entire system. If individual zone diversities are provided on plans, they may be used. Otherwise, a single system-wide diversity ratio should be used in this calculation.
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a) For any zone with an occupancy sensor, \( D_i \) shall be set to zero when the occupancy sensor shows that the zone is unpopulated.

3) Every 5 minutes, the EMCS shall calculate the current system ventilation efficiency \( E_v \). This is the smallest value of the zone ventilation efficiency \( E_{vz} \) for any zone in Occupied Mode, calculated in accordance with Appendix A of Standard 62.1.

   a) For single-supply systems: \( E_{vz} = 1 + (V_{ou} / V_{ps}) - Z_{pz} \)

   b) Where \( Z_{pz} \) is the zone primary outdoor air fraction [see 1.3B.2.c.3] and \( V_{ps} \) is the system primary airflow at the air handler.

4) Every 5 minutes, the EMCS shall calculate the minimum outdoor air setpoint \( \text{MinOAsp} \). This shall be the uncorrected outdoor air intake \( V_{ou} \), divided by the system ventilation efficiency \( E_v \), but shall be not be greater than “Des Min OA” as scheduled on the drawings:

\[
\text{MinOAsp} = \text{MINIMUM} \left( \frac{V_{ou}}{E_v} \right) \text{Des Min OA}
\]

d. Minimum Outdoor Air Control Loop

1) Minimum outdoor air control loop is enabled when the AHU is in Occupied Mode and disabled and output set to zero otherwise.

2) The outdoor airflow rate shall be maintained at the minimum outdoor air setpoint \( \text{MinOAsp} \) by a reverse-acting control loop whose output is mapped to economizer damper minimum position, \( \text{MinOA-P} \), and maximum return air damper position, \( \text{MaxRA-P} \), as indicated in the figure below.
7. Economizer Lockout

a. The normal sequencing of the economizer dampers (above) shall be disabled whenever the outdoor air temperature exceeds the economizer lockout temperature as specified in the following table, which varies by climate zone and economizer control device type:

<table>
<thead>
<tr>
<th>Device Type</th>
<th>ASHRAE Climate Zones</th>
<th>Economizer Lockout Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Dry Bulb</td>
<td>1B, 2B, 3B, 3C, 4B, 4C, 5B, 5C, 6B, 7, 8</td>
<td>T_{OA} &gt; 75°F</td>
</tr>
<tr>
<td></td>
<td>5A, 6A</td>
<td>T_{OA} &gt; 70°F</td>
</tr>
<tr>
<td></td>
<td>1A, 2A, 3A, 4A</td>
<td>T_{OA} &gt; 65°F</td>
</tr>
<tr>
<td>Differential Dry Bulb</td>
<td>1B, 2B, 3B, 3C, 4B, 4C, 5A, 5B, 5C, 6A, 6B, 7, 8</td>
<td>T_{OA} &gt; T_{RA}</td>
</tr>
<tr>
<td>Fixed Enthalpy + Fixed Drybulb</td>
<td>All</td>
<td>h_{OA} &gt; 28 Btu/lb or T_{OA} &gt; 75°F</td>
</tr>
</tbody>
</table>

b. Once the economizer is disabled, it shall not be re-enabled within 10 minutes, and vice versa.

---

The following paragraph applies to air handlers with a separate minimum OA damper. It should be deleted if the unit has a common minimum OA and economizer damper. The three minute delay is because the minimum OA damper may be pressure controlled. In that case, delay allows time for the plenum pressure to stabilize, so that the return damper loop doesn’t go crazy chasing a fluctuating pressure reading.

---

The following paragraph applies to air handlers with a common minimum OA and economizer damper (i.e. no separate minimum OA damper). It should be deleted if the unit has a separate minimum OA damper.

c. If the unit has a separate minimum outdoor air damper: When economizer is disabled, the return air damper shall be fully opened, wait 15 seconds, then the economizer outdoor air damper shall be shut. After 3 minute time delay, return air damper shall be released for Minimum Outdoor Air Control (see above).

d. If the unit has a common damper for minimum outdoor air and economizer functions: When economizer is enabled, MaxOA-P = 100%. When economizer is first disabled, the return air damper shall be fully opened, wait 15 seconds, then set MaxOA-P equal to MinOA-P and release return air damper for minimum outdoor air control. See Minimum Outdoor Air Control above for minimum outdoor air and maximum return air damper setpoints.
8. Actuated Relief Dampers Without Fans, if applicable

If net minimum outdoor air (minimum outdoor air less fixed exhaust such as toilet exhaust) is less than about 0.10 CFM/ft², a building of typical tightness will exfiltrate the outdoor air and avoid overpressurization. In this case, use paragraph (a) below and delete paragraph (b), so that relief system is enabled only when economizer is active.

If net minimum outdoor air is greater than 0.10 CFM/ft², or if building envelope is unusually tight, relief will be required regardless of economizer status. In this case, use paragraph (b) below and delete paragraph (a).

a. Relief dampers shall be enabled when the associated supply fan is proven on in Occupied Mode and the associated economizer is enabled, and disabled otherwise.

b. Relief dampers shall be enabled when the associated supply fan is proven on in Occupied Mode, and disabled otherwise.

c. When enabled, modulate relief dampers to maintain 0.05” building static pressure. Close damper when disabled.

9. Relief Fans, if applicable

Relief fans are enabled and disabled with their associated supply fans, but all relief fans that are running, and serve a common volume of space, run at the same speed. This prevents relief fans from fighting each other, which can lead to flow reversal or space pressurization problems.

The appropriate boundaries between relief systems, establishing which relief fans run together, will need to be determined by the engineer based on building geometry.

a. All operating relief fans that serve a common/shared air volume shall be controlled as if they were one system, running at the same speed and using the same control loop, even if they are associated with different air handling units.

b. A relief fan shall be enabled when its associated supply fan is enabled in Occupied Mode and the supply fan’s economizer is enabled, and shall be disabled otherwise.

c. A relief fan shall be enabled when its associated supply fan is enabled in Occupied Mode, and shall be disabled otherwise.

d. Building static pressure shall be time averaged with a sliding 5 minute window (to dampen fluctuations). The averaged value shall be that displayed and used for control.
e. A control loop maintains the building pressure at a setpoint of 0.05 inches with an output ranging from 0 to 100%. The loop is disabled and output set to zero when relief system is disabled.

1) Barometric relief: When relief system is enabled and the control loop output is above 5%, open the motorized dampers to all relief fans serving the building that are enabled; close the dampers when the loop output drops to 0% for 5 minutes.

2) Powered relief: When control loop is above minimum speed plus 10% for 1 minute, relief fans shall start. Fan speed signal to all enabled relief fans shall be the same and shall be equal to the control loop signal but no less than the minimum speed. When control loop signal drops to minimum speed for 1 minute, fans shall stop but relief dampers shall remain open for barometric relief per previous paragraph.

f. For fans in a Level 2 alarm, discharge damper shall be closed.

10. Return Fans, if applicable

a. Return fan operates whenever associated supply fan is proven on.

b. Return fan speed shall be controlled to maintain return fan discharge static pressure at setpoint. The setpoint shall be reset from RFSPmin to RFSPmax. Setpoints are determined in conjunction with the air balancer as follows:

1) RFSPmin: That required to deliver the design return air volume across the return air damper when the supply air fan is at design airflow and on minimum outdoor air. This setpoint shall be no less than 0.01 inches, to maintain positive discharge flow.

2) RFSPmax: That required to exhaust enough air to maintain building static pressure at setpoint (0.05 inches) when the supply air fan is at design airflow and on 100% outdoor air.

The designer should choose one static pressure setpoint reset scheme below, and delete the other one, depending on availability of total outdoor airflow information.

c. Return fan discharge static pressure setpoint shall be reset as follows

1) If there is an AFMS across the entire outdoor air intake (i.e. both the economizer intake and the minimum outdoor air intake): The setpoint shall be reset linearly from RFSPmin at the minimum outdoor airflow to RFSPmax at 100% of design outdoor airflow.

2) If there is not an AFMS at the outdoor air intake: The setpoint shall be reset using Trim & Respond logic [see 1.3A.11] with the following parameters:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP₀</td>
<td>RFSPₘᵢₙ</td>
</tr>
<tr>
<td>SPₘᵢₙ</td>
<td>RFSPₘᵢₙ</td>
</tr>
<tr>
<td>SPₘₐₓ</td>
<td>RFSPₘᵢₙ</td>
</tr>
<tr>
<td>Tₛ</td>
<td>5 minutes</td>
</tr>
<tr>
<td>T</td>
<td>2 minutes</td>
</tr>
<tr>
<td>I</td>
<td>0</td>
</tr>
<tr>
<td>R</td>
<td>Building Static Request</td>
</tr>
</tbody>
</table>
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<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SP&lt;sub&gt;trim&lt;/sub&gt;</td>
<td>-0.03”</td>
</tr>
<tr>
<td>SP&lt;sub&gt;res&lt;/sub&gt;</td>
<td>+0.05”</td>
</tr>
<tr>
<td>SP&lt;sub&gt;res-max&lt;/sub&gt;</td>
<td>+0.05”</td>
</tr>
</tbody>
</table>

a) A Building Static Request is generated when the building static pressure control loop output is above 95% until it falls below 80%.

d. Exhaust dampers shall only be enabled when the associated supply and return fans are proven on and the minimum outdoor air damper is open. The exhaust dampers shall be closed when disabled.

e. Building static pressure shall be time averaged with a sliding 5-minute window (to dampen fluctuations). The averaged value shall be that displayed and used for control.

Due the potential for interaction between the building pressurization and return fan control loops, extra care must be taken in selecting the control loop gains. To prevent excessive control loop interaction, the closed loop response time of the building pressurization loop should not exceed 1/5 the closed loop response time of the return fan control loop. This can be accomplished by decreasing the gain of the building pressurization controller.

f. When exhaust dampers are enabled, a control loop shall modulate exhaust dampers to maintain the building pressure at a setpoint of 0.05 inches.

11. Freeze Protection

If a freezestat is present, it may be hardwired to perform some or all of these functions. In that case, eliminate those functions from sequence logic, but maintain the alarm.

a. Upon signal from the freezestat (if installed) or if mixed air temperature drops below 40°F for 5 minutes, shut down supply and return fan(s), close outdoor air damper, make the minimum heating coil valve position 50% and the minimum cooling coil valve position 20%, send a Boiler Plant Request, and set a Level 2 alarm indicating the unit is shut down by freeze protection.

b. If freeze protection is triggered by software, it shall remain in effect until it is reset by a software switch from the operator’s workstation. If a freeze stat with a physical reset switch is used instead, there shall be no software reset switch.

12. Alarms

a. Maintenance interval alarm when fan has operated for more than 1500 hours: Level 5. Reset interval counter when alarm is acknowledged.

b. Fan alarm is indicated by the status being different from the command for a period of 15 seconds.
   1) Commanded on, status off: Level 2
   2) Commanded off, status on: Level 4

c. Filter pressure drop exceeds alarm limit: Level 5. The alarm limit shall vary with total airflow (if available; use fan speed if total airflow is not known) as follows:

\[
DP_x = DP_{100} (x)^{1/4}
\]
where DP100 is the high limit pressure drop at design airflow (determine limit from filter manufacturer) and DPx is the high limit at airflow rate (or speed signal) x (expressed as a fraction). For instance, the setpoint at 50% of design airflow would be \((.5)^{1.4}\) or 38% of the design high limit pressure drop.

d. High building pressure (more than 0.10\(\text{”}\)): Level 3

e. Low building pressure (less than 0.0\(\text{”}\)): Level 4

The Automatic Fault Detection and Diagnostics (AFDD) routines for AHUs continually assesses AHU performance by comparing the values of EMCS inputs and outputs to a subset of potential fault conditions. The subset of potential fault conditions that is assessed at any point depends on the Operating State of the AHU, as determined by the position of the cooling and heating valves and the economizer damper. Time delays are applied to the evaluation and reporting of fault conditions, to suppress false alarms. Fault conditions which pass these filters are reported to the building operator along with a series of possible causes. These equations assume that the air handler is equipped with hydronic heating and cooling coils, as well as a fully integrated economizer. If any of these components are not present, the associated tests, and variables, should be omitted from the programming.

Note that these alarms rely on reasonably accurate measurement of mixed air temperature. An MAT sensor is required for many of these alarms to work, and an averaging sensor is strongly recommended for best accuracy.

13. Automatic Fault Detection and Diagnostics

a. AFDD conditions are evaluated continuously and separately for each operating air handling unit.

b. The Operating State (OS) of each AHU shall be defined by the commanded positions of the heating coil control valve, cooling coil control valve, and economizer damper in accordance with the following table and corresponding graphic. The Operating State (OS) of each AHU shall be defined by the commanded positions of the heating coil control valve, cooling coil control valve, and economizer damper in accordance with the following table and corresponding graphic.
The Operating State is distinct from and should not be confused with the Zone Status (Cooling, Heating, Deadband) or Zone Group Mode (Occupied, Warm-up, etc). OS#1 – OS#4 represent normal operation during which a fault may nevertheless occur, if so determined by the fault condition tests in section e below. By contrast, OS#5 typically represents an abnormal or incorrect condition (such as simultaneous heating and cooling) arising from a controller failure or programming error, but it may also occur normally, e.g. when dehumidification is active.

<table>
<thead>
<tr>
<th>Operating State</th>
<th>Heating Valve Position</th>
<th>Cooling Valve Position</th>
<th>Outdoor Air Damper Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1: Heating</td>
<td>&gt; 0</td>
<td>= 0</td>
<td>= MIN</td>
</tr>
<tr>
<td>#2: Free Cooling, Modulating OA</td>
<td>= 0</td>
<td>= 0</td>
<td>MIN &lt; X &lt; 100%</td>
</tr>
<tr>
<td>#3: Mechanical + Economizer Cooling</td>
<td>= 0</td>
<td>&gt; 0</td>
<td>= 100%</td>
</tr>
<tr>
<td>#4: Mechanical Cooling, Min OA</td>
<td>= 0</td>
<td>&gt; 0</td>
<td>= MIN</td>
</tr>
<tr>
<td>#5: Unknown or Dehumidification</td>
<td>No other OS applies</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For the AFDD routines to be effective, an averaging sensor is recommended for supply air temperature. An averaging sensor is essential for mixed air temperature, as the environment of the mixing box will be subject to non-uniform and fluctuating air temperatures. It is recommended that the OAT sensor be located at the AHU, so that it accurately represents the temperature of the incoming air.

1) Supply air temperature
2) Mixed air temperature
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3) Return air temperature
4) Outdoor air temperature
5) Duct static pressure
6) SATSP = supply air temperature setpoint
7) DSPSP = duct static pressure setpoint
8) HC = heating coil valve position command; 0% ≤ HC ≤ 100%
9) CC = cooling coil valve position command; 0% ≤ CC ≤ 100%
10) FS = fan speed command; 0% ≤ FS ≤ 100%

d. The following values must be continuously calculated by the AFDD routines for each AHU:

1) Five minute (default) rolling averages of the following point values; operator shall have the
   ability to adjust the averaging window for each point independently
   a) SAT_{AVG} = rolling average of supply air temperature
   b) MAT_{AVG} = rolling average of mixed air temperature
   c) RAT_{AVG} = rolling average of return air temperature
   d) OAT_{AVG} = rolling average of outdoor air temperature
   e) DSP_{AVG} = rolling average of duct static pressure

2) %OA = actual outdoor air fraction as a percentage = \frac{\text{MAT - RAT}}{\text{OAT - RAT}}
or per airflow measurement station if available.

3) %OA_{MIN} = Active minimum OA setpoint (MinOAsp) divided by actual total airflow (from
   sum of VAV box flows, or by airflow measurement station) as a percentage.

4) ΔOS = number of changes in Operating State during the previous 60 minutes (moving
   window)

e. The following internal variables shall be defined for each AHU. All parameters are adjustable by
   the operator, with initial values as given below:
Default values are derived from NISTIR 7365 (Jeffery Schein, October 2006) and have been validated in field trials. They are expected to be appropriate for most circumstances, but individual installations may benefit from tuning to improve sensitivity and reduce false alarms. The default values have been intentionally biased towards minimizing false alarms, if necessary at the expense of missing real alarms. This avoids excessive false alarms that will erode user confidence and responsiveness. However, if the goal is to achieve the best possible energy performance and system operation, these values should be adjusted based on field measurement and operational experience.

Values for physical factors such as fan heat, duct heat gain, and sensor error can be measured in the field or derived from trendlogs. Likewise the occupancy delay and switch delays can be refined by observing in trend data the time required to achieve quasi steady state operation. Other factors can be tuned by observing false positives and false negatives (i.e. unreported faults). If transient conditions or noise cause false errors, increase the alarm delay. Likewise, failure to report real faults can be addressed by adjusting the heating coil, cooling coil, temperature, or flow thresholds.

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Description</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔTₜₛ</td>
<td>Temperature rise across supply fan</td>
<td>2° F</td>
</tr>
<tr>
<td>ΔTₘᵋᵡ</td>
<td>Minimum difference between OAT and RAT to evaluate economizer error conditions (FC#6)</td>
<td>10° F</td>
</tr>
<tr>
<td>εₚₐₜ</td>
<td>Temperature error threshold for SAT sensor</td>
<td>2° F</td>
</tr>
<tr>
<td>εₚₐₜ</td>
<td>Temperature error threshold for RAT sensor</td>
<td>2° F</td>
</tr>
<tr>
<td>εₚₐₜ</td>
<td>Temperature error threshold for MAT sensor</td>
<td>5° F</td>
</tr>
<tr>
<td>εₚₐₜ</td>
<td>Temperature error threshold for OAT sensor</td>
<td>2° F if local sensor @ unit. 5° F if global sensor.</td>
</tr>
<tr>
<td>εₚ</td>
<td>Airflow error threshold</td>
<td>30%</td>
</tr>
<tr>
<td>εᵥᶠᵈˢᵖᵈ</td>
<td>VFD speed error threshold</td>
<td>5%</td>
</tr>
<tr>
<td>εᵥᶠᵈˢᵖᵈ</td>
<td>Duct static pressure error threshold</td>
<td>0.1&quot;</td>
</tr>
<tr>
<td>Δ₀ₛₘₐₓ</td>
<td>Maximum number of changes in Operating State</td>
<td>7</td>
</tr>
<tr>
<td>ModeDelay</td>
<td>Time in minutes to suspend Fault Condition evaluation after a change in Mode</td>
<td>90</td>
</tr>
<tr>
<td>AlarmDelay</td>
<td>Time in minutes to that a Fault Condition must persist before triggering an alarm</td>
<td>60</td>
</tr>
</tbody>
</table>

The purpose of ΔTₘᵋᵡ is to ensure that the mixing box/economizer damper tests are meaningful. These tests are based on the relationship between supply, return, and outdoor air. If RAT ≈ MAT, these tests will not be accurate and will produce false alarms.

f. There are 13 potential Fault Conditions that can be evaluated by the AFDD routines. If the equation statement is true, then the specified fault condition exists. The Fault Conditions to be evaluated at any given time will depend on the Operating State of the AHU.
These equations assume that the SAT sensor is located downstream of the supply fan, and the RAT sensor is located downstream of the return fan. If actual sensor locations differ from these assumptions, it may be necessary to add or delete fan heat correction factors.

<table>
<thead>
<tr>
<th>FC #1</th>
<th>Equation</th>
<th>( \text{DSP} &lt; \text{DSPSP} - \epsilon_{\text{DSP}} ) and ( \text{VFDSPD} \geq 99% - \epsilon_{\text{VFDSPD}} )</th>
<th>Applies to OS #1 – #5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Duct static pressure is too low with fan at full speed</td>
<td><strong>Possible Diagnosis</strong></td>
<td>Problem with VFD mechanical problem with fan Fan undersized SAT Setpoint too high (too much zone demand)</td>
</tr>
<tr>
<td>FC #2</td>
<td>Equation</td>
<td>( \text{MAT}<em>{\text{AVG}} + \epsilon</em>{\text{MAT}} &lt; \min [(\text{RAT}<em>{\text{AVG}} - \epsilon</em>{\text{RAT}}), (\text{OAT}<em>{\text{AVG}} - \epsilon</em>{\text{OAT}})] )</td>
<td>Applies to OS #1 – #5</td>
</tr>
<tr>
<td>Description</td>
<td>MAT too low; should be between OAT and RAT</td>
<td><strong>Possible Diagnosis</strong></td>
<td>RAT sensor error MAT sensor error OAT sensor error</td>
</tr>
<tr>
<td>FC #3</td>
<td>Equation</td>
<td>( \text{MAT}<em>{\text{AVG}} - \epsilon</em>{\text{MAT}} &gt; \max [(\text{RAT}<em>{\text{AVG}} + \epsilon</em>{\text{RAT}}), (\text{OAT}<em>{\text{AVG}} + \epsilon</em>{\text{OAT}})] )</td>
<td>Applies to OS #1 – #5</td>
</tr>
<tr>
<td>Description</td>
<td>MAT too high; should be between OAT and RAT</td>
<td><strong>Possible Diagnosis</strong></td>
<td>RAT sensor error MAT sensor error OAT sensor error</td>
</tr>
<tr>
<td>FC #4</td>
<td>Equation</td>
<td>( \Delta \text{OS} &gt; \Delta \text{OS}_{\text{MAX}} )</td>
<td>Applies to OS #1 – #5</td>
</tr>
<tr>
<td>Description</td>
<td>Too many changes in Operating State</td>
<td><strong>Possible Diagnosis</strong></td>
<td>Unstable control due to poorly tuned loop or mechanical problem</td>
</tr>
<tr>
<td>FC #5</td>
<td>Equation</td>
<td>( \text{SAT}<em>{\text{AVG}} + \epsilon</em>{\text{SAT}} \leq \text{MAT}<em>{\text{AVG}} - \epsilon</em>{\text{MAT}} + \Delta T_{\text{SF}} )</td>
<td>Applies to OS #1</td>
</tr>
<tr>
<td>Description</td>
<td>SAT too low; should be higher than MAT</td>
<td><strong>Possible Diagnosis</strong></td>
<td>SAT sensor error MAT sensor error Cooling coil valve leaking or stuck open Heating coil valve stuck closed or actuator failure Fouled or undersized heating coil HHW temperature too low or HHW unavailable</td>
</tr>
<tr>
<td>FC #6</td>
<td>Equation</td>
<td>(</td>
<td>\text{RAT}<em>{\text{AVG}} - \text{OAT}</em>{\text{AVG}}</td>
</tr>
<tr>
<td>Description</td>
<td>OA fraction is too low or too high; should equal %OA_{\text{MIN}}</td>
<td><strong>Possible Diagnosis</strong></td>
<td>RAT sensor error MAT sensor error OAT sensor error Leaking or stuck economizer damper or actuator</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>FC #</th>
<th>Equation</th>
<th>Description</th>
<th>Possible Diagnosis</th>
<th>Applies to OS</th>
</tr>
</thead>
</table>
| 7    | SAT_{AVG} < SAT_{SP} - \varepsilon_{SAT}  
and  
HC \geq 99\%            | SAT too low in full heating (coil is saturated)                              | SAT sensor error  
Cooling coil valve leaking or stuck open  
Heating coil valve stuck closed or actuator failure  
Fouled or undersized heating coil  
HHW temperature too low or HHW unavailable | #1             |
| 8    | | | | #2             |
| 9    | OAT_{AVG} - \varepsilon_{OAT} > SAT_{SP} - \Delta T_{SF} + \varepsilon_{SAT} | OAT is too high for free cooling without additional mechanical cooling      | SAT sensor error  
OAT sensor error  
Cooling coil valve leaking or stuck open  
Heating coil valve leaking or stuck open | #2             |
| 10   | | | | #3             |
| 11   | OAT_{AVG} + \varepsilon_{OAT} < SAT_{SP} - \Delta T_{SF} - \varepsilon_{SAT} | OAT is too low for 100% OA cooling                                          | SAT sensor error  
OAT sensor error  
Heating coil valve leaking or stuck open  
Leaking or stuck economizer damper or actuator | #3             |
| 12   | SAT_{AVG} - \varepsilon_{SAT} - \Delta T_{SF} \geq MAT_{AVG} + \varepsilon_{MAT} | SAT too high; should be less than MAT                                      | SAT sensor error  
MAT sensor error  
Cooling coil valve stuck closed or actuator failure  
Fouled or undersized cooling coil  
CHW temperature too high or CHW unavailable  
Heating coil valve leaking or stuck open | #3, #4         |
### FC #13

**Equation**: \( \text{SAT}_{\text{avg}} > \text{SAT}_{\text{SP}} + \varepsilon_{\text{SAT}} \)

and

\( \text{CC} \geq 99\% \)

**Description**: SAT too high in full cooling (coil is saturated)

**Possible Diagnosis**

- SAT sensor error
- Cooling coil valve stuck closed or actuator failure
- Fouled or undersized cooling coil
- CHW temperature too low or CHW unavailable
- Heating coil valve leaking or stuck open

**Applies to OS #3, #4**

---

g. A subset of all potential fault conditions is evaluated by the AFDD routines. The set of applicable fault conditions depends on the Operating State of the AHU:

1) In OS #1 (Heating), the following Fault Conditions shall be evaluated:
   a) FC#1: Duct static pressure is too low with fan at full speed
   b) FC#2: MAT too low; should be between RAT and OAT
   c) FC#3: MAT too high; should be between RAT and OAT
   d) FC#4: Too many changes in Operating State
   e) FC#5: SAT too low; should be higher than MAT
   f) FC#6: OA fraction is too low or too high; should equal \%OAMIN
   g) FC#7: SAT too low in full heating (coil is saturated)

2) In OS#2 (Modulating Economizer), the following Fault Conditions shall be evaluated:
   a) FC#1: Duct static pressure is too low with fan at full speed
   b) FC#2: MAT too low; should be between RAT and OAT
   c) FC#3: MAT too high; should be between RAT and OAT
   d) FC#4: Too many changes in Operating State
   e) FC#8: SAT too high or too low; should equal MAT
   f) FC#9: OAT is too high for free cooling without mechanical cooling

3) In OS#3 (Mechanical + 100% Economizer Cooling), the following Fault Conditions shall be evaluated:
   a) FC#1: Duct static pressure is too low with fan at full speed
   b) FC#2: MAT too low; should be between RAT and OAT
   c) FC#3: MAT too high; should be between RAT and OAT
   d) FC#4: Too many changes in Operating State
   e) FC#10: MAT is too high or too low; should equal OAT
   f) FC#11: OAT too low for 100% OA
   g) FC#12: SAT too high; should be less than MAT
   h) FC#13: SAT too high in full cooling (coil is saturated)
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4) In OS#4 (Mechanical Cooling, Min OA), the following Fault Conditions shall be evaluated:
   a) FC#1: Duct static pressure is too low with fan at full speed
   b) FC#2: MAT too low; should be between RAT and OAT
   c) FC#3: MAT too high; should be between RAT and OAT
   d) FC#4: Too many changes in Operating State
   e) FC#6: OA fraction is too low or too high; should equal %OAMIN
   f) FC#12: SAT too high; should be less than MAT
   g) FC#13: SAT too high in full cooling (coil is saturated)

5) In OS#5 (Other), the following Fault Conditions shall be evaluated:
   a) FC#1: Duct static pressure is too low with fan at full speed
   b) FC#2: MAT too low; should be between RAT and OAT
   c) FC#3: MAT too high; should be between RAT and OAT
   d) FC#4: Too many changes in Operating State
   e) FC#12: SAT too high; should be less than MAT
   f) FC#13: SAT too high in full cooling (coil is saturated)

h. For each air handler, the operator shall be able to suppress the alarm for any Fault Condition.

i. Evaluation of Fault Conditions shall be suspended under the following conditions:
   1) When AHU is not operating.
   2) For a period of ModeDelay minutes following a change in Mode (e.g. from Warm-up to Occupied) of any Zone Group served by the AHU.

j. Fault Conditions which are not applicable to the current Operating State shall not be evaluated.

k. A Fault Condition that evaluates as true must do so continuously for AlarmDelay minutes before it is reported to the operator.

l. When a Fault Condition is reported to the operator, it shall be a Level 3 alarm and shall include the description of the fault and the list of possible diagnoses from the table in 1.3M.13.f.

Per 1.3A.9, all hardware points can be overridden through the EMCS. Each of the following points is interlocked so that they can be overridden together at a Zone Group level, per 1.3C.6. E.g. The CxA can check for leaking dampers by forcing all VAV boxes in a Zone Group closed and then recording airflow at the AHU.

14. Testing/Commissioning Overrides: Provide software points that interlock to a chilled water and hot water plant level to
   a. If there is a hot water coil, force hot water valve full open
   b. If there is a hot water coil, force hot water valve full closed
   c. Force chilled water valve full open
   d. Force chilled water valve full closed
Central plant sequences are not part of the initial scope of RP-1455, but they are being preserved for future use, when central plant sequences are added.

Typically, the chiller or boiler plant will start when there is at least one request for 5 minutes, and stop when there are no requests for 5 minutes, after a minimum run-time has elapsed.

CHWST and HWST reset requests are used in Trim & Respond loops to control supply water temperature based on zone and AHU demands.

15. Plant Requests

a. Cooling CHWST Reset Requests
   1) If the CHW valve is less than 85%, send 0 Requests.
   2) If the CHW valve is greater than 95%, send 1 Request.
   3) If the supply air temperature exceeds the supply air temperature setpoint by 3°F for 2 minutes, send 2 Requests.
   4) If the supply air temperature exceeds the supply air temperature setpoint by 5°F for 2 minutes, send 3 Requests.

b. Chiller Plant Requests. Send the chiller plant that serves the system a Chiller Plant Request as follows:
   1) If the CHW valve is less than 10%, send 0 Requests.
   2) If the CHW valve is greater than 95%, send 1 Request.

c. If there is a hot water coil, Heating HWST Reset Requests
   1) If the HW valve is less than 85%, send 0 Requests.
   2) If the HW valve is greater than 95%, send 1 Request.
   3) If the supply air temperature is 15°F less than setpoint for 5 minutes, send 2 Requests.
   4) If the supply air temperature is 30°F less than setpoint for 5 minutes, send 3 Requests.

d. If there is a hot water coil and a boiler plant, send the boiler plant that serves the system a Boiler Plant Request as follows:
   1) If the HW valve is less than 10%, send 0 Requests.
   2) If the HW valve is greater than 95%, send 1 Request.

The alarms described in the next section were removed from the main sequences as they have been superseded by the AFDD alarms above. However, if the AFDD alarms are not installed or used for whatever reason, then these alarms should be included to replace their functionality.

16. Alternate Alarms (do not use if AFDD is installed)

a. Low static pressure (more than 0.25 inches below setpoint) when fan control loop is active for longer than 5 minutes: Level 3.

b. Outdoor airflow less than setpoint by 10% for 10 minutes when loop is active: Level 3.
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c. High supply air temperature (more than 5°F above setpoint) off cooling coils when coil control loop is active for longer than 15 minutes and chiller plant is proven on: Level 3.

d. If there is a hot water coil:

1) Low supply air temperature (more than 15°F below setpoint) off heating coils when coil control loop is active for longer than 15 minutes and boiler plant is proven on: Level 3.

2) While heating valve is closed, if the temperature rise across the heating coil exceeds 2°F continuously for 30 minutes; or if the discharge temperature is more than 5°F above setpoint for more than 30 minutes continuously: Level 4 indicating possibly leaking valve.

e. If there is a mixed air temperature sensor:

1) While cooling valve is closed, if the temperature drop across the cooling coil exceeds 2°F continuously for 30 minutes; or if the discharge temperature is more than 5°F below setpoint for more than 30 minutes continuously: Level 4 indicating possibly leaking valve.

2) If the outdoor air temperature is above the supply air temperature setpoint and the economizer is enabled and the mixed air temperature is more than 2°F different from the outdoor air temperature for more than 30 minutes continuously; OR if the outdoor air temperature is more than 5°F below the supply air temperature setpoint and the chilled water valve is open (or compressors are on): Level 4 indicating economizer damper control problems.
### 1.4 Programming Parameters, Settings & Variables

The following pages list the parameters/variables which must be programmed when setting up control sequences for various types of equipment. Variable names are those used in the EIKON implementation of these sequences, which was produced by Automated Logic Corp in the course of this research. (Many terminal unit types require the same parameters, but are described separately because the demo system variable names are different for historical reasons.)

#### A. Generic Thermal Zones

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Description</th>
<th>Hints/Comments</th>
<th>Variable Name in Demo System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title 24 Ventilation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Varea-min</td>
<td>CFM</td>
<td>Minimum OA for building area</td>
<td></td>
<td>min_oa_bldg</td>
</tr>
<tr>
<td>Vocc-min</td>
<td>CFM</td>
<td>Minimum OA for occupants</td>
<td></td>
<td>min_oa_occ</td>
</tr>
<tr>
<td><strong>Standard 62.1 Ventilation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>-</td>
<td>Zone occupant diversity ratio</td>
<td></td>
<td>zone_d</td>
</tr>
<tr>
<td>VbzP</td>
<td>CFM</td>
<td>Breathing zone population OA</td>
<td>((R_p * P_z)) in 62.1</td>
<td>oa_people</td>
</tr>
<tr>
<td>VbzA</td>
<td>CFM</td>
<td>Breathing zone area OA</td>
<td>((R_a * A_z)) in 62.1</td>
<td>oa_area</td>
</tr>
<tr>
<td>EzH</td>
<td>-</td>
<td>Zone heating air distribution effectiveness</td>
<td></td>
<td>ezh</td>
</tr>
<tr>
<td>EzC</td>
<td>-</td>
<td>Zone cooling air distribution effectiveness</td>
<td></td>
<td>ezc</td>
</tr>
</tbody>
</table>

#### Tuning

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Description</th>
<th>Hints/Comments</th>
<th>Variable Name in Demo System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prestart Tuning</td>
<td>On/Off</td>
<td>Automatic prestart tuning</td>
<td>Set to 0 to disable requests from a zone</td>
<td>auto_prestart_tuning</td>
</tr>
<tr>
<td>Heat Importance Factor</td>
<td>-</td>
<td>Heat request scalar</td>
<td>Set to 0 to disable requests from a zone</td>
<td>heat_request_x</td>
</tr>
<tr>
<td>Cool Importance Factor</td>
<td>-</td>
<td>Cool request scalar</td>
<td>Set to 0 to disable requests from a zone</td>
<td>cool_request_x</td>
</tr>
<tr>
<td>Static Importance Factor</td>
<td>-</td>
<td>Static pressure request scalar</td>
<td>Set to 0 to disable requests from a zone</td>
<td>static_request_x</td>
</tr>
</tbody>
</table>

#### B. VAV Terminal Unit, w/ Reheat

(in addition to Generic Zone parameters)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Description</th>
<th>Hints/Comments</th>
<th>Variable Name in Demo System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vm</td>
<td>CFM</td>
<td>Minimum airflow allowed by controls</td>
<td></td>
<td>min_CFM</td>
</tr>
<tr>
<td>Vmin</td>
<td>CFM</td>
<td>Minimum zone airflow when occupied</td>
<td></td>
<td>occ_min</td>
</tr>
<tr>
<td>Vcool-max</td>
<td>CFM</td>
<td>Zone airflow at 100% cooling</td>
<td></td>
<td>air_flow – “Cooling Max Airflow”</td>
</tr>
<tr>
<td>Vheat-max</td>
<td>CFM</td>
<td>Zone airflow at 100% heating</td>
<td></td>
<td>air_flow – “Heating Max Airflow”</td>
</tr>
</tbody>
</table>
### C. Parallel Fan-Powered Terminal Unit, Constant Volume Fan
(in addition to Generic Zone parameters)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Description</th>
<th>Hints/Comments</th>
<th>Variable Name in Demo System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vm</td>
<td>CFM</td>
<td>Minimum airflow allowed by controls</td>
<td></td>
<td>min_CFM</td>
</tr>
<tr>
<td>Vmin</td>
<td>CFM</td>
<td>Minimum zone airflow when occupied</td>
<td></td>
<td>occ_min</td>
</tr>
<tr>
<td>Vcool-max</td>
<td>CFM</td>
<td>Zone airflow at 100% cooling</td>
<td></td>
<td>vcool_max</td>
</tr>
<tr>
<td>CV Fan Flow</td>
<td>CFM</td>
<td>Rated flow of CV fan</td>
<td></td>
<td>fan_flowrate</td>
</tr>
</tbody>
</table>

### D. Parallel Fan-Powered Terminal Unit, Variable Volume Fan
(in addition to Generic Zone parameters)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Description</th>
<th>Hints/Comments</th>
<th>Variable Name in Demo System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vm</td>
<td>CFM</td>
<td>Minimum airflow allowed by controls</td>
<td></td>
<td>min_CFM</td>
</tr>
<tr>
<td>Vmin</td>
<td>CFM</td>
<td>Minimum zone airflow when occupied</td>
<td></td>
<td>occ_min</td>
</tr>
<tr>
<td>Vcool-max</td>
<td>CFM</td>
<td>Zone airflow at 100% cooling</td>
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<tr>
<td>Pfan-z</td>
<td>CFM</td>
<td>Parallel fan airflow at minimum speed</td>
<td></td>
<td>pfanz</td>
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<tr>
<td>Pfan-max</td>
<td>CFM</td>
<td>Parallel fan maximum airflow</td>
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### E. Series Fan-Powered Terminal Unit, Constant Volume Fan
(in addition to Generic Zone parameters)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Description</th>
<th>Hints/Comments</th>
<th>Variable Name in Demo System</th>
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<tbody>
<tr>
<td>Vm</td>
<td>CFM</td>
<td>Minimum airflow allowed by controls</td>
<td></td>
<td>min_CFM</td>
</tr>
<tr>
<td>Vmin</td>
<td>CFM</td>
<td>Minimum zone airflow when occupied</td>
<td></td>
<td>occ_min</td>
</tr>
<tr>
<td>Vcool-max</td>
<td>CFM</td>
<td>Zone airflow at 100% cooling</td>
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### F. Dual Duct VAV Terminal Unit, Snap Acting Control, Dual Inlet Sensors
(in addition to Generic Zone parameters)

<table>
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<tr>
<th>Parameter</th>
<th>Units</th>
<th>Description</th>
<th>Hints/Comments</th>
<th>Variable Name in Demo System</th>
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<tr>
<td>Vm</td>
<td>CFM</td>
<td>Minimum airflow allowed by controls</td>
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<td>min_CFM</td>
</tr>
<tr>
<td>Vmin</td>
<td>CFM</td>
<td>Minimum zone airflow when occupied</td>
<td></td>
<td>occ_min</td>
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<tr>
<td>Vcool-max</td>
<td>CFM</td>
<td>Zone airflow at 100% cooling</td>
<td></td>
<td>vcool_max</td>
</tr>
<tr>
<td>Vheat-max</td>
<td>CFM</td>
<td>Zone airflow at 100% heating</td>
<td></td>
<td>hd_air_flow – “Heating Max Airflow”</td>
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### G. Dual Duct VAV Terminal Unit, Snap Acting Control, Discharge Sensor
(in addition to Generic Zone parameters)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
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<th>Hints/Comments</th>
<th>Variable Name in Demo System</th>
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</thead>
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<td>Vm</td>
<td>CFM</td>
<td>Minimum airflow allowed by controls</td>
<td></td>
<td>min_CFM</td>
</tr>
<tr>
<td>Vmin</td>
<td>CFM</td>
<td>Minimum zone airflow when occupied</td>
<td></td>
<td>occ_min</td>
</tr>
<tr>
<td>Vcool-max</td>
<td>CFM</td>
<td>Zone airflow at 100% cooling</td>
<td>air_flow – “Cooling Max Airflow”</td>
<td></td>
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<tr>
<td>Vheat-max</td>
<td>CFM</td>
<td>Zone airflow at 100% heating</td>
<td>hd_air_flow – “Heating Max Airflow”</td>
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### H. Dual Duct VAV Terminal Unit, Mixing Control, Dual Inlet Sensors
(in addition to Generic Zone parameters)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Description</th>
<th>Hints/Comments</th>
<th>Variable Name in Demo System</th>
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<td>Vm</td>
<td>CFM</td>
<td>Minimum airflow allowed by controls</td>
<td></td>
<td>min_CFM</td>
</tr>
<tr>
<td>Vmin</td>
<td>CFM</td>
<td>Minimum zone airflow when occupied</td>
<td></td>
<td>occ_min</td>
</tr>
<tr>
<td>Vcool-max</td>
<td>CFM</td>
<td>Zone airflow at 100% cooling</td>
<td>air_flow – “Cooling Max Airflow”</td>
<td></td>
</tr>
<tr>
<td>Vheat-max</td>
<td>CFM</td>
<td>Zone airflow at 100% heating</td>
<td>hd_air_flow – “Heating Max Airflow”</td>
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### I. Dual Duct VAV Terminal Unit, Mixing Control, Discharge Sensor
(in addition to Generic Zone parameters)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Description</th>
<th>Hints/Comments</th>
<th>Variable Name in Demo System</th>
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</thead>
<tbody>
<tr>
<td>Vm</td>
<td>CFM</td>
<td>Minimum airflow allowed by controls</td>
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<td>min_CFM</td>
</tr>
<tr>
<td>Vmin</td>
<td>CFM</td>
<td>Minimum zone airflow when occupied</td>
<td></td>
<td>occ_min</td>
</tr>
<tr>
<td>Vcool-max</td>
<td>CFM</td>
<td>Zone airflow at 100% cooling</td>
<td>vcool_max</td>
<td></td>
</tr>
<tr>
<td>Vheat-max</td>
<td>CFM</td>
<td>Zone airflow at 100% heating</td>
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</tr>
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### J. Dual Duct VAV Terminal Unit, Cold Duct Minimum Control
(in addition to Generic Zone parameters)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Description</th>
<th>Hints/Comments</th>
<th>Variable Name in Demo System</th>
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</thead>
<tbody>
<tr>
<td>Vm</td>
<td>CFM</td>
<td>Minimum airflow allowed by controls</td>
<td></td>
<td>min_CFM</td>
</tr>
<tr>
<td>Vmin</td>
<td>CFM</td>
<td>Minimum zone airflow when occupied</td>
<td>air_flow – “Cooling Max Airflow”</td>
<td></td>
</tr>
<tr>
<td>Vcool-max</td>
<td>CFM</td>
<td>Zone airflow at 100% cooling</td>
<td>hd_air_flow – “Heating Max Airflow”</td>
<td></td>
</tr>
<tr>
<td>Vheat-max</td>
<td>CFM</td>
<td>Zone airflow at 100% heating</td>
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</table>
## K. Multiple Zone VAV Air Handling Unit

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Description</th>
<th>Hints/Comments</th>
<th>Variable Name in Demo System</th>
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<tbody>
<tr>
<td><strong>SAT and Fan Control</strong></td>
<td></td>
<td></td>
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<tr>
<td>Supply Fan Minimum Speed</td>
<td>%</td>
<td>Minimum allowed supply fan VFD speed</td>
<td>vfd_min</td>
<td></td>
</tr>
<tr>
<td>Max Reset OAT</td>
<td>°F</td>
<td>OAT for maximum SAT reset</td>
<td>oat_max_reset</td>
<td></td>
</tr>
<tr>
<td>No Reset OAT</td>
<td>°F</td>
<td>OAT for no SAT reset</td>
<td>oat_no_reset</td>
<td></td>
</tr>
<tr>
<td>Tmin</td>
<td>°F</td>
<td>Cooling coil setpoint at maximum reset</td>
<td>t_min</td>
<td></td>
</tr>
<tr>
<td>HW-OA Threshold</td>
<td>%</td>
<td>Control loop % for HW-OA changeover</td>
<td>hw_oa_threshold</td>
<td></td>
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<tr>
<td>OA-RA Threshold</td>
<td>%</td>
<td>Control loop % for OA-RA changeover</td>
<td>oa_ra_threshold</td>
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<tr>
<td>RA-CHW Threshold</td>
<td>%</td>
<td>Control loop % for RA-CHW changeover</td>
<td>ra_chw_threshold</td>
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</tr>
<tr>
<td><strong>Static Pressure SP Reset</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>SP&lt;sub&gt;0&lt;/sub&gt;</td>
<td>inH₂O</td>
<td>Initial setpoint</td>
<td>sa_static_stpt – &quot;Initial&quot;</td>
<td></td>
</tr>
<tr>
<td>SP&lt;sub&gt;min&lt;/sub&gt;</td>
<td>inH₂O</td>
<td>Minimum setpoint</td>
<td>sa_static_stpt – &quot;Minimum&quot;</td>
<td></td>
</tr>
<tr>
<td>SP&lt;sub&gt;max&lt;/sub&gt;</td>
<td>inH₂O</td>
<td>Maximum setpoint</td>
<td>sa_static_stpt – &quot;Maximum&quot;</td>
<td></td>
</tr>
<tr>
<td>T&lt;sub&gt;d&lt;/sub&gt;</td>
<td>mins</td>
<td>T&amp;R delay after fan proven on</td>
<td>sp_tr_delay</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>mins</td>
<td>Time between T&amp;R output updates</td>
<td>sa_static_stpt – &quot;Every&quot;</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td></td>
<td>How many reset requests to ignore</td>
<td>ignore_air_req</td>
<td></td>
</tr>
<tr>
<td>SP&lt;sub&gt;trim&lt;/sub&gt;</td>
<td>inH₂O</td>
<td>Setpoint trim amount</td>
<td>sa_static_stpt – Trim by</td>
<td></td>
</tr>
<tr>
<td>S&lt;sub&gt;res&lt;/sub&gt;</td>
<td>inH₂O</td>
<td>Respond amount</td>
<td>sa_static_stpt – &quot;and respond by&quot;</td>
<td></td>
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<tr>
<td>S&lt;sub&gt;res-max&lt;/sub&gt;</td>
<td>inH₂O</td>
<td>Max response amount per update</td>
<td>sa_static_stpt – &quot;... respond by more than&quot;</td>
<td></td>
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<tr>
<td><strong>SAT Setpoint Reset</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SP&lt;sub&gt;0&lt;/sub&gt;</td>
<td>inH₂O</td>
<td>Initial setpoint</td>
<td>sat_stpt_cool – &quot;Initial&quot;</td>
<td></td>
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<tr>
<td>SP&lt;sub&gt;min&lt;/sub&gt;</td>
<td>inH₂O</td>
<td>Minimum setpoint</td>
<td>sat_stpt_cool – &quot;Minimum&quot;</td>
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<tr>
<td>SP&lt;sub&gt;max&lt;/sub&gt;</td>
<td>inH₂O</td>
<td>Maximum setpoint</td>
<td>sat_stpt_cool – &quot;Maximum&quot;</td>
<td></td>
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<tr>
<td>T&lt;sub&gt;d&lt;/sub&gt;</td>
<td>mins</td>
<td>T&amp;R delay after fan proven on</td>
<td>sat_tr_delay</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>mins</td>
<td>Time between T&amp;R output updates</td>
<td>sat_stpt_cool – &quot;Every&quot;</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td></td>
<td>How many reset requests to ignore</td>
<td>ignore_cool_req</td>
<td></td>
</tr>
<tr>
<td>SP&lt;sub&gt;trim&lt;/sub&gt;</td>
<td>inH₂O</td>
<td>Setpoint trim amount</td>
<td>sat_stpt_cool – Trim by</td>
<td></td>
</tr>
<tr>
<td>S&lt;sub&gt;res&lt;/sub&gt;</td>
<td>inH₂O</td>
<td>Respond amount</td>
<td>sat_stpt_cool – &quot;and respond by&quot;</td>
<td></td>
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<tr>
<td>S&lt;sub&gt;res-max&lt;/sub&gt;</td>
<td>inH₂O</td>
<td>Max response amount per update</td>
<td>sat_stpt_cool – &quot;... respond by more than&quot;</td>
<td></td>
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<tr>
<td><strong>Misc</strong></td>
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<td>AHU Design Flow</td>
<td>CFM</td>
<td>Used for dirty filter detection</td>
<td>design_flow</td>
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<td>Dirty Filter Alarm Limit</td>
<td>inH₂O</td>
<td>Max allowed filter pressure at 100% flow</td>
<td>filter_dp100</td>
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<tr>
<td>Setback/Warmup Fan</td>
<td>Y/N</td>
<td>Run Supply Fan in Unoccupied Heat</td>
<td>fa_unocc_heat</td>
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<tr>
<td>Parameter</td>
<td>Units</td>
<td>Description</td>
<td>Hints/Comments</td>
<td>Variable Name in Demo System</td>
</tr>
<tr>
<td>----------------------------------------</td>
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<td>--------------------------------------------------------------------------------</td>
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<tr>
<td><strong>Outside Air/Economizer Control</strong></td>
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<td></td>
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<tr>
<td>ASHRAE Climate Zone</td>
<td>-</td>
<td>ASHRAE Climate Zone for OA lockout</td>
<td>Use ASHRAE Std 62 ventilation</td>
<td>ashrae_climate_zone</td>
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<tr>
<td>Economizer Control Type</td>
<td>-</td>
<td>Control method for OA lockout</td>
<td>Enable for Std 62, disable for Title24</td>
<td>econ_control_type</td>
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<td>Probe Gain</td>
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<td>Static pressure probe gain</td>
<td></td>
<td>oa_probe_gain</td>
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<td>ASHRAE 62.1 Compliance</td>
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<td>Use ASHRAE Std 62 ventilation</td>
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<td>ashrae_ventilation</td>
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<td>Absolute Minimum OA</td>
<td>CFM</td>
<td>Absolute Min OA scheduled on drawings</td>
<td></td>
<td>abs_min_oa</td>
</tr>
<tr>
<td>Design Minimum OA</td>
<td>CFM</td>
<td>Design Min OA scheduled on drawings</td>
<td>Only applicable if OA ∆P sensor used</td>
<td>des_min_oa</td>
</tr>
<tr>
<td>Absolute Minimum ∆P</td>
<td>inH₂O</td>
<td>∆P = Absolute Min OA scheduled on drawings</td>
<td></td>
<td>abs_min_dp</td>
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<tr>
<td>Design Minimum ∆P</td>
<td>inH₂O</td>
<td>dp= Design Min OA scheduled on drawings</td>
<td>Only applicable if OA ∆P sensor used</td>
<td>des_min_dp</td>
</tr>
<tr>
<td>Relief Fan Minimum Speed</td>
<td>%</td>
<td>Minimum allowed relief fan VFD speed</td>
<td>Only applicable if Relief Fan installed</td>
<td>rf_vfd_min</td>
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<tr>
<td><strong>Return Fan Control (Only applicable for Return Fan with OA ∆P)</strong></td>
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<td></td>
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<tr>
<td>$SP_0$</td>
<td>inH₂O</td>
<td>Initial setpoint</td>
<td></td>
<td>n/a</td>
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<tr>
<td>$RFSP_{min}$</td>
<td>inH₂O</td>
<td>Minimum return fan pressure setpoint</td>
<td></td>
<td>n/a</td>
</tr>
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<td>$RFSP_{max}$</td>
<td>inH₂O</td>
<td>Maximum return fan pressure setpoint</td>
<td></td>
<td>n/a</td>
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<tr>
<td>$T_d$</td>
<td>mins</td>
<td>T&amp;R delay after fan proven on</td>
<td></td>
<td>n/a</td>
</tr>
<tr>
<td>$T$</td>
<td>mins</td>
<td>Time between T&amp;R output updates</td>
<td></td>
<td>n/a</td>
</tr>
<tr>
<td>$I$</td>
<td>-</td>
<td>How many reset requests to ignore</td>
<td></td>
<td>n/a</td>
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<tr>
<td>$SP_{trim}$</td>
<td>inH₂O</td>
<td>Setpoint trim amount</td>
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<td>n/a</td>
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<tr>
<td>$S_{res}$</td>
<td>inH₂O</td>
<td>Respond amount</td>
<td></td>
<td>n/a</td>
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<td>$S_{res-max}$</td>
<td>inH₂O</td>
<td>Max response amount per update</td>
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<td><strong>Automatic Fault Detection &amp; Diagnostics</strong></td>
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<tr>
<td>Mode Switch Delay</td>
<td>mins</td>
<td>Rule evaluation delay after mode switch</td>
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<td>modesw_delay</td>
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<tr>
<td>Alarm Delay</td>
<td>mins</td>
<td>Fault persistence time before alarm</td>
<td></td>
<td>alarm_delay</td>
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<tr>
<td>Mode Change Max</td>
<td>-</td>
<td>Max mode switches per hour</td>
<td></td>
<td>mode_sw_max</td>
</tr>
<tr>
<td>Supply Fan $dT$</td>
<td>°F</td>
<td>Expected supply fan heat rise</td>
<td></td>
<td>dt_sf</td>
</tr>
<tr>
<td>OAT-RAT $dT$ Min</td>
<td>°F</td>
<td>Min OAT-RAT $dT$ for OA fraction test</td>
<td></td>
<td>e_oat, e_sat, e_mat, e_rat</td>
</tr>
<tr>
<td>Temperature Error</td>
<td>°F</td>
<td>Expected temp sensor error (per sensor)</td>
<td></td>
<td>e_sat, e_rat, e_mat, e_oat</td>
</tr>
<tr>
<td>OACFM Error</td>
<td>%</td>
<td>Expected OA CFM sensor error</td>
<td></td>
<td>e_oaCFM</td>
</tr>
<tr>
<td>VFD Speed Error</td>
<td>%</td>
<td>Expected VFD speed error</td>
<td></td>
<td>e_vfd</td>
</tr>
<tr>
<td>Duct Static Pressure Error</td>
<td>inH₂O</td>
<td>Expected static pressure sensor error</td>
<td></td>
<td>sat_avg_k, mat_avg_k, sp_avg_k</td>
</tr>
<tr>
<td>Sensor Average K Factor</td>
<td>-</td>
<td>Weighted average K factor (per sensor)</td>
<td></td>
<td>sat_avg_window, mat_avg_window, sp_avg_window</td>
</tr>
<tr>
<td>Sensor Average Window</td>
<td>mins</td>
<td>Weighted average window (per sensor)</td>
<td></td>
<td>sat_avg_window, mat_avg_window, sp_avg_window</td>
</tr>
<tr>
<td>Fault Detect Enable</td>
<td>Y/N</td>
<td>Enable FDD fault detection (per FC)</td>
<td></td>
<td>rp1455_fc1_ena, .. , rp1455_fc13_ena</td>
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</tbody>
</table>
### Alarm Levels in ALC Implementation

Automated Logic Corp’s software supports three alarm levels. These are mapped to the ASHRAE alarm levels described in 1.3A.13.a as follows:

<table>
<thead>
<tr>
<th>Level</th>
<th>ASHRAE/RP-1455 Alarm Level Description</th>
<th>ALC Alarm Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Critical/Life Safety</td>
<td>HVAC Critical (none in demo system)</td>
</tr>
<tr>
<td>2</td>
<td>Significant Equipment Failure</td>
<td>HVAC Critical</td>
</tr>
<tr>
<td>3</td>
<td>Non-Critical Equipment Failure</td>
<td>HVAC General</td>
</tr>
<tr>
<td>4</td>
<td>Energy Conservation Alert</td>
<td>HVAC General</td>
</tr>
<tr>
<td>5</td>
<td>Maintenance Notification</td>
<td>HVAC Maintenance</td>
</tr>
</tbody>
</table>