GUIDELINE

ASHRAE Guideline 36-2018

High-Performance Sequences of Operation for HVAC Systems

Approved by ASHRAE on June 4, 2018.

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NOTE

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(This foreword is not part of this guideline. It is merely informative and does not contain requirements necessary for conformance to the guideline. It has not been processed according to the ANSI requirements for a guideline and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

FOREWORD

This guideline establishes a set of standardized advanced sequences of operation for common HVAC systems. Standardized advanced control sequences provide the following benefits:

- *Reduced engineering time. Rather than develop sequences themselves, design engineers can adapt existing standard sequences that have been proven to perform.*
- *Reduced programming and commissioning time for contractors.*
- *Reduced energy consumption by making systems less dependent on proper implementation and commissioning of control sequences.*
- *Reduced energy consumption by ensuring that proven, cost-effective strategies, including those required by ASHRAE standards and building codes, are fully implemented.*
- *Improved indoor air quality by ensuring control sequences are in compliance with IAQ standards and codes such as ASHRAE Standard 62.1.*
- *Reduced energy consumption and reduced system downtime by including diagnostic software to detect and diagnose system faults and make operators aware of them before they cause performance problems.*
- *A common set of terms to facilitate communication between specifiers, contractors, and operators.*

The intended audience for the guideline includes HVAC designers, control contractors, commissioning agents, and building owners, operators, and maintenance technicians.

This initial version of the guideline is limited to variable-air-volume (VAV) systems, but it is expected that sequences for other HVAC systems will be added over time. It is also expected that the sequences herein will be adjusted, augmented, and possibly replaced over time, based on feedback from users.

This document falls under ASHRAE's continuous maintenance process. For more information, visit ASHRAE's website, or refer to the forms at the end of the guideline.

Note on Format

This guideline includes two kinds of informative notes:

Notes in bold between thick lines provide direction to the editor of these sequences so that they are properly implemented (e.g., identifying mutually exclusive options).

Notes in italics between thin lines provide guidance or additional information about specific sequences.

These notes are not a part of this guideline. They are merely informative and do not contain requirements necessary for conformance to the guideline.

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1. PURPOSE

The purpose of this guideline is to provide uniform sequences of operation for heating, ventilating, and air-conditioning (HVAC) systems that are intended to maximize HVAC system energy efficiency and performance, provide control stability, and allow for real-time fault detection and diagnostics.

2. SCOPE

2.1 This guideline provides detailed sequences of operation for HVAC systems.

2.2 This guideline describes functional tests that, when performed, will confirm implementation of the sequences of operation.

3. SET POINTS, DESIGN, AND FIELD DETERMINED

3.1 Information Provided by Designer

The design set points listed in this section must be scheduled in design documents for each zone and air handler by the design engineer.

3.1.1 General Zone Information

3.1.1.1 Zone Temperature Set Points

Zone temperature initial set points can be specified by the designer in a number of ways. The most flexible way is to include them for each zone in variable-air-volume (VAV) box and single-zone VAV (SZVAV) air-handling unit (AHU) equipment schedules. They can also be generically listed by zone type, such as the example in (a) below.

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a. Default set points shall be based on zone type as shown in Table 3.1.1.1.

3.1.1.2 Outdoor Air Ventilation Set Points

Ventilation set points can be specified by the designer in a number of ways. The most flexible is to include them for each zone in VAV box and single-zone (SZ) equipment schedules.

The engineer must select between ventilation logic options:

- **If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep subsection (a) and delete subsection (b).**
- **If the project is to comply with California Title 24 ventilation requirements, keep subsection (b) and delete subsection (a).**

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a. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1-2016:

Table 3.1.1.1 Default Set Points

Zone Type	Occupied		Unoccupied	
	Heating	**Cooling**	**Heating**	**Cooling**
VAV	21°C (70°F)	24°C (75°F)	16°C (60°F)	32°C (90°F)
Mechanical/electrical rooms	18°C (65°F)	29°C (85°F)	18°C (65°F)	29°C (85°F)
Networking/computer	18°C (65°F)	24°C (75°F)	18°C (65°F)	24°C (75°F)

1. The area component of the breathing zone outdoor airflow Vbz-A

*This is the zone floor area times the outdoor airflow rate per unit area, as given in Standard 62.1-2016, Table 6.2.2.1; i.e., Vbz-A = Az*Ra.*

2. The population component of the breathing zone outdoor airflow Vbz-P

*This is the zone design population (without diversity) times the outdoor airflow rate per occupant, as given in Standard 62.1-2016, Table 6.2.2.1; i.e.; Vbz-P = Pz*Rp.*

3. Zone air distribution effectiveness EzH in heating
4. Zone air distribution effectiveness EzC in cooling

Zone air distribution effectiveness depends on the relative locations of supply and return in the space, per ASHRAE Standard 62.1-2016, Table 6.2.2.2.

5. Indicate where occupied-standby mode is allowed, based on the zone occupancy category per Standard 62.1-2016, Table 6.2.2.1.

Occupied-standby mode applies to individual zones, is considered a zonal subset of occupied mode and is not considered a zone-group operating mode. See Section 5.4.6 for zone-group operating modes.

b. For projects complying with California Title 24 ventilation standards:
   1. ***Vocc-min.*** Zone minimum outdoor airflow for occupants, per California Title 24 prescribed airflow-per-occupant requirements.
   2. ***Varea-min.*** Zone minimum outdoor airflow for building area, per California Title 24 prescribed airflow-per-area requirements.

3.1.1.3 CO_2 Set Points

Space CO_2 set points are used for demand-controlled ventilation (DCV) and monitoring/alarming as required by LEED and other green building standards.

It is the designer's responsibility to determine CO_2 set points. The maximum set point varies by ventilation standard. Some guidance is provided below for Standard 62.1 and Title 24. The designer may also decide to set lower, more conservative set points for improved indoor air quality but at the expense of higher energy use.

Standard 62.1 CO_2 Set Point Guidance†

Recommended maximum CO_2 is 90% of the steady state concentration:

$$CO_2 setpoint = 0.9\left[C_{OA} + \frac{8400Ezm}{Rp + (RaAz/Pz)}\right]$$

where C_{OA} is the outdoor air CO_2 concentration in ppm, E_z is the zone ventilation effectiveness, m is the metabolic rate of occupants, R_p is the people-based component of the ventilation rate, Ra is the area-based component of the ventilation rate, A_z is the zone floor area, and P_z is the number of occupants.

The CO_2 set points in Informative Table 3.1.1.3 assume an ambient concentration of 400 ppm in lieu of using an ambient CO_2 sensor. These sequences are based on not having an ambient sensor. This will be conservative in areas with high ambient CO_2 concentrations; few areas have lower concentrations.

Set points vary by occupancy type, so the easiest way to include this info is by including a column in VAV box and SZ unit schedules and entering the set point individually for each zone.

Demand controlled ventilation (DCV) is an active area of research under ASHRAE RP-1747, "Implementation of RP-1547 CO_2-Based Demand Controlled Ventilation for Multiple Zone HVAC Systems in Direct Digital Control Systems."

California Title 24 CO_2 Set Point Guidance

Title 24 stipulates the set point for all occupancies must be 600 ppm above ambient. Ambient concentration may be assumed to be 400 ppm, or an ambient sensor may be provided. These sequences are currently based on not having an ambient sensor, so the CO_2 set point for all occupancy types is 1000 ppm.

3.1.2 VAV Box Design Information

For the terminal unit sequences, the engineer must provide the set point information in the following subsections, typically on VAV box schedules on drawings.

3.1.2.1 VAV Cooling-Only Terminal Unit

a. Zone maximum cooling airflow set point (Vcool-max)
b. Zone minimum airflow set point (Vmin)

† **Source:** Lawrence, T. 2008. Selecting CO_2 criteria for outdoor air monitoring. *ASHRAE Journal* 50(12).

Informative Table 3.1.1.3 Default CO_2 Set Points per ASHRAE Standard 62.1

Occupancy Category	CO_2 Set Point, ppm	Occupancy Category	CO_2 Set Point, ppm
Correctional Facilities		**Office Buildings**	
Cell	965	Office space	894
Dayroom	1656	Reception areas	1656
Guard stations	1200	Telephone/data entry	1872
Booking/waiting	1200	Main entry/lobbies	1391
Educational Facilities		**Miscellaneous Spaces**	
Day care (through age 4)	1027	Bank vaults/safe deposit	805
Day care sickroom	716	Computer (not printing)	738
Classrooms (ages 5 to 8)	864	Pharmacy (preparation area)	820
Classrooms (ages 9+)	942	Photo studios	983
Lecture classroom	1305	Transportation waiting	1305
Lecture hall (fixed seats)	1305	**Public Assembly Spaces**	
Art classroom	837	Auditorium seating area	1872
Science laboratories	894	Place of religious worship	1872
University/college lab	894	Courtrooms	1872
Wood/metal shop	1156	Legislative chambers	1872
Computer lab	965	Libraries	805
Media center	965	Lobbies	2628
Music/theater/dance	1620	Museums (children's)	1391
Multiuse assembly	1778	Museum/galleries	1620
Food and Beverage Service		**Retail**	
Restaurant dining rooms	1418	Sales (except below)	1069
Cafeteria/fast-food dining	1536	Mall common areas	1620
Bars, cocktail lounges	1536	Barbershop	1267
General		Beauty and nail salons	723
Break rooms	1267	Pet shops (animal areas)	709
Coffee stations	1185	Supermarket	1116
Conference/meeting	1620	Coin-operated laundries	1322
Hotels, Motels, Resorts, Dormitories		**Sports and Entertainment**	
Bedroom/living area	910	Spectator areas	1778
Barracks sleeping areas	1116	Disco/dance floors	1440
Laundry rooms, central	1249	Health clubs/aerobics room	1735
Laundry within dwelling	983	Health clubs/weight room	1232
Lobbies/prefunction	1494	Bowling alley (seating)	1232
Multipurpose assembly	2250	Gambling casinos	1368
		Game arcades	894
		Stages, studios	1391

For ASHRAE Standard 62.1 ventilation, select Vmin to prevent creating critical zones. Critical zones are zones with the highest zone primary outdoor air fraction Zpz, which results in lower system ventilation efficiency Ev and higher effective minimum outdoor air set point MinOAsp. For calculation of MinOAsp for Standard 62.1 ventilation, see Section 5.16.3.1. This will lead to Vmin being higher than code minimum ventilation for all zones that require outdoor air. For California Title 24 ventilation, Vmin should be selected as the larger of Varea-min and Vocc-min, except for zones that have CO_2 DCV, for which Vmin should be equal to Varea-min. When selecting Vmin, do not consider the limitations of the VAV box controller to measure and control airflow; that is addressed by the control sequences themselves (see Section 5.1.16).

3.1.2.2 VAV Reheat Terminal Unit

a. Zone maximum cooling airflow set point (Vcool-max)
b. Zone minimum airflow set point (Vmin)

For ASHRAE Standard 62.1 ventilation, select Vmin to prevent creating critical zones. Critical zones are zones with the highest zone primary outdoor air fraction Zpz, which results in lower system ventilation efficiency Ev and higher effective minimum outdoor air set point MinOAsp. For calculation of MinOAsp for Standard 62.1 ventilation, see Section 5.16.3.1. This will lead to Vmin being higher than code minimum ventilation for all zones that require outdoor air. For California Title 24 ventilation, Vmin should be selected as the larger of Varea-min and Vocc-min, except for zones that have CO_2 DCV, for which Vmin should be equal to Varea-min. When selecting Vmin, do not consider the limitations of the VAV box controller to measure and control airflow; that is addressed by the control sequences themselves (see Section 5.1.16).

c. Zone maximum heating airflow set point (Vheat-max)

The design engineer should set Vheat-max such that the design heating load is met by Vheat-max airflow at a discharge air temperature (DAT) equal to MaxΔT plus the heating set point. MaxΔT can be no higher than 11°C (20°F) above space temperature set point per ASHRAE/IES Standard 90.1-2016 (e.g., DAT no more than 32°C [90°F] at 21°C [70°F] space temperature set point) for systems supplying air greater than 1.8 m (6 ft) above floor, e.g., ceiling supply systems. Zone air distribution effectiveness EzH can be improved if MaxΔT is less than 8°C (15°F), provided that the 0.8 m/s (150 fpm) supply air jet reaches to within 1.4 m (4.5 ft) of floor level as indicated in ASHRAE Standard 62.1-2016, Table 6.2.2.2.

d. Zone maximum DAT above heating set point (MaxΔT)
e. The heating minimum airflow set point (Vheat-min)

Vheat-min is the minimum airflow required for reheat coil operation, as is often required of electric resistance coils. It should be as low as possible for best efficiency. For reheat coils with no minimum flow requirement, such as hot-water coils, Vheat-min should be zero.

3.1.2.3 Parallel Fan-Powered Terminal Unit, Constant-Volume Fan

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

For ASHRAE Standard 62.1 ventilation, select Vmin to prevent creating critical zones. Critical zones are zones with the highest zone primary outdoor air fraction Zpz, which results in lower system ventilation efficiency Ev and higher effective minimum outdoor air set point MinOAsp. For calculation of MinOAsp for Standard 62.1 ventilation, see Section 5.16.3.1. This will lead to Vmin being higher than code minimum ventilation for all zones that require outdoor air. For California Title 24 ventilation, Vmin should be selected as the larger of Varea-min and Vocc-min, except for zones that have CO_2 DCV, for which Vmin should be equal to Varea-min. When selecting Vmin, do not consider the limitations of the VAV box controller to measure and control airflow; that is addressed by the control sequences themselves (see Section 5.1.16).

c. Zone maximum DAT above heating set point (MaxΔT)

3.1.2.4 Parallel Fan-Powered Terminal Unit, Variable-Volume Fan

Fans powered by electronically commutated motors (ECMs) must be programmed with the relationship between control signal and airflow. ECMs can be programmed to control either a specific airflow (with fan curve mapped into logic) or torque (pressure dependent airflow). For these sequences, the ECM fan should be configured for airflow control. This must be addressed by the design engineer in terminal-unit specifications.

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

For ASHRAE Standard 62.1 ventilation, select Vmin to prevent creating critical zones. Critical zones are zones with the highest zone primary outdoor air fraction Zpz, which results in lower system ventilation efficiency Ev and higher effective minimum outdoor air set point MinOAsp. For calculation of MinOAsp for Standard 62.1 ventilation, see Section 5.16.3.1. This will lead to Vmin being higher than code minimum ventilation for all zones that require outdoor air. For California Title 24 ventilation, Vmin should be selected as the larger of Varea-min and Vocc-min, except for zones that have CO_2 DCV, for which Vmin should be equal to Varea-min. When selecting Vmin, do not consider the limitations of the VAV box controller to measure and control airflow; that is addressed by the control sequences themselves (see Section 5.1.16).

c. Parallel fan maximum heating airflow set point (Pfan-htgmax)

The design engineer should set Pfan-htgmax such that the design heating load is met by the sum of Pfan-htgmax and Vmin at a DAT equal to MaxΔT plus the heating set point. MaxΔT can be no higher than 11°C (20°F) above space temperature set point per ASHRAE/IES Standard 90.1-2016 (e.g., DAT no more than 32°C [90°F] at 21°C [70°F] space temperature set point) for systems supplying air greater than 1.8 m (6 ft) above floor, e.g., ceiling supply systems. Zone air distribution effectiveness EzH can be improved if MaxΔT is less than 8°C (15°F), provided that the 0.8 m/s (150 fpm) supply air jet reaches to within 1.4 m (4.5 ft) of floor level as indicated in ASHRAE Standard 62.1-2016, Table 6.2.2.2. This can be done in most zones by setting Pfan-htgmax to ensure these conditions are maintained.

d. Zone maximum DAT above heating set point (MaxΔT)

3.1.2.5 Series Fan-Powered Terminal Unit, Constant-Volume Fan

a. Zone maximum cooling airflow set point (Vcool-max)
b. Zone minimum airflow set point (Vmin)

For ASHRAE Standard 62.1 ventilation, select Vmin to prevent creating critical zones. Critical zones are zones with the highest zone primary outdoor air fraction Zpz, which results in lower system ventilation efficiency Ev and higher effective minimum outdoor air set point MinOAsp. For calculation of MinOAsp for Standard 62.1 ventilation, see Section 5.16.3.1. This will lead to Vmin being higher than code minimum ventilation for all zones that require outdoor air. For California Title 24 ventilation, Vmin should be selected as the larger of Varea-min and Vocc-min, except for zones that have CO_2 DCV for which Vmin should be equal to Varea-min. When selecting Vmin, do not consider the limitations of the VAV box controller to measure and control airflow; that is addressed by the control sequences themselves (see Section 5.1.16).

Series fan airflow is not a design variable because it is not controlled. It must be designed and balanced to be equal to or greater than Vcool-max. Typically, the series fan airflow is equal to Vcool-max but may be higher if some blending is desired, such as on cold primary air systems. It may also be higher to improve zone air distribution effectiveness.

The design engineer should set the series fan airflow such that the design heating load is met with a DAT equal to MaxΔT plus the heating set point. MaxΔT can be no higher than 11°C (20°F) above space temperature set point per Standard 90.1-2016 (e.g., DAT no more than 32°C [90°F] at 21°C [70°F] space temperature set point) for systems supplying air greater than 1.8 m (6 ft) above floor, e.g., ceiling supply systems. Zone air distribution effectiveness EzH can be improved if MaxΔT is less than 8°C (15°F), provided that the 0.8 m/s (150 fpm) supply air jet reaches to within 1.4 m (4.5 ft) of floor level as indicated in ASHRAE Standard 62.1-2016, Table 6.2.2.2. This can be done in most zones by setting the series fan airflow to ensure these conditions are maintained.

c. Zone maximum DAT above heating set point (MaxΔT)

3.1.2.6 Series Fan-Powered Terminal Unit, Variable-Volume Fan

Fans powered by electronically commutated motors (ECMs) must be programmed with the relationship between control signal and airflow. ECMs can be programmed to control either a specific airflow (with fan curve mapped into logic) or torque (pressure dependent airflow). For these sequences, the ECM fan should be configured for airflow control. This must be addressed by the design engineer in terminal unit specifications.

a. Zone maximum cooling airflow set point (Vcool-max)
b. Zone minimum airflow set point (Vmin)

For ASHRAE Standard 62.1 ventilation, select Vmin to prevent creating critical zones. Critical zones are zones with the highest zone primary outdoor air fraction Zpz, which results in lower system ventilation efficiency Ev and higher effective minimum outdoor air set point MinOAsp. For calculation of MinOAsp for Standard 62.1 ventilation, see Section 5.16.3.1. This will lead to Vmin being higher than code minimum ventilation for all zones that require outdoor air. For California Title 24 ventilation, Vmin should be selected as the larger of Varea-min and Vocc-min, except for zones that have CO_2 DCV, for which Vmin should be equal to Varea-min. When selecting Vmin, do not consider the limitations of the VAV box controller to measure and control airflow; that is addressed by the control sequences themselves (see Section 5.1.16).

c. Series fan maximum heating airflow set point (Sfan-htgmax)

The design engineer should set Sfan-htgmax such that the design heating load is met by the sum of Sfan-htgmax and Vmin at a DAT equal to MaxΔT plus the heating set point. MaxΔT can be no higher than 11°C (20°F) above space temperature set point per Standard 90.1-2016 (e.g., DAT no more than 32°C [90°F] at 21°C [70°F] space temperature set point) for systems supplying air greater than 1.8 m (6 ft) above floor, e.g., ceiling supply systems. Zone air distribution effectiveness EzH can be improved if MaxΔT is less than 8°C (15°F), provided that the 0.8 m/s (150 fpm) supply air jet reaches to within 1.4 m (4.5 ft) of floor level as indicated in ASHRAE Standard 62.1-2016, Table 6.2.2.2. This can be done in most zones by setting Sfan-htgmax to ensure these conditions are maintained.

d. Zone maximum DAT above heating set point (MaxΔT)

3.1.2.7 Dual-Duct VAV Terminal Unit

a. Zone maximum cooling airflow set point (Vcool-max)

For ASHRAE Standard 62.1 ventilation, select Vmin to prevent creating critical zones. Critical zones are zones with the highest zone primary outdoor air fraction Zpz, which results in lower system ventilation efficiency Ev and higher effective minimum outdoor air set point MinOAsp. For calculation of MinOAsp for Standard 62.1 ventilation, see Section 5.16.3.1.

Informative Table 3.1.3 Example Zone-Group Table

Zone Group Name	AH Tag	Terminal Unit Tags	Default Schedule
First-floor assembly	AH-1	VAV-1-1 through 11	WD: 6 am to 8pm WE: 8 am to 10pm HOL: OFF
Second-floor office	AH-1	VAV-2-1 through 15	WD: 7 am to 7 pm SAT: 9 am to 2 pm SUN: OFF HOL: OFF
IDF rooms	AH-1	VAV-1-12, VAV-2-16	ALL: 12 am to 12 am
First-floor lobby	AH-2		WD: 6 am to 8 pm WE: 8 am to 10 pm HOL: OFF

This will lead to Vmin being higher than code minimum ventilation for all zones that require outdoor air. For California Title 24 ventilation, Vmin should be selected as the larger of Varea-min and Vocc-min. When selecting Vmin, do not consider the limitations of the VAV box controller to measure and control airflow; that is addressed by the control sequences themselves (see Section 5.1.16).

b. Zone minimum airflow set point (Vmin)
c. Zone maximum heating airflow set point (Vheat-max)

3.1.3 Zone Group Assignments

Zones must be assigned to zone groups, such as by using a table (see example Informative Table 3.1.3) either on drawings or in Building Automation System (BAS) specifications. Other formats may be used if they convey the same information.

Guidance for Zone Group Assignments

- *Each zone served by a single-zone air handler shall be its own Zone Group.*
- *Rooms*
- *occupied 24/7, such as computer rooms, networking closets, mechanical, and electrical rooms served by the air handler shall be assigned to a single Zone Group. These rooms do not apply to the zone group restrictions below.*
- *A Zone Group shall not span floors (per*
- *Section 6.4.3.3.4 of ASHRAE 90.1 2016).*
- *A Zone Group shall not exceed 2,300 m^2 (25,000 ft^2) (per Section 6.4.3.3.4 of ASHRAE 90.1 2016).*
- *If future occupancy patterns are known, a single Zone Group shall not include spaces belonging to more than one tenant.*
- *A zone shall not be a member of more than one zone group.*

3.1.4 Multiple-Zone VAV Air-Handler Design Information

3.1.4.1 Temperature Set Points

AHU set points required by the designer are best conveyed in equipment schedules because the set points vary for each AHU.

a. Min_ClgSAT, lowest cooling supply air temperature set point

The Min_ClgSAT variable should be set no lower than the design coil leaving air temperature to prevent excessive CHW temperature reset requests, which will reduce chiller plant efficiency.

b. Max_ClgSAT, highest cooling supply air temperature set point

The Max_ClgSAT variable is typically 18°C (65°F) in mild and dry climates and 16°C (60°F) or lower in humid climates. It should not typically be greater than 18°C (65°F) because this may lead to excessive fan energy that can offset the mechanical cooling savings from economizer operation.

c. OAT_Min, the lower value of the OAT reset range
d. OAT_Max, the higher value of the OAT reset range

Occupied mode supply air temperature set-point reset logic uses a combination of reset by outdoor air temperature (intended to reduce fan energy during warm weather) and zone feedback (SAT needed to satisfy the zone requiring the coldest air to meet space temperature set point). OAT_Min and OAT_Max define the range of outdoor air temperatures used for the OAT reset logic. Typical values are OAT_Min = 16°C (60°F) and OAT_Max = 21°C (70°F), selected to maximize economizer operation and minimize reheat losses, offset partially by higher fan energy. A lower range, e.g., 18°C (65°F) and 13°C (55°F), respectively, may improve net energy performance for some applications:

- *The chiller plant operates continuously, so extended economizer operation does not reduce plant runtime.*
- *The system has very little reheat inherently, such as dual-fan dual-duct systems or fan-powered box systems with very low primary air minimums.*
- The climate is warm or humid, limiting available economizer hours.

3.1.4.2 Ventilation Set Points

a. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1:
   1. DesVou, the uncorrected design outdoor air rate, including diversity where applicable
   2. DesVot, design total outdoor air rate (Vou adjusted for ventilation efficiency)

DesVou and DesVot can be determined using the 62MZCalc spreadsheet provided with Standard 62.1 User's Manual.

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b. For projects complying with California Title 24 Ventilation Standards:
   1. AbsMinOA, the design outdoor air rate when all zones with CO_2 sensors or occupancy sensors are unpopulated
   2. DesMinOA, the design minimum outdoor airflow with areas served by the system are occupied at their design population, including diversity where applicable

3.1.4.3 Economizer High Limit

The engineer must select between economizer high-limit options:

- **If the project is to comply with ASHRAE/IES Standard 90.1 economizer high-limit requirements, keep subsection (a) and delete subsection (b).**
- **If the project is to comply with California Title 24 economizer high-limit requirements, keep subsection (b) and delete subsection (a).**

The control logic will automatically select the correct set points based on climate zone and high-limit type selected. Note that points lists and schematics show herein do not include enthalpy sensors; they must be added if the designer wishes to use high-limit logic that includes enthalpy.

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a. ASHRAE/IES Standard 90.1 economizer high limit
   1. Select ASHRAE climate zone number and suffix in which air handling system is located.
   2. Choose one of the following high limit options:
      i. Fixed dry bulb
      ii. Differential dry bulb

While not listed as such in Standard 90.1, it is possible to use both fixed and differential dry-bulb high limits.

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      iii. Fixed dry bulb + differential dry bulb
      iv. Fixed enthalpy + fixed dry bulb
      v. Differential enthalpy + fixed dry bulb

b. California Title 24 economizer high limit
   1. Indicate California climate zone number in which air-handling system is located.
   2. Choose one of the following high limit options:
      i. Fixed dry bulb
      ii. Differential dry bulb

While not listed as such in Title 24, it is possible to use both fixed and differential dry-bulb high limits.

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      iii. Fixed dry bulb + differential dry bulb
      iv. Fixed enthalpy + fixed dry bulb

3.1.5 Dual-Fan Dual-Duct VAV Air-Handler Design Information

3.1.5.1 Temperature Set Points

a. Max_HtgSAT, highest heating supply air temperature, typically design heating coil leaving air temperature

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Max_HtgSAT can be no higher than 11°C (20°F) above space temperature set point per Standard 90.1-2016 (e.g., no more than 32°C [90°F] at 21°C [70°F] space temperature set point) for systems supplying air greater than 1.8 m (6 ft) above floor, e.g., ceiling supply systems. Zone air distribution effectiveness EzH can be improved if Max_HtgSAT is less than 8°C (15°F), provided that the 0.8 m/s (150 fpm) supply air jet reaches to within 1.4 m (4.5 ft) of floor level as indicated in ASHRAE Standard 62.1-2016, Table 6.2.2.2.

3.1.6 Single-Zone VAV Air-Handler Design Information

3.1.6.1 Set Points

a. Cool_SAT, lowest cooling supply air temperature set point
b. Heat_SAT, highest heating supply air temperature set point

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Cool_SAT is typically the design coil leaving air temperature. Heat_SAT is typically the design coil leaving air temperature, no more than 11°C (20°F) above the active heating set point.

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c. MaxDPT, maximum supply air dew-point temperature

MaxDPT is used to limit supply air temperature to ensure that supply air is not too humid resulting in high space humidity. This is typically only needed in humid type "A" climates, A typical value is 17°C (62°F). For mild and dry climates, a high set point (e.g. 24°C [75°F]) should be entered for maximum efficiency.

3.1.6.2 Economizer High Limit

The engineer must select between economizer high-limit options:

- **If the project is to comply with ASHRAE/IES Standard 90.1 economizer high-limit requirements, keep subsection (a) and delete subsection (b).**
- **If the project is to comply with California Title 24 economizer high limit requirements, keep subsection (b) and delete subsection (a).**

The control logic will automatically select the correct set points based on thermal zone and high-limit type selected. Note that points lists and schematics show herein do not include enthalpy sensors; they must be added if the designer wishes to use high-limit logic that includes enthalpy.

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a. ASHRAE 90.1 economizer high limit
   1. Select ASHRAE thermal zone number and suffix in which air handling system is located.
   2. Choose one of the following high limit options:
      i. Fixed dry bulb
      ii. Differential dry bulb

While not listed as such in Standard 90.1, it is possible to use both fixed and differential dry-bulb high limits.

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      iii. Fixed dry bulb + differential dry bulb
      iv. Fixed enthalpy + Fixed dry bulb
      v. Differential enthalpy + fixed dry bulb

b. California Title 24 economizer high limit
   1. Indicate California thermal zone number in which air handling system is located.
   2. Choose one of the following high limit options:
      i. Fixed dry bulb
      ii. Differential dry bulb

While not listed as such in Title 24, it is possible to use both fixed and differential dry-bulb high limits.

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      iii. Fixed dry bulb + differential dry bulb
      iv. Fixed enthalpy + fixed dry bulb

3.2 Information Provided by (or in Conjunction with) the Testing, Adjusting, and Balancing Contractor

3.2.1 Multiple-Zone Air-Handler Information

3.2.1.1 Duct Design Maximum Static Pressure Max_DSP

3.2.1.2 Minimum Fan Speed

a. Minimum speed set points for all VFD-driven equipment shall be determined in accordance with the testing, adjusting, and balancing (TAB) specifications for the following, as applicable:
   1. Supply fan
   2. Return fan
   3. Relief fan

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 equipment with gear boxes, use whatever minimum speed is recommended by the tower manufacturer.*
- *Observe the fan/pump in the field to ensure it is visibly rotating. If it is not, gradually increase speed until it is.*
- *The speed at this point shall be the minimum speed set point for this piece of equipment.*

3.2.1.3 Ventilation Plenum Pressures. (For minimum outdoor air control with separate outdoor air damper and differential pressure [DP] control, see Section 5.16.4.)

a. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1:
   1. DesMinDP, the design minimum outdoor air damper DP that provides the design minimum outdoor airflow DesVot

b. For projects complying with California Title 24 Ventilation Standards:
   1. AbsMinDP, the absolute minimum outdoor air damper DP that provides an outdoor airflow equal to the absolute minimum outdoor airflow AbsMinOA
   2. DesMinDP, the design minimum outdoor air damper DP that provides the design minimum outdoor airflow DesMinOA.

Instructions for establishing MinDP are given in the TAB specification. For example:

a. Open the minimum outdoor air damper and return air damper fully; close the economizer outdoor air damper.

b. Measure outdoor airflow.

c. If outdoor airflow rate is above design minimum (DesVot for ASHRAE Standard 62.1 or DesMinOA for California Title 24), adjust damper linkage on minimum outdoor air damper so that intake is at design minimum with damper fully stroked.

d. If outdoor airflow rate is below design minimum, temporarily adjust return air damper position via the BAS 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.

e. Note DP across the outdoor air damper. This value becomes the design minimum outdoor air DP set point DesMinDP in the BAS. Convey this set point to BAS installer and note on air balance report.

f. 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 set point (AbsMinOA for California Title 24) on AHU schedule.

g. Note DP across the outdoor air damper. This value becomes the absolute minimum outdoor air DP set point (AbsMinDP for California Title 24) in the BAS. Convey this set point to BAS installer and note on air balance report.

3.2.1.4 Return-Fan Discharge Static Pressure Set Points. (For return-fan direct building pressure control, see Section 5.16.10.)

a. **RFDSPmin.** 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 set point shall be no less than 2.4 Pa (0.01 in. of water) to ensure outdoor air is not drawn backwards through the relief damper.

b. **RFDSPmax.** That required to exhaust enough air to maintain building static pressure at set point 12 Pa (0.05 in. of water) when the supply air fan is at design airflow and on 100% outdoor air.

3.2.1.5 Return-Fan Airflow Differential. (For return-fan airflow tracking control, see Section 5.16.11.)

a. **S-R-DIFF.** The airflow differential between supply air and return air fans required to maintain building pressure at desired pressure (e.g., 12 Pa [0.05 in. of water]) using a handheld sensor if a permanent sensor is not provided. All exhaust fans that normally operate with the air handler should be on.

3.2.2 Single-Zone Air-Handler Information

3.2.2.1 Fan Speed Set Points

a. **MinSpeed.** The speed that provides supply airflow equal to DesOA (see Section 3.2.2.2) with the economizer outdoor air damper fully open.
b. **MaxHeatSpeed.** The speed that provides supply airflow equal to the design heating airflow scheduled on plans. If no heating airflow is provided on plans, default to half of the maximum cooling speed.
c. **MaxCoolSpeed.** The speed that provides supply airflow equal to the design cooling airflow scheduled on plans.

3.2.2.2 Minimum Outdoor Air Damper Positions

The engineer must select between options for determining the outdoor airflow set point.

- **If the project is to comply with ASHARE Standard 62.1 ventilation requirements, keep subsection (a) and delete subsection (b).**
- **If the project is to comply with California Title 24, keep subsection (b) and delete subsection (a).**

---

a. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1, for purposes of determining outdoor air damper positions in (c) through (f):
   1. MinOA shall equal Vbz-A/EzC.
   2. DesOA shall equal (Vbz-A + Vbz-P)/EzH.
b. For projects complying with the Title 24 Ventilation Rates, for purposes of determining outdoor air damper positions in (c) through (f):
   1. MinOA shall equal Varea-min.
   2. DesOA shall equal the larger of Varea-min and Vocc-min
c. **MinPosMin.** The outdoor air damper position required to provide MinOA when the supply fan is at MinSpeed.
d. **MinPosMax.** The outdoor air damper position required to provide MinOA when the supply fan is at MaxCoolSpeed.
e. **DesPosMin.** The outdoor air damper position required to provide DesOA when the supply fan is at MinSpeed.
f. **DesPosMax.** The outdoor air damper position required to provide DesOA when the supply fan is at MaxCoolSpeed.

3.2.2.3 Relief-Damper Positions (if nonpowered relief)

a. **MinRelief.** The relief-damper position that maintains a building pressure of 12 Pa (0.05 in. of water) while the system is at MinPosMin (i.e., the economizer damper is positioned to provide MinOA while the supply fan is at minimum speed).
b. **MaxRelief.** The relief-damper position that maintains a building pressure of 12 Pa (0.05 in. of water) while the economizer damper is fully open and the fan speed is at cooling maximum.

3.2.2.4 Return-Fan Speed Differential (if return fan is used) S-R-DIFF. The speed differential between supply air and return air fans required to maintain building pressure at desired pressure (e.g., 12 Pa [0.05 in. of water]) using a handheld sensor if a permanent sensor is not provided. All exhaust fans that normally operate with the air handler should be on.

4. LIST OF HARDWIRED POINTS

This section provides, for various equipment, a list of the minimum points required in order to implement the sequences as written. Points listed as "if applicable" are required if, and only if, the associated hardware is installed. The points listed that are required to implement the basic sequences of control have an "R" in the "Required" column; points that apply only if included by the designer for some applications have an "A" in this column; points included as optional monitoring points only have an "O" in this column; alarms are included for these points, but they are not used for sequences of operation. Additional points may be specified as desired. The design engineer should edit these lists as required for the project.

Point Types

AO = analog output

DO = digital output (also, BO = binary output)

AI = analog input

DI = digital input (aka BI = Binary Input)

Note that terminal-unit discharge air sensors are actively used for control and, therefore, must be reasonably accurate. If a single-point-probe type sensor is used, it should be located at least five duct diameters downstream of the coil due to stratification off of the heating coil, particularly at low loads. However, this is seldom practical in practice. If an averaging type sensor is used, it should be located at least 12 in. downstream of the coil if possible and 6 in. at a minimum. Averaging sensors are costlier and may present installation issues, especially if installed after ductwork is fully installed, which is typically the case. Reasonable results can be obtained by using a single-point-probe sensor mounted as far from the coil as possible but upstream of the first diffuser with the probe located as near as possible to the center of the duct both vertically and horizontally.

Occupancy sensors are listed as an optional hardwired point. This point is also commonly a software point mapped from a networked lighting control system or security system.

4.1 VAV Terminal Unit—Cooling Only

Required?	Description	Type	Device
R	VAV box damper position	AO **OR** two DOs	Modulating actuator **OR** Floating actuator
R	Discharge airflow	AI	Differential pressure (DP) transducer connected to flow sensor
R	Zone temperature	AI	Room temperature sensor
A	Local override (if applicable)	DI	Zone thermostat override switch
A	Occupancy sensor (if applicable)	DI	Occupancy sensor
A	Window switch (if applicable)	DI	Window switch
A	Zone temperature set point adjustment (if applicable)	AI	Zone thermostat adjustment
A	Zone CO_2 level (if applicable)	AI	Room CO_2 sensor

4.2 VAV Terminal Unit with Reheat

Required?	Description	Type	Device
R	VAV box damper position	AO **OR** two DOs	Modulating actuator **OR** Floating actuator
R	Heating signal	AO **OR** two DOs	Modulating valve **OR** Floating actuator **OR** Modulating electric heating coil
R	Discharge airflow	AI	DP transducer connected to flow sensor
R	Discharge air temperature (DAT)	AI	Duct temperature sensor (probe or averaging at designer's discretion)
R	Zone temperature	AI	Room temperature sensor
A	Local override (if applicable)	DI	Zone thermostat override switch
A	Occupancy sensor (if applicable)	DI	Occupancy sensor
A	Window switch (if applicable)	DI	Window switch
A	Zone temperature set point adjustment (if applicable)	AI	Zone thermostat adjustment
A	Zone CO_2 level (if applicable)	AI	Room CO_2 sensor

4.3 Fan-Powered Terminal Unit (Series or Parallel, Constant- or Variable-Speed Fan)

Required?	Description	Type	Device
A	Fan speed command (if applicable)	AO	Connect to electronically commutated motor (ECM)
R	Fan start/stop (if separate from fan speed point)	DO	Connect to ECM
O	Fan status **OR** Fan speed feedback	DI **OR** AI	Connect to current switch **OR** Connect to ECM
R	VAV box damper position	AO **OR** two DOs	Modulating actuator **OR** Floating actuator
R	Heating signal	AO **OR** two DOs	Modulating valve **OR** Floating actuator **OR** Modulating electric heating coil
R	Primary airflow	AI	DP transducer connected to flow sensor
R	Discharge air temperature (DAT)	AI	Duct temperature sensor (probe or averaging at designer's discretion)
R	Zone temperature	AI	Room temperature sensor
A	Local override (if applicable)	DI	Zone thermostat override switch
A	Occupancy sensor (if applicable)	DI	Occupancy sensor
A	Window switch (if applicable)	DI	Window switch
A	Zone temperature set point adjustment (if applicable)	AI	Zone thermostat adjustment
A	Zone CO_2 level (if applicable)	AI	Room CO_2 sensor

4.4 Dual-Duct Terminal Unit with Inlet Sensors

Required?	Description	Type	Device
R	Cooling damper position	AO **OR** two DOs	Modulating actuator **OR** Floating actuator
R	Heating damper position	AO **OR** two DOs	Modulating actuator **OR** Floating actuator
R	Cooling airflow	AI	DP transducer connected to flow sensor
R	Heating airflow	AI	DP transducer connected to flow sensor
R	Zone temperature	AI	Room temperature sensor
A	Local override (if applicable)	DI	Zone thermostat override switch
A	Occupancy sensor (if applicable)	DI	Occupancy sensor
A	Window switch (if applicable)	DI	Window switch
A	Zone temperature set point adjustment (if applicable)	AI	Zone thermostat adjustment
A	Zone CO_2 level (if applicable, cold-duct minimum control only)	AI	Room CO_2 sensor

4.5 Dual-Duct Terminal Unit with Discharge Sensor

Required?	Description	Type	Device
R	Cooling damper position	AO **OR** two DOs	Modulating actuator **OR** Floating actuator
R	Heating damper position	AO **OR** two DOs	Modulating actuator **OR** Floating actuator
R	Discharge airflow	AI	DP transducer connected to flow sensor
R	Zone temperature	AI	Room temperature sensor
A	Local override (if applicable)	DI	Zone thermostat override switch
A	Occupancy sensor (if applicable)	DI	Occupancy sensor
A	Window switch (if applicable)	DI	Window switch
A	Zone temperature set point adjustment (if applicable)	AI	Zone thermostat adjustment
A	Zone CO_2 level (if applicable, mixing control only)	AI	Room CO_2 sensor

4.6 Multiple-Zone VAV Air-Handling Unit

Required?	Description	Type	Device
R	Supply fan start/stop	DO	Connect to VFD Run
A	Supply fan high static alarm reset (optional—see control schematic)	DO	Dry contact to 120 or 24 V control circuit
R	Supply fan speed	AO	Connect to VFD Speed
O	Supply fan status	DI	Connect to VFD Status
R	Supply air temperature	AI	Duct temperature sensor (probe or averaging at designer's discretion)
R	Duct static pressure (DSP)	AI	DP transducer down duct
O	Filter pressure drop	AI	DP transducer across filter
O	Heating coil supply air temperature	AI	Averaging temperature sensor
R	Economizer outdoor air damper	AO	Modulating actuator
R	Return air damper	AO	Modulating actuator
R	Outdoor air temperature	AI	Temperature sensor at outdoor air intake
O	Mixed air temperature	AI	Averaging temperature sensor
A	Return air temperature	AI	Duct temperature sensor
R	Cooling signal	AO	Modulating CHW valve
A	Heating signal	AO	Modulating HW valve **OR** Modulating electric heating coil
For units with a common economizer/minimum OA damper, include the following points.			
A	Outdoor airflow	AI	Airflow measurement station (AFMS)
For units with a separate minimum outdoor air damper and DP sensor, include the following points.			
A	Minimum outdoor air damper open/close	DO	Two position actuator
A	Minimum outdoor air damper DP	AI	DP transducer

Required?	Description	Type	Device
For units with a separate minimum outdoor air damper and AFMS, include the following points.			
A	Minimum outdoor air damper	AO	Modulating actuator
A	Minimum outdoor airflow	AI	Airflow measurement station
For units with actuated relief dampers but no relief fan, include the following points.			
A	Relief damper open/close	AO	Modulating actuator
A	Building static pressure	AI	DP transducer between representative space and outdoors
For units with a relief fan, include the following points.			
A	Relief-fan start/stop	DO	Connect to VFD Run
O	Relief-fan status	DI	Connect to VFD Status
A	Relief-fan speed	AO	Connect to VFD Speed
A	Relief damper open/close	DO	Two position actuator
A	Building static pressure (if direct building pressure logic is used)	AI	DP transducer between representative space and outdoors
For units with a return fan, include the following points.			
A	Return fan start/stop	DO	Connect to VFD Run
O	Return-fan status	DI	Connect to VFD Status
A	Return-fan high-static alarm reset (optional—see control schematic)	DO	Dry contact to 120V or 24V control circuit
A	Return-fan speed	AO	Connect to VFD Speed
A	Supply airflow (if airflow tracking logic used)	AI	Airflow measurement station at supply fan (or sum of VAV zones)
A	Return airflow (if airflow tracking logic used)	AI	Airflow measurement station at return fan
A	Return-fan discharge static pressure (if direct building pressure logic is used)	AI	DP transducer at fan
A	Exhaust damper	AO	Modulating actuator
A	Building static pressure (if direct building pressure logic is used)	AI	DP transducer between representative space and outdoors

4.7 Dual-Fan Dual-Duct Heating VAV Air-Handling Unit

Required?	Description	Type	Device
R	Supply fan start/stop	DO	Connect to VFD Run
A	Supply fan high static alarm reset (optional—see control schematic)	DO	Dry contact to 120 or 24 V control circuit
R	Supply fan speed	AO	Connect to VFD Speed
	Supply fan status	DI	Connect to VFD Status
R	Supply air temperature	AI	Duct temperature sensor (probe or averaging at designer's discretion)
R	Heating signal	AO	Modulating HW valve **OR** Modulating electric heating coil
R	Duct static pressure	AI	DP transducer down duct
O	Filter pressure drop	AI	DP transducer across filter
O	Return air temperature	AI	Duct temperature sensor

4.8 Single-Zone VAV Air-Handling Unit

Required?	Description	Type	Device
R	Supply fan start/stop	DO	Connect to VFD Run
R	Supply fan speed	AO	Connect to VFD Speed
O	Supply fan status	DI	Connect to VFD Status
R	Supply air temperature	AI	Duct temperature sensor (probe or averaging at designer's discretion)
R	Outdoor/return air damper	AO	Modulating actuators
R	Outdoor air temperature	AI	Temperature sensor at outdoor air intake
O	Mixed air temperature	AI	Averaging temperature sensor
O	Return air temperature	AI	Duct temperature sensor
R	Cooling signal	AO	Modulating CHW valve **OR** Variable-capacity compressor
A	Heating signal	AO	Modulating HW valve **OR** Modulating electric heating coil
R	Zone temperature	AI	Room temperature sensor
A	Local override (if applicable)	DI	Zone thermostat override switch
A	Occupancy sensor (if applicable)	DI	Occupancy sensor
A	Window switch (if applicable)	DI	Window switch
A	Zone temperature set point adjustment (if applicable)	AI	Zone thermostat adjustment
A	Zone CO_2 level (if applicable)	AI	Room CO_2 sensor
For units with actuated relief dampers but no relief fan, include the following points.			
A	Relief damper	AO	Modulating actuator
	For units with a relief fan, include the following points		

Required?	Description	Type	Device
A	Relief-fan start/stop	DO	Connect to VFD Run
O	Relief-fan status	DI	Connect to VFD Status
A	Relief-fan speed	AO	Connect to VFD Speed
A	Relief-damper open/close	DO	Two position actuator
A	Building static pressure	AI	DP transducer between representative space and outdoors
For units with a return fan, include the following points.			
A	Return fan start/stop	DO	Connect to VFD Run
O	Return-fan status	DI	Current switch
A	Return-fan speed	AO	Connect to VFD Speed
A	Exhaust air damper (if applicable—damper may be barometric)	DO	Two position actuator

5. SEQUENCES OF OPERATIONS

5.1 General

5.1.1 These sequences are intended to be performance based. Implementations that provide the same functional result using different underlying detailed logic will be acceptable.

The intention of these sequences is to specify the functional result of the programming logic. While all sequences are described using specific programming logic as a way to clearly document the resulting functionality, implementations using alternative logic that result in the same functional performance are acceptable. Verification of conformance to these sequences will eventually be through functional performance tests (FPTs) that demonstrate that the sequences were properly implemented, rather than verification of the detailed logic. FPTs for RP-1455 sequences are currently under development through RP-1746; they will be adapted to Guideline 36 sequences and issued as an appendix in a future addendum.

5.1.2 Unless otherwise indicated, control loops shall be enabled and disabled based on the status of the system being controlled to prevent windup.

5.1.3 When a control loop is enabled or reenabled, it and all its constituents (such as the proportional and integral terms) shall be set initially to a neutral value.

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

5.1.5 When there are multiple outdoor air temperature sensors, the system shall use the valid sensor that most accurately represents the outdoor air conditions at the equipment being controlled.

5.1.5.1 Outdoor air temperature sensors at air-handler outdoor air intakes shall be considered valid only when the supply fan is proven ON and the unit is in occupied mode or in any other mode with the economizer enabled.

5.1.5.2 The outdoor air temperature used for optimum start, plant lockout, and other global sequences shall be the average of all valid sensor readings. If there are four or more valid outdoor air temperature sensors, discard the highest and lowest temperature readings.

5.1.6 The term "proven" (i.e., "proven ON"/"proven OFF") shall mean that the equipment's DI status point (where provided, e.g., current switch, DP switch, or VFD status) matches the state set by the equipment's DO command point.

5.1.7 The term "software point" shall mean an analog variable, and "software switch" shall mean a digital (binary) variable, that are not associated with real I/O points. They shall be read/write capable (e.g., BACnet analog variable and binary variable).

5.1.8 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 guidelines in the following subsections shall be followed.

5.1.8.1 Use proportional only (P-only) loops for limiting loops (such as zone CO_2 control loops, etc.).

Limiting loops are used to prevent controlled variables from rising above or dropping below set point (depending on the application) by defining a fixed threshold at which the loop output reaches 100%. Limiting loops should use proportional-only control to prevent integral windup from causing the controlled sensor to overshoot set point due to the sensor generally being far from set point.

5.1.8.2 Do not use the derivative term on any loops unless field tuning is not possible without it.

Use of the derivative term makes loop tuning difficult in practice. It can make loops unstable because it increases as the rate of change of the error increases, amplifying the error signal. It is used in industrial process controls and systems that have to react quickly but is rarely if ever needed in HVAC system.

5.1.9 To avoid abrupt changes in equipment operation, the output of every control loop shall be capable of being limited by a user adjustable maximum rate of change, with a default of 25% per minute.

5.1.10 All set points, timers, deadbands, PID gains, etc. listed in sequences shall be adjustable by the user with appropriate access level whether indicated as adjustable in sequences or not. Software points shall be used for these variables. Fixed scalar numbers shall not be embedded in programs except for physical constants and conversion factors.

5.1.11 Values for all points, including real (hardware) points used in control sequences shall be capable of being overridden by the user with appropriate access level (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. Exceptions shall be made for machine or life safety.

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 BAS overrides.

The requirement to equate hardware points to software points is necessary for systems that do not allow overriding real input points.

It is recommended that the user interface allow the user to set an expiration period that automatically releases the override after the period has expired. The system should also keep track of who initiates each override and when.

5.1.12 Alarms

Defining the operator's interface falls outside the scope of Guideline 36, but effective use of alarms by building personnel requires an effective user interface. We recommend including at least the following requirements in the specification for the BAS 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 level, latching (Requires Acknowledgment of a Return to Normal/Does Not Require Acknowledgment of a Return to Normal), entry delay, exit deadband, and postsuppression period.*
- *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, per Section 5.1.18, that serves the equipment in alarm.*

5.1.12.1 There shall be 4 levels of alarm

a. Level 1: Life-safety message
b. Level 2: Critical equipment message
c. Level 3: Urgent message
d. Level 4: Normal message

5.1.12.2 Maintenance Mode. Operators shall have the ability to put any device (e.g., AHU) in/out of maintenance mode.

a. All alarms associated with a device in maintenance mode will be suppressed. ***Exception:*** Life safety alarms shall not be suppressed.
b. If a device is in maintenance mode, issue a daily Level 3 alarm at a scheduled time indicating that the device is still in maintenance mode.

5.1.12.3 Entry Delays. All alarms shall have an adjustable delay time such that the alarm is not triggered unless the alarm condition is TRUE for the delay time. Default entry delays are as follows:

a. Level 1 alarms: 1 seconds
b. Level 2 alarms: 10 seconds
c. Level 3 alarms: 1 minutes
d. Level 4 alarms: 5 minutes

5.1.12.4 Exit Hysteresis

a. Each alarm shall have an adjustable time-based hysteresis (default: 5 seconds) to exit the alarm. Once set, the alarm does not return to normal until the alarm conditions have ceased for the duration of the hysteresis.
b. Each analog alarm shall have an adjustable percent-of-limit-based hysteresis (default: 0% of the alarm threshold, i.e., no hysteresis; alarm exits at the same value as the alarm threshold) the alarmed variable required to exit the alarm. Alarm conditions have ceased when the alarmed variable is below the triggering threshold by the amount of the hysteresis.

Examples of Exit Hysteresis

If a high-temperature alarm is triggered at 100°F and has an exit hysteresis of 5% for 1 minute, the alarm will remain active until the alarmed temperature drops below 95°F (100°F minus 5%) continuously for 1 minute.

If a low-pressure alarm is triggered at 0.5 in. of water and has exit hysteresis of 20% for 10 seconds, the alarm will remain active until the alarmed pressure rises above 0.6 in. of water (0.5 in. of water plus 20%) continuously for 10 seconds.

5.1.12.5 Latching. Any alarm can be configured as latching or nonlatching. A latching alarm requires acknowledgment from the operators before it can return to normal, even if the exit deadband has been met. A nonlatching alarm does not require acknowledgment. Default latching status is as follows:

a. Level 1 alarms: latching
b. Level 2 alarms: latching
c. Level 3 alarms: nonlatching
d. Level 4 alarms: nonlatching

5.1.12.6 Postexit Suppression Period. To limit alarms, any alarm may have an adjustable suppression period such that, if the alarm is triggered, its postsuppression timer is triggered and the alarm may not trigger again until the postsuppression timer has expired. Default suppression periods are as follows:

a. Level 1 alarms: 0 minutes
b. Level 2 alarms: 5 minutes
c. Level 3 alarms: 24 hours
d. Level 4 alarms: 7 days

Note that postsuppression only applies to a particular instance of an alarm, e.g., a high SAT alarm on AHU-1 will suppress more high SAT alarms on AHU-1 but not on AHU-2.

5.1.12.7 For both latching and nonlatching alarms, the operators may acknowledge the alarm. Acknowledging an alarm clears the alarm, the exit deadband, and suppression period. A device can go right back into alarm as soon as the entry delay elapses.

5.1.13 VFD Speed Points

To avoid operator confusion, the speed command point (and speed feedback point, if used) for VFDs should be configured so that a speed of 0% corresponds to 0 Hz, and 100% corresponds to maximum speed set in the VFD, not necessarily 60 Hz. The maximum speed may be limited below 60 Hz to protect equipment, or it may be above 60 Hz for direct drive equipment. Drives are often configured such that a 0% speed signal corresponds to the minimum speed programmed into the VFD, but that causes the speed AO value and the actual speed to deviate from one another.

5.1.13.1 The speed AO sent to VFDs shall be configured such that 0% speed corresponds to 0 Hz, and 100% speed corresponds to maximum speed configured in the VFD.

It is desirable that the minimum speed reside in the VFD to avoid problems when the VFD is manually controlled at the drive. But minimums can also be adjusted inadvertently in the VFD to a set point that is not equal to the minimum used in software. The following prevents separate, potentially conflicting minimum speed set points from existing in the BAS software and the drive firmware.

5.1.13.2 For each piece of equipment, the minimum speed shall be stored in a single software point. This value shall be written to the VFD's minimum speed set point every 15 minutes 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 BAS. See Section 3.2.1.2 for minimum speed set points.

5.1.14 Trim & Respond Set-Point Reset Logic

Trim & Respond (T&R) logic resets a set point for pressure, temperature, or other variables at an air handler or plant. It reduces the set point 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 set point 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 set point resumes decreasing at its fixed rate. A running total of the requests generated by each zone is kept to identify zones that are driving the reset logic.

T&R logic is optimal for controlling a single variable that is subject to the requirements of multiple downstream zones (such as the static pressure set point 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 nondisruptive.

See Section 5.1.14.4 for an example of T&R implementation.

5.1.14.1 T&R set-point reset logic and zone/system reset requests, where referenced in sequences, shall be implemented as described below.

5.1.14.2 A "request" is a call to reset a static pressure or temperature set point 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 that generated the request.

a. For each downstream zone or system, and for each type of set-point reset request listed for the zone/system, provide the following software points:
   1. **Importance-Multiplier (default = 1)**

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.

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   2. **Request-Hours Accumulator.** Provided SystemOK (see Section 5.1.18) is TRUE for the zone/system, every x minutes (default 5 minutes), add x divided by 60 times the current number of requests to this request-hours accumulator point.
   3. **System Run-Hours Total.** This is the number of hours the zone/system has been operating in any mode other than unoccupied mode.

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, because a single rogue zone can keep the T&R loop at maximum and prevent it from saving any energy.

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   4. **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.
   5. The Request-Hours Accumulator and System Run-Hours Total are reset to zero as follows:
      i. Reset automatically for an individual zone/system when the System Run-Hours Total exceeds 400 hours.

Table 5.1.14.3 Trim & Respond Variables

Variable	Definition
Device	Associated device (e.g., fan, pump)
SP0	Initial set point
SPmin	Minimum set point
SPmax	Maximum set point
Td	Delay timer
T	Time step
I	Number of ignored requests
R	Number of requests from zones/systems
SPtrim	Trim amount
SPres	Respond amount (must be opposite in sign to SPtrim)
SPres-max	Maximum response per time interval (must be same sign as SPres)

Informative Note: Note that it is recommended that |SPres| > |SPtrim| so that the reset logic does not become stuck at a value, as can happen if SPres and SPtrim are equal in absolute value. The number of ignored requests (I) should be set to zero for critical zones or air handlers.

ii. Reset manually by a global operator command. This command will simultaneously reset the Request-Hours point for all zones served by the system.

6. 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.

b. See zone and air-handling system control sequences for logic to generate requests.

c. 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 T&R logic.

5.1.14.3 For each upstream system or plant set point being controlled by a T&R loop, define the following variables. Initial values are defined in system/plant sequences below. Values for trim, respond, time step, etc. shall be tuned to provide stable control. See Table 5.1.14.3.

5.1.14.4 Trim & Respond logic shall reset the set point within the range SPmin to SPmax. When the associated device is OFF, the set point shall be SP0. The reset logic shall be active while the associated device is proven ON, starting Td after initial device start command. When active, every time step T, trim the set point by SPtrim. If there are more than I requests, respond by changing the set point by SPres*(R – I), (i.e., the number of requests minus the number of ignored requests) but no more than SPres-max. In other words, every time step T.

Change Set Point by SPtrim

If R > I, also change set point by (R – I)*SPres but no larger than SPres-max

Informative Table 5.1.14.4 Example Sequence T&R Variables

Variable	Definition
Device	Supply fan
SP0	120 Pa (0.5 in. of water)
SPmin	37 Pa (0.15 in. of water)
SPmax	370 Pa (1.50 in. of water)
Td	5
T	2
I	2
SPtrim	–10 Pa (–0.04 in. of water)
SPres	15 Pa (0.06 in. of water)
SPres-max	37 Pa (0.15 in. of water)

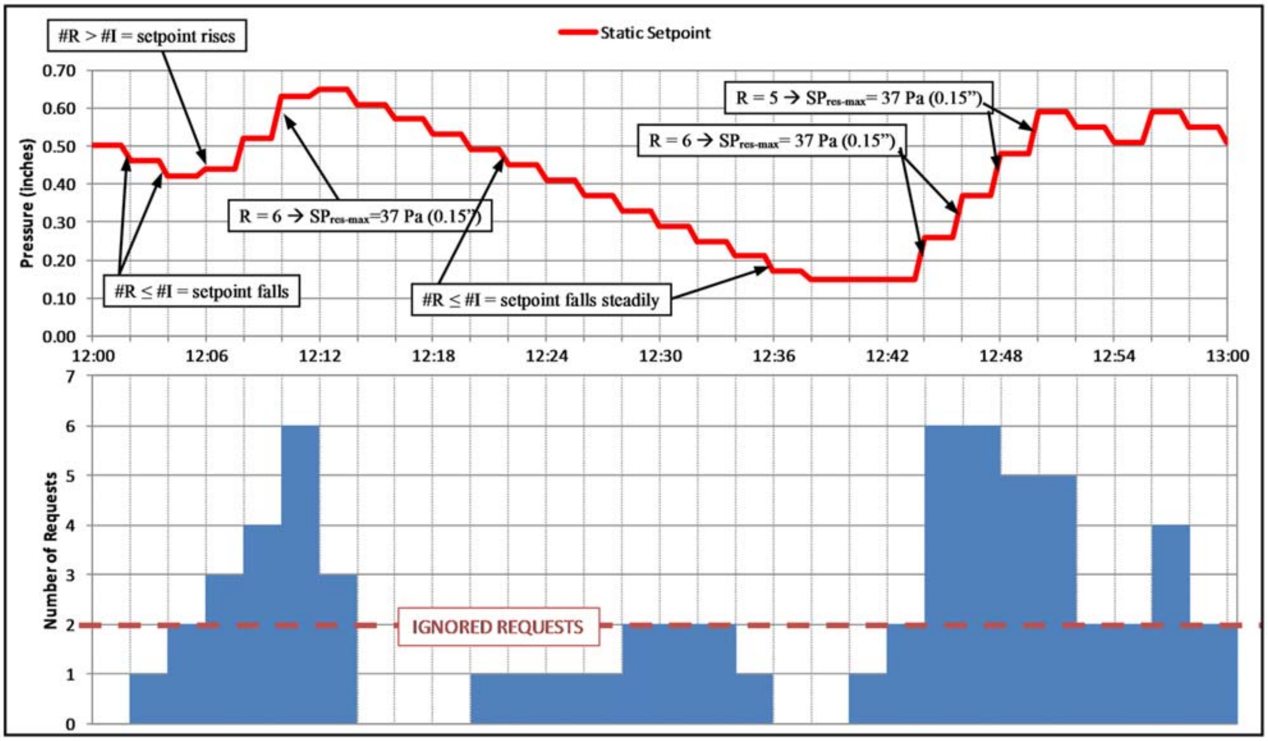
The following is an example of a sequence that uses T&R to control the static pressure set point of a VAV AHU serving multiple downstream zones. This sequence defines the T&R variables as shown in Informative Table 5.1.14.4.

Description of General Operation

Starting 5 minutes after the fan status indicates the supply fan is ON, the sequence will slowly reduce the AHUs static pressure set point by 10 Pa (0.04 in. of water) 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 more than 95% open, the system will respond by increasing static pressure set point by 15 Pa (0.06 in. of water) for every request but no more than a maximum of 37 Pa (0.15 in. of water), regardless of the number of requests. The set point will continue to increase every 2 minutes until all but 2 VAV boxes (for Ignored Request value of 2) are satisfied (damper position < 85%). Subsequently, the set point will continue to decrease by 10 Pa (0.04 in. of water) every 2 minutes.

Example

- *System starts at 11:55. Initial set point is 120 Pa (0.5 in. of water). At 12:00 (Td after start time), the reset begins.*
- *At 12:02 (i.e., 1*T after reset begins), there is one request (i.e., R = 1). Trim component reduces set point by SPtrim, which is 10 Pa (0.04 in. of water); because R – I < 0, there is no response component. Net result: set point is 110 Pa (0.46 in. of water).*
- *At 12:04 (i.e., 2*T), there are two requests (i.e., R = 2). Trim component reduces set point by 10 Pa (0.04 in. of water); because R – I = 0, there is no response component. Net result: set point is 100 Pa (0.42 in. of water).*
- *At 12:06 (i.e., 3*T), there are three requests (i.e., R = 3): Trim component reduces set point by 10 Pa (0.04 in. of water); because R – I = 1, response component increases set point by 15 Pa (0.06 in. of water) (i.e., 1*SPres). Net result: set point is 105 Pa (0.44 in. of water) (i.e., +5.0 Pa [+0.02 in. of water] net change).*



Informative Figure 5.1.14.4 Example sequence trend graph.

- *At 12:08 (i.e., 4*T), there are four requests (i.e., R = 4). Trim component reduces set point by 10 Pa (0.04 in. of water); because R – I = 2, response component increases set point by 30 Pa (0.12 in. of water) (i.e., 2*SPres). Net result: set point is 125 Pa (0.52 in. of water) (i.e., +20 Pa [+0.08 in. of water] net change).*
- *At 12:10 (i.e., 5*T), there are six requests (i.e., R = 6). Trim component reduces set point by 10 Pa (0.04 in. of water); because R – I = 4, but SPres $_{max}$ = 37 Pa (0.15 in. of water), response component increases set point by the maximum of 37 Pa (0.15 in. of water) (i.e., not 4*SPres = 60 Pa [0.24 in. of water]). Net result: set point is 152 Pa (0.63 in. of water) (i.e., 37 Pa [+0.15 in. of water] net change).*
- *At 12:12 (i.e., 6*T), there are three requests (i.e., R = 3). Trim component reduces set point by 10 Pa (0.04 in. of water); because R – I = 1, response component increases set point by 15 Pa (0.06 in. of water) (i.e., 1*SPres). Net result: set point is 157 Pa (0.65 in. of water).*
- *At 12:14 (i.e., 7*T), there are zero requests (i.e., R = 0). Trim component reduces set point by 10 Pa (0.04 in. of water); because R – I < 0, there is no response component. Net result: set point is 147 Pa (0.61 in. of water).*

Informative Figure 5.1.14.4 shows a trend graph of the example above, continued for a period of an hour.

The system will tend toward minimum static pressure (thus saving energy) but respond rapidly to increasing demand from the terminal units. A cyclic pattern is characteristic of a robust T&R loop—the set point is not expected to remain static except at its minimum and maximum values. Note that Informative Figure 5.1.14.4 was created to illustrate how requests are used to reset the set point and does not necessarily represent the expected behavior of an actual T&R loop, although the long, slow cycling of the set point value is typical of T&R control.

5.1.15 Equipment Staging and Rotation

Sequences for automatic lead/lag equipment staging and rotation will be added in a later version of Guideline 36.

5.1.15.1 Operators with appropriate access level shall be able to manually command staging order via software points, but not overriding the In-Alarm or Hand-Operation logic in the following subsections.

5.1.15.2 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 staging order until the alarm is reset by an operator. A device in alarm can only automatically move up in the staging order if another device goes into alarm.

This 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 call 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. 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 a hand-OFF-auto (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 that 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.

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a. Alarm conditions include the following:
   1. Variable-speed fans
      i. Status point not matching its ON/OFF point for 3 seconds after a time delay of 15 seconds while the device is commanded ON

Current scope of these sequences only include variable-speed fans. Pumps, chillers, and boilers are currently beyond the scope of Guideline 36. They will be incorporated into this logic as a part of RP-1711, which addresses sequences for central heating and cooling plants.

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b. **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 the following:

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).

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   2. Variable-speed fans
      i. Status point not matching its ON/OFF point for 15 seconds while the device is commanded OFF

Current scope of these sequences only include variable-speed fans. Pumps, chillers, and boilers are currently beyond the scope of Guideline 36. They will be incorporated into this logic as a part of RP-1711, which addresses sequences for central heating and cooling plants.

5.1.16 VAV Box Controllable Minimum

5.1.16.1 This section is used to determine the lowest possible VAV box airflow set point (other than zero) allowed by the controls (Vm) used in VAV box control sequences. The minimums shall be stored as software points.

5.1.16.2 Option 1. If the VAV box controls simply stop moving the damper when the airflow reading becomes too low to register, and then reenables the damper when the airflow reading rises above that threshold, Vm shall be equal to zero.

VAV box controllers that stop moving the damper when they are unable to read an airflow signal may avoid the need to determine a minimum. When given a set point below controllable minimum, the controller will control as low as it can, which is the desired behavior. This assumes that DSP will not decrease after this damper stop occurs, so this option is not always a reliable approach to maintaining minimum airflow. Option 2 is more fool-proof and is recommended for most applications.

5.1.16.3 Option 2. The minimum set point Vm shall be determined as follows:

a. Determine the velocity pressure sensor reading VPm in Pa (in. of water) 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 converter of 12 bits or counts (assuming a 10-bit A/D converter). This is considered sufficient resolution for stable control.

b. Determine the minimum velocity vm 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 vm as

$$vm = 1.28\sqrt{\frac{VPm}{F}} \quad \text{(SI)}$$

$$vm = 4005\sqrt{\frac{VPm}{F}} \quad \text{(I-P)}$$

Where F is not known, in I-P units it can be calculated from the measured airflow at 1 in. of water signal from the VP sensor

$$F = \left(\frac{4005A}{CFM_{@1\text{ in. of water}}}\right)^2$$

where A is the nominal duct area (ft^2), equal to

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

where D is the nominal duct diameter (in.).

c. Calculate the minimum airflow set point allowed by the controls (Vm) for each VAV box size as

$$Vm = vmA$$

5.1.17 Air Economizer High Limits

5.1.17.1 Economizer shall be disabled whenever the outdoor air conditions exceed the economizer high-limit set point as specified by local code. Set points shall be automatically determined by the control sequences (to ensure they are correct and meet code) based on energy standard, climate zone, and economizer high-limit-control device type selected by the design engineer in Section 3.1.4.3 or 3.1.6.2. Set points listed below are for current ASHRAE and California Energy Standards.

The engineer must specify the code basis of the economizer high limit and the high-limit control device being used. See Sections 3.1.4.3 and 3.1.6.2.

5.1.17.2 ASHRAE 90.1-2016

Device Type	Allowed only in these ASHRAE Climate Zones	Required High Limit (Economizer OFF when)
Fixed dry bulb	1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8	TOA > 24°C (75°F)
	5a, 6a	TOA > 21°C (70°F)
	1a, 2a, 3a, 4a	TOA > 18°C (65°F)
Differential dry bulb	1b, 2b, 3b, 3c, 4b, 4c,5a, 5b, 5c, 6a, 6b, 7, 8	TOA > TRA
Fixed enthalpy + fixed dry bulb	All	hOA > 66 kJ/kg (28 Btu/lb) or TOA > 24°C (75°F)
Differential enthalpy + fixed dry bulb	All	hOA > hRA TOA > 24°C (75°F)

5.1.17.3 Title 24-2016

Device Type	California Climate Zones	Required High Limit (Economizer OFF when)
Fixed dry bulb	1, 3, 5, 11 to 16	TOA > 24°C (75°F)
	2, 4, 10	TOA > 23°C (73°F)
	6, 8, 9	TOA > 22°C (71°F)
	7	TOA > 21°C (69°F)
Differential dry bulb	1, 3, 5, 11 to 16	TOA > TRA
	2, 4, 10	TOA > TRA – 1°C (2°F)
	6, 8, 9	TOA > TRA –2°C (4°F)
	7	TOA > TRA – 3°C (6°F)
Fixed enthalpy + fixed dry bulb	All	hOA > 66 kJ/kg (28 Btu/lb) or TOA > 24°C (75°F)

5.1.18 Damper/Valve Position

5.1.18.1 Knowledge of damper and valve position are required for proper generation of T&R reset requests.

5.1.18.2 The following are acceptable methods for determining position:

a. **Analog actuator.** Position may be assumed to be equal to analog signal to actuator.
b. **Floating actuator.** Provide either
   1. Position feedback AI

The engineer may choose to disallow the following option, which is less accurate than the other options for determining damper position, but doing so may limit controller manufacturer because not all manufacturers offer the other options.

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   2. Position estimated by timing pulse-open and pulse-closed commands with autozeroing whenever zone is in unoccupied mode and damper is driven full closed. This option is not acceptable for 24/7 applications.

5.1.19 Hierarchical Alarm Suppression

Hierarchical alarm suppression is described in the January 2006 HVAC&R Research paper, "A Hierarchical Rule-Based Fault Detection and Diagnostic Method for HVAC Systems," by Jeffrey Schein and Steven Bushby.

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, 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 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 down-

stream 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).

Note that this logic is intended to suppress alarm visual and audible displays, notifications (e.g., email or SMS), listing in primary alarm logs, and other actions that can distract the operator or make it more difficult to diagnose and respond to alarms. The alarm may still be generated and recorded to a database.

5.1.19.1 For each piece of equipment or space controlled by the BAS, define its relationship (if any) to other equipment in terms of "source," "load," or "system."

For equipment that participates in a T&R 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.

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a. A component is a "source" if it provides resources to a downstream component, such as a chiller providing chilled water (CHW) to an AHU.
b. A component is a "load" if it receives resources from an upstream component, such as an AHU that receives CHW from a chiller.
c. The same component may be both a load (receiving resources from an upstream source) and a source (providing resources to a downstream load).
d. 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).
    1. 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.
    2. For equipment with associated pumps (chillers, boilers, cooling towers):
        i. 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), as a pump failure will necessarily disable its associated equipment.
        ii. 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.*

5.1.19.2 For each system as defined in Section 5.1.19.1(d), there shall be a SystemOK flag, which is either TRUE or FALSE.

5.1.19.3 SystemOK shall be TRUE when all of the following are true:

a. The system is proven ON.
b. The system is achieving its temperature and/or pressure set point(s) for at least 5 minutes
c. The system is ready and able to serve its load

5.1.19.4 SystemOK shall be FALSE while the system is starting up (i.e., before reaching set point) 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.

a. By default, Level 1 through Level 3 component alarms (indicating equipment failure) shall inhibit SystemOK. Level 4 component alarms (maintenance and energy efficiency alarms) shall not affect SystemOK.
b. The operator shall have the ability to individually determine which component alarms may or may not inhibit SystemOK.

Examples

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 set point.

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).

5.1.19.5 The BAS shall selectively suppress (i.e., fail to announce; alarms may still be logged to a database) alarms for load components if SystemOK is FALSE for the source system that serves that load.

a. 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.
b. 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.
c. If SystemOK is FALSE for an air-side system (air handler, fan coil, VAV box, etc.), then all alarms from the loads shall be suppressed.

5.1.19.6 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 CW pumps), a chiller system (chillers and CHW pumps), and a boiler system (boilers and HW pumps). These systems serve several air handlers (each considered its own system), and each air handler serves a series of VAV boxes (each also considered its own system).

- *If SystemOK is FALSE for the cooling-tower system, then high- temperature alarms are suppressed for the chillers, the air handlers, and 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 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_2) are suppressed for the zone served by that VAV box only. No other alarms are suppressed.*

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

a. Life/safety and Level 1 alarms
b. Failure-to-start alarms (i.e., equipment is commanded ON, but status point shows equipment to be OFF)
c. Failure-to-stop/hand alarms (i.e., equipment is commanded OFF, but status point shows equipment to be ON)

5.1.20 Time-Based Suppression

5.1.20.1 Calculate a time-delay period after any change in set point based on the difference between the controlled variable (e.g., zone temperature) at the time of the change and the new set point. The default time delay period shall be as follows:

Time-based suppression is used to suppress reset requests and alarms after a change in set point. This includes automatic changes in set point, e.g., due to a change in window switch or occupancy sensor status, as well as changes made by occupants.

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a. For thermal zone temperature alarms: 18 minutes per °C (10 minutes per °F) of difference but no longer than 120 minutes

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*For example, if set point changes from 20°C (68°F) to 21°C (70°F), and the zone temperature is 20.2°C (68.5°F) at the time of the change, inhibit alarm for 15 minutes (0.8°C*18 minutes per °C [1.5°F*10 minutes/°F]) after the change.*

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b. For thermal zone temperature cooling requests: 9 minutes per °C (5 minutes per °F) of difference but no longer than 30 minutes
c. For thermal zone temperature heating requests: 9 minutes per °C (5 minutes per °F) of difference but no longer than 30 minutes

5.2 Generic Ventilation Zones

A ventilation zone is a space or group of spaces served by one ventilation control device. For VAV systems, ventilation zones and thermal zones are one and the same, but Guideline 36 will eventually be expanded to include dedicated outdoor air systems (DOAS) serving one or more thermal zones controlled by radiant systems, chilled beams, fan-coils, etc.

5.2.1 Zone Minimum Outdoor Air and Minimum Airflow Set Points

5.2.1.1 For every zone that requires mechanical ventilation, the zone minimum outdoor airflows and set points shall be calculated depending on the governing standard or code for outdoor air requirements.

5.2.1.2 See Section 3.1.2 for zone minimum airflow set point Vmin.

The engineer must select between ventilation logic options:

- **If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, use Section 5.2.1.3 and delete Section 5.2.1.4.**
- **If the project is to comply with California Title 24 ventilation requirements, use Section 5.2.1.4 and delete Section 5.2.1.3.**

5.2.1.3 For compliance with the Ventilation Rate Procedure of ASHRAE Standard 62.1-2016, outdoor air and zone minimum set points shall be calculated as follows:

a. See Section 3.1.1.2 for zone ventilation set points.
b. Determine zone air distribution effectiveness Ez.
   1. If the DAT at the terminal unit is less than or equal to zone space temperature, Ez shall be equal to EzC (default to 1.0 if no value is scheduled).

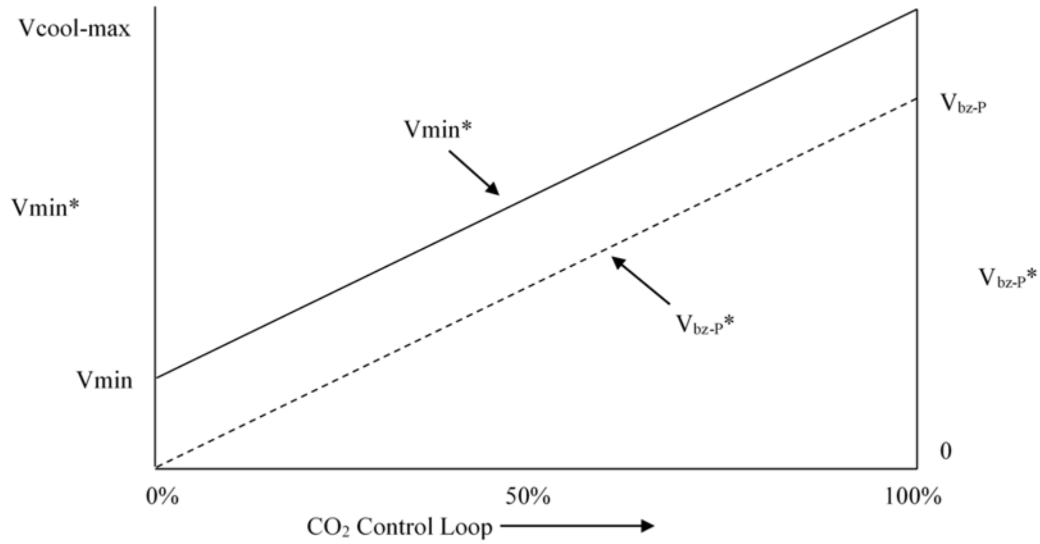

Figure 5.2.1.3-1 Vmin* and Vbz-P* reset with CO_2 loop.

2. If the DAT at the terminal unit is greater than zone space temperature, Ez shall be equal to EzH (default to 0.8 if no value is scheduled).

c. Vbz-P* is the population component of the required breathing zone outdoor airflow. The normal value of Vbz-P* shall be Vbz-P.

d. The occupied minimum airflow Vmin* shall be equal to Vmin except as noted in Section 5.2.1.3(e).

e. The required zone outdoor airflow Voz shall be calculated as Voz = (Vbz-A + Vbz-P*)/Ez, where the normal values of Vbz-A and Vbz-P* are modified if any of the following conditions are met, in order from higher to lower priority:

1. If the zone is in any mode other than occupied mode, and for zones that have window switches and the window is open: Vbz-P* = 0, Vbz-A = 0, and Vmin* = 0.
2. If the zone has an occupancy sensor, is unpopulated, and occupied-standby mode is permitted: Vbz-P* = 0, Vbz-A = 0, and Vmin* = 0
3. Else, if the zone has an occupancy sensor, is unpopulated, but occupied-standby mode is not permitted: Vbz-P* = 0 and Vmin* = Vmin.

Occupied-standby mode applies to individual zones, is considered a zonal subset of occupied mode, and is not considered a zone-group operating mode.

4. If the zone has a CO_2 sensor:
   i. See Section 3.1.1.3 for CO_2 set points.
   ii. During occupied mode, a P-only loop shall maintain CO_2 concentration at set point; reset from 0% at set point minus 200 PPM and to 100% at set point.
   iii. Loop is disabled and output set to zero when the zone is not in occupied mode.

CO_2 DCV is not yet well defined for Standard 62.1. RP-1747 is under way and should provide a detailed procedure. In the meantime, sequences have been included at the zone level, matching California's DCV approach as a first step. Because outdoor air rates at the AHU level dynamically calculate outdoor air rates using the Standard 62.1 multiple-spaces procedure, compliance with the standard is assured. Doing no DCV at all is not an option, because it is required by Standard 90.1-2016.

   iv. For cooling-only VAV terminal units, reheat VAV terminal units, constant-volume series fan-powered terminal units, dual-duct VAV terminal units with mixing control and inlet airflow sensors, dual-duct VAV terminal units with mixing control and a discharge airflow sensor, or dual-duct VAV terminal units with cold-duct minimum control:
      (a) The CO_2 control loop output shall reset both the occupied minimum airflow set point (Vmin*) and the population component of the required breathing zone outdoor airflow (Vbz-P*) in parallel. Vmin* shall be reset from the zone minimum airflow set point Vmin at 0% loop output up to maximum cooling airflow set point Vcool-max at 100% loop output. Vbz-P* shall be reset from 0 L/s (0 cfm) at 0% loop output up to the Vbz-P at 100% loop output. See Figure 5.2.1.3-1.

The CO_2 control loop graph in Figure 5.2.1.3-1 is provided as a visual representation of the reset logic and is not representative of magnitude of Vbz-P in relation to Vbz-A or Vmin*.*

   v. For parallel fan-powered terminal units:
      (a) Determine VCO_2-max as follows:
         (1) When the zone state is cooling, VCO_2-max is equal to the maximum cooling airflow set point Vcool-max.
         (2) When the zone state is heating or deadband, VCO_2-max is equal to Vcool-max minus the parallel fan airflow

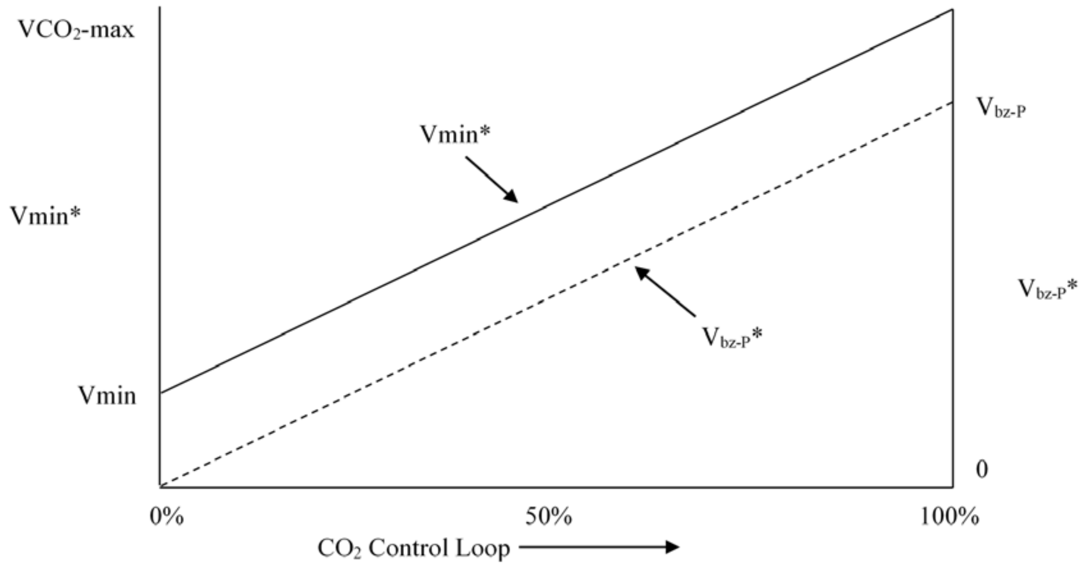

Figure 5.2.1.3-2 Vmin* and Vbz-P* reset with CO_2 loop (parallel fan-powered).

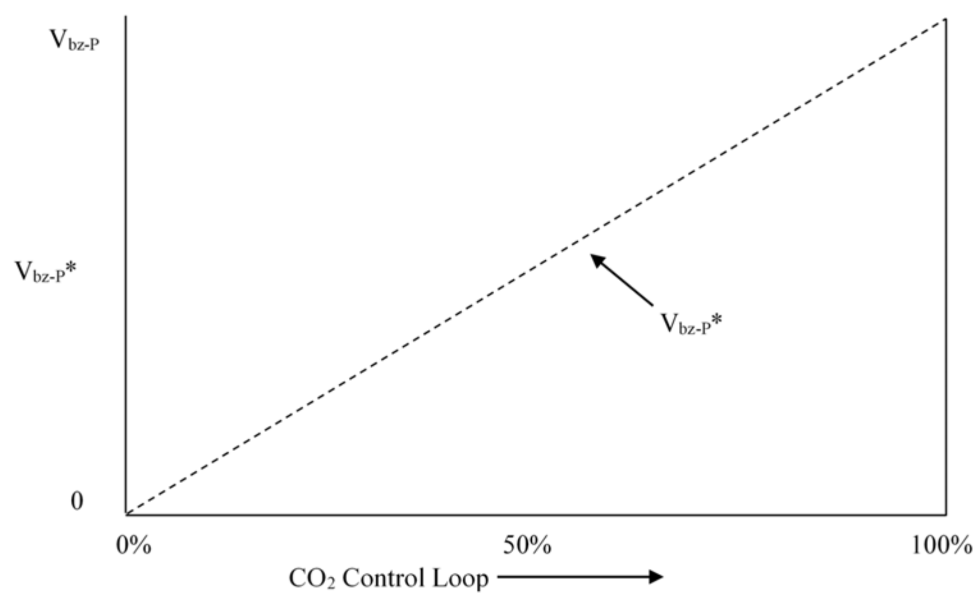

Figure 5.2.1.3-3 Vmin* and Vbz-P* reset with CO_2 loop (SZVAV).

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

(b) The CO_2 control loop output shall reset both the occupied minimum airflow set point Vmin* and the population component of the required breathing zone outdoor airflow Vbz-P* in parallel. Vmin* shall be reset from the zone minimum airflow set point Vmin at 0% loop output up to maximum cooling airflow set point VCO_2-max at 100% loop output. Vbz-P* shall be reset from 0 L/s (0 cfm) at 0% loop output up to the Vbz-P at 100% loop output. See Figure 5.2.1.3-2.

The CO_2 control loop graph in Figure 5.1.2.1.3-2 is provided as a visual representation of the reset logic and is not representative of magnitude of Vbz-P in relation to Vbz-A or Vmin*.*

vi. For SZVAV AHUs:

(a) The minimum outdoor air set point MinOAsp is equal to Voz. The CO_2 control loop output shall reset the population component of the required breathing zone outdoor airflow Vbz-P* from 0 L/s (0 cfm) at 0% loop output up to Vbz-P at 100% loop output. See Figure 5.2.1.3-3.

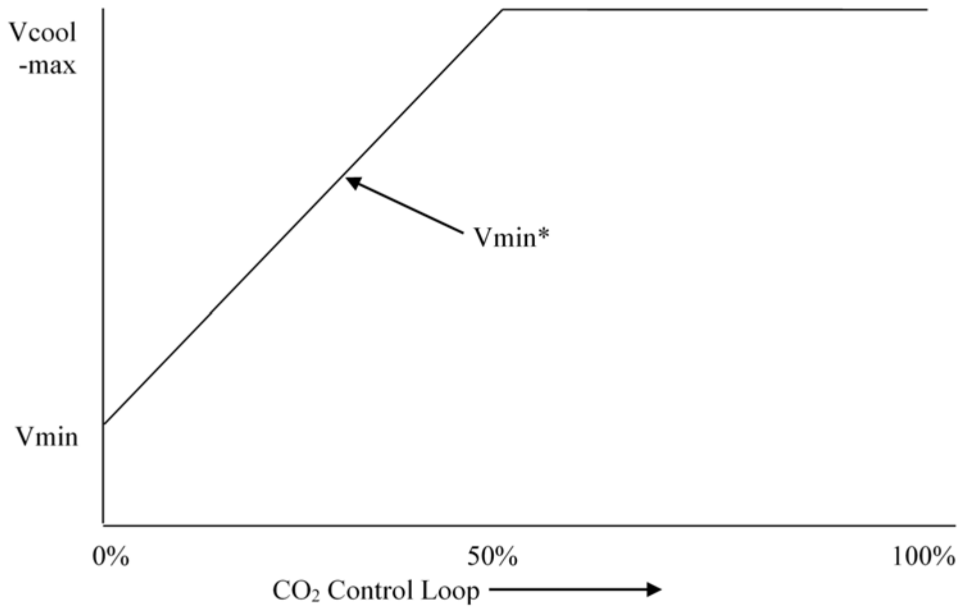

Figure 5.2.1.4-1 Vmin* reset with CO_2 loop.

The engineer must select between ventilation logic options:

- **If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, use Section 5.2.1.3 and delete Section 5.2.1.4.**
- **If the project is to comply with California Title 24 ventilation requirements, use Section 5.2.1.4 and delete Section 5.2.1.3.**

5.2.1.4 For compliance with California Title 24, outdoor air set points shall be calculated as follows:

a. See Section 3.1.1.2.2 for zone ventilation set points.
b. Determine the zone minimum outdoor air set points Zone-Abs-OA-min and Zone-Des-OA-min.

Zone-Abs-OA-min is used in terminal-unit sequences and air-handler sequences. Zone-Des-OA-min is used in air-handler sequences only.

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1. Zone-Abs-OA-min shall be reset based on the following conditions in order from highest to lowest priority:
   i. Zero if the zone has a window switch and the window is open.
   ii. Twenty-five percent (25%) of Varea-min if the zone has an occupancy sensor and is unpopulated.

The term "populated" is used instead of "occupied" to mean that a zone occupancy sensor senses the presence of people, because the term "occupied" is used elsewhere to mean "scheduled to be occupied."

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   iii. Varea-min if the zone has a CO_2 sensor.
   iv. Zone-Des-OA-min otherwise.
2. Zone-Des-OA-min is equal to the following:
   i. Zero if the zone has a window switch and the window is open.
   ii. Twenty-five percent (25%) of Varea-min if the zone has an occupancy sensor and is unpopulated.
   iii. The larger of Varea-min and Vocc-min otherwise.

c. The occupied minimum airflow Vmin* shall be equal to Vmin except as noted below:
   1. If the zone has an occupancy sensor, Vmin* shall be equal to 25% of Varea-min when the room is unpopulated.
   2. If the zone has a window switch, Vmin* shall be zero when the window is open.
   3. If the zone has a CO_2 sensor:
      i. See Section 3.1.1.3 for CO_2 set points.
      ii. During occupied mode, a P-only loop shall maintain CO_2 concentration at set point; reset from 0% at set point minus 200 PPM and to 100% at set point.
      iii. Loop is disabled and output set to zero when the zone is not in occupied mode.
      iv. For cooling-only VAV terminal units, reheat VAV terminal units, constant-volume series fan-powered terminal units, dual-duct VAV terminal units with mixing control and inlet airflow sensors, dual-duct VAV terminal units with mixing control and a discharge airflow sensor, or dual-duct VAV terminal units with cold-duct minimum control:
         (a) The CO_2 control loop output shall reset the occupied minimum airflow set point Vmin* from the zone minimum airflow set point Vmin at 0% up to maximum cooling airflow set point Vcool-max at 50%, as shown in Figure 5.2.1.4-1. The loop output from 50% to 100% will be used at the system level to reset outdoor air minimum; see AHU controls.

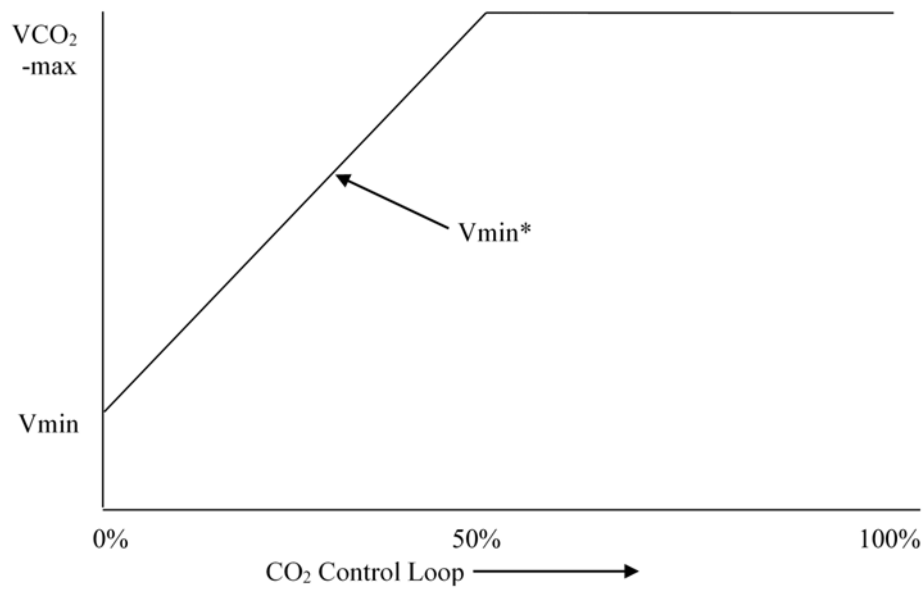

Figure 5.2.1.4-2 Vmin* reset with CO_2 loop (parallel fan-powered).

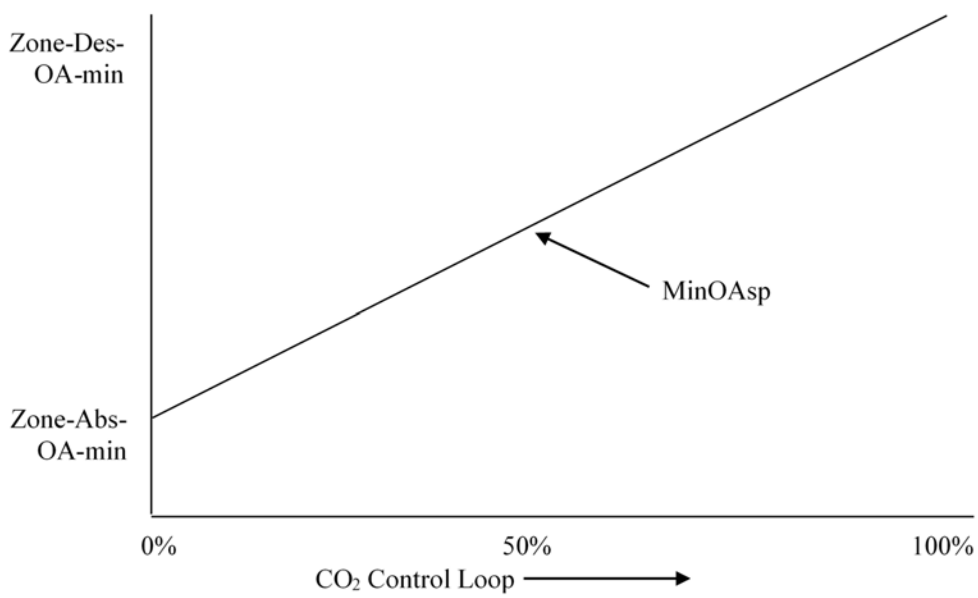

Figure 5.2.1.4-3 Vmin* reset with CO_2 loop (SZVAV).

v. For parallel fan-powered terminal units:
   (a) Determine VCO_2-max as follows:
      (1) When the zone state is cooling, VCO_2-max is equal to the maximum cooling airflow set point Vcool-max.
      (2) When the zone state is heating or deadband, VCO_2-max is equal to Vcool-max minus the parallel fan airflow

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

   (b) The CO_2 control loop output shall reset the occupied minimum airflow set point Vmin* from the zone minimum airflow set point Vmin at 0% up to maximum cooling airflow set point VCO_2-max at 50%, as shown in Figure 5.2.1.4-2. The loop output from 50% to 100% will be used at the system level to reset outdoor air minimum; see AHU controls.

vi. For SZVAV AHUs:
   (a) The minimum outdoor air set point MinOAsp shall be reset based on the zone CO_2 control-loop signal from Zone-Abs-OA-min at 0% signal to Zone-Des-OA-min at 100% signal. See Figure 5.2.1.4-3.

This concludes the section where the ventilation logic is selected. When the sequences are complete, only one of Sections 5.2.1.3 and 5.2.1.4 should remain. The other section should be deleted, along with these flag notes.

5.2.2 Time-Averaged Ventilation

ASHRAE Standard 62.1 and California Title 24 allow for ventilation to be provided based on average conditions over a specific period of time. This time-averaging method allows for zone airflows to effectively be controlled to values below the VAV box controllable minimum value, which may reduce energy use and the risk of overcooling when the zone ventilation requirement is less than the VAV box controllable minimum.

5.2.2.1 When the active airflow set point Vspt is nonzero and is less than the lowest possible airflow set point allowed by the controls (Vm), the airflow set point shall be pulse width modulated as follows:

a. The time-averaged ventilation (TAV) ratio shall be determined as TAVratio = Vspt/Vm
b. The total cycle time (TCT) shall be 15 minutes (adjustable)
c. **Open period.** During the open period, the TAV airflow set point Vspt* shall be equal to Vm for a period of time OP, which is the larger of the following:
   1. 1.5 minutes or
   2. TCT multiplied by TAVratio
d. **Closed period.** During the closed period, Vspt* shall be set to 0 for a period of time CP, where CP = TCT – OP. The VAV damper control loop shall be disabled with output set equal to 0 during the closed period. At the end of each closed period, the VAV damper shall be commanded to the last position from the previous open period prior to reenabling the control loop.
e. During TAV mode, each cycle shall consist of an open and closed period that alternate until Vspt is greater than Vm.

The following logic ensures that multiple zones do not enter TAV mode at the same time, avoiding the synchronized opening and closing of VAV dampers. Where there are a small number of zones and the majority may potentially be in TAV mode synchronously, avoiding this issue may be more reliably achieved by sequencing the VAV terminal units deterministically so that each VAV terminal unit always opens at a specific minute into the total cycle time. The aim of this sequencing is to ensure that the total airflow is as constant as possible over the total cycling time even if all of the VAV terminal units enter TAV mode at the same time (e.g. when a building-wide temperature setback occurs).

For example, the total OPEN *cycle for VAV terminal-unit A opens at minute 1 of the total cycle time, VAV terminal-unit B opens at minute* x *of the total cycle time, etc.*

f. When first entering TAV mode, start with an initial open period of duration RNDM*OP, where RNDM is a random number between 0.0 and 1.0.

5.2.2.2 The VAV damper shall be modulated by a control loop to maintain the measured airflow at the active set point of Vspt* when in TAV mode, or otherwise Vspt.

5.3 Generic Thermal Zones

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

5.3.2 Set Points

5.3.2.1 See Section 3.1.1.1 for zone temperature set points.

5.3.2.2 Each zone shall have separate occupied and unoccupied heating and cooling set points.

5.3.2.3 The active set points shall be determined by the operating mode of the zone group (see Section 5.4.6).

a. The set points shall be the occupied set points during occupied mode, warm-up mode, and cooldown mode.
b. The set points shall be the unoccupied set points during unoccupied mode, setback mode, and setup mode.

5.3.2.4 The software shall prevent the following:

a. The heating set point from exceeding the cooling set point minus 0.5°C (1°F) (i.e., the minimum difference between heating and cooling set points shall be 0.5°C [1°F]).
b. The unoccupied heating set point from exceeding the occupied heating set point.
c. The unoccupied cooling set point from being less than the occupied cooling set point.

5.3.2.5 Where the zone has a local set point adjustment knob/button:

a. The set point adjustment offsets established by the occupant shall be software points that are persistent (e.g., not reset daily), but the actual offset used in control logic shall be adjusted based on limits and modes as describe below.
b. The adjustment shall be capable of being limited in software.

These are absolute limits imposed by programming, which are in addition to the range limits (e.g., ±4°F) of the thermostat adjustment device.

   1. As a default, the active occupied cooling set point shall be limited between 22°C (72°F) and 27°C (80°F).
   2. As a default, the active occupied heating set point shall be limited between 18°C (65°F) and 22°C (72°F).

c. The active heating and cooling set points shall be independently adjustable, respecting the limits and anti-overlap logic described in Sections 5.3.2.4 and 5.3.2.5(b). If zone thermostat provides only a single set-point adjustment, then the adjustment shall move both the active heating and cooling set points upward or downward by the same amount, within the limits described in Section 5.3.2.5(b).

d. The adjustment shall only affect occupied set points in occupied mode, warm-up mode, and cooldown mode and shall have no impact on set points in all other modes.
e. At the onset of demand limiting, the local set-point adjustment value shall be frozen. Further adjustment of the set point by local controls shall be suspended for the duration of the demand-limit event.

Demand limits can be triggered for different reasons, including initiating utility demand shed events, exceeding 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 use a sliding window method selectable in increments of 1 minute, up to 60 minutes, with a 15-minute default.*
- ***Demand-Limit Levels.*** *Demand time periods shall be set up as per utility rate schedule. For each on-peak or partial-peak period, three demand 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 for a minimum of 15 minutes, and the time is no longer within the on-peak or partial-peak window, the switch shall be reset. These levels are used at the zone level (see Sections 5.3.2.6 and 5.3.2.7) to shed demand.*

An override for critical zones such as data centers or equipment rooms should be provided through the graphical user interface (GUI). This override feature should require some level of supervision so that all zones do not declare themselves critical.

Demand limits can also be simultaneously applied to lighting for systems with daylighting/dimming capability and that are integrated with the HVAC BAS.

5.3.2.6 Cooling Demand Limit Set-Point Adjustment. The active cooling set points 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 BAS user interface. Changes due to demand limits are not cumulative.

a. At demand-limit Level 1, increase set point by 0.5°C (1°F).
b. At demand-limit Level 2, increase set point by 1°C (2°F).
c. At demand-limit Level 3, increase set point by 2°C (4°F).

5.3.2.7 Heating Demand-Limit Set-Point Adjustment. The active heating set points 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 BAS user interface. Changes due to demand limits are not cumulative.

a. At demand-limit Level 1, decrease set point by 0.5°C (1°F).
b. At demand-limit Level 2, decrease set point by 1°C (2°F).
c. At demand-limit Level 3, decrease set point by 2°C (4°F).

Heating demand limits may be desirable in buildings with electric heat or heat pumps or in regions with limited gas distribution infrastructure.

5.3.2.8 Window Switches. For zones that have operable windows with indicator switches, when the window switch indicates the window is open, the heating set point shall be temporarily set to 4°C (40°F) and the cooling set point shall be temporarily set to 49°C (120°F). When the window switch indicates that the window is open during other than occupied mode, a Level 4 alarm shall be generated.

5.3.2.9 Occupancy Sensors. For zones that have an occupancy switch:

a. When the switch indicates that the space has been unpopulated for 5 minutes continuously during the occupied mode, the active heating set point shall be decreased by 0.5°C (1°F) and the cooling set point shall be increased by 0.5°C (1°F).

The mild 0.5°C (1°F) setback/setup is per ASHRAE/IES Standard 90.1. It is deliberately mild for the following reasons:

- *Complaints are likely if the space temperature is too uncomfortable when occupants return.*
- *Spaces recovering from setback/setup can become temporary rogues zones, pushing supply air temperature and static pressure set points to less efficient values;*
- *The primary purpose of the reset is to push the zone into deadband to minimize airflow and eliminate simultaneous heating and cooling. This can occur with only a minor setback.*
- *Heating and cooling loads are only slightly affected by setback/setup (and not affected at all for interior zones), so there is not much value in larger setback/setup offsets.*

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b. When the switch indicates that the space has been populated for 1 minute continuously, the active heating and cooling set points shall be restored to their previous values.

Occupancy sensors are often provided as part of the lighting control system due to ASHRAE/IES Standard 90.1 and California Title 24 requirements. The point can be tied into the HVAC BAS in several ways to avoid the cost of an additional occupancy sensor:

- *If the occupancy sensor is an addressable point and the lighting controls have BACnet or other interface capability, the point can be mapped to the BAS via this interface.*
- *Some occupancy sensors include auxiliary dry contacts that can be wired to a digital input at the zone controller.*

5.3.2.10 Hierarchy of Set-Point Adjustments. The following adjustment restrictions shall prevail in order from highest to lowest priority:

a. Set point overlap restriction (Section 5.3.2.4.1)
b. Absolute limits on local set point adjustment (Section 5.3.2.5.1)

c. Window switches
d. Demand limit
   1. **Occupancy sensors.** Change of set point by occupancy sensor is added to change of set point by any demand limits in effect.
   2. **Local set-point adjustment.** Any changes to set point 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.
e. Scheduled set points based on zone group mode

5.3.3 Local Override. When thermostat override buttons are depressed, the call for occupied mode operation shall be sent to the zone group control for 60 minutes.

Local overrides will cause all zones in the zone group to operate in occupied mode to ensure that the system has adequate load to operate stably.

5.3.4 Control Loops

5.3.4.1 Two separate control loops, the cooling loop and the heating loop, shall operate to maintain space temperature at set point.

a. The heating loop shall be enabled whenever the space temperature is below the current zone heating set-point temperature and disabled when space temperature is above the current zone heating set point temperature and the loop output is zero for 30 seconds. The loop may remain active at all times if provisions are made to minimize integral windup.
b. The cooling loop shall be enabled whenever the space temperature is above the current zone cooling set-point temperature and disabled when space temperature is below the current zone cooling set-point temperature and the loop output is zero for 30 seconds. The loop may remain active at all times if provisions are made to minimize integral windup.

5.3.4.2 The cooling loop shall maintain the space temperature at the active cooling set point. The output of the loop shall be a software point ranging from 0% (no cooling) to 100% (full cooling).

5.3.4.3 The heating loop shall maintain the space temperature at the active heating set point. The output of the loop shall be a software point ranging from 0% (no heating) to 100% (full heating).

5.3.4.4 Loops shall use proportional + integral logic or other technology with similar performance. 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.

5.3.4.5 See other sections for how the outputs from these loops are used.

5.3.5 Zone State

5.3.5.1 Heating. When the output of the space heating control loop is nonzero and the output of the cooling loop is equal to zero.

5.3.5.2 Cooling. When the output of the space cooling control loop is nonzero and the output of the heating loop is equal to zero.

5.3.5.3 Deadband. When not in either heating or cooling.

5.3.6 Zone Alarms

5.3.6.1 Zone Temperature Alarms

a. High-temperature alarm
   1. If the zone is 2°C (3°F) above cooling set point for 10 minutes, generate Level 3 alarm.
   2. If the zone is 3°C (5°F) above cooling set point for 10 minutes, generate Level 2 alarm.
b. Low-temperature alarm
   1. If the zone is 2°C (3°F) below heating set point for 10 minutes, generate Level 3 alarm.
   2. If the zone is 3°C (5°F) below heating set point for 10 minutes, generate Level 2 alarm.

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.

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c. Suppress zone temperature alarms as follows:
   1. After zone set point is changed per Section 5.1.19.
   2. While zone group is in warm-up or cooldown modes.

Zone alarms are not suppressed in setup, setback, or unoccupied modes so that heating or cooling equipment or control failures are detected that could result in excessive pull-down or pick-up loads and even freezing of pipes if left undetected. See Section 5.4.6 for description of zone-group operating modes.

5.3.6.2 For zones with CO_2 sensors:

a. If the CO_2 concentration is less than 300 ppm, or the zone is in unoccupied mode for more than 2 hours and zone CO_2 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.
b. If the CO_2 concentration exceeds set point plus 10% for more than 10 minutes, generate a Level 3 alarm.

5.4 Zone Groups

Zone scheduling groups, or zone groups, are sets of zones served by a single air handler that operate together for ease of scheduling and/or in order to ensure sufficient load to maintain stable operation in the upstream equipment. A zone group is equivalent to an isolation area as defined in ASHRAE/IES Standard 90.1 2016, Section 6.4.3.3.4.

5.4.1 Each system shall be broken into separate zone groups composed of a collection of one or more zones served by a single air handler. See Section 3.1.3 for zone group assignments.

5.4.2 Each zone group shall be capable of having 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 BAS, individual zone schedules are superimposed to create a zone-group schedule, which then drives system behavior.

The schedule may govern operation of other integrated systems such as lights, daylighting, or other, in addition to the HVAC system.

5.4.3 All zones in each zone group shall be in the same zone-group operating mode as defined in Section 5.4.6. If one zone in a zone group is placed in any zone-group operating mode other than unoccupied mode (due to override, sequence logic, or scheduled occupancy), all zones in that zone group shall enter that mode.

Occupied-standby mode applies to individual zones, is considered a zonal subset of occupied mode, and shall not be considered a zone-group operating mode.

5.4.4 A zone group may be in only one mode at a given time.

5.4.5 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 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 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, for example, 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.

5.4.6 Zone-Group Operating Modes. Each zone group shall have the modes shown in the following subsections.

The modes presented in this section are to enable different set points and ventilation requirements to be applied to zone groups based on their operating schedule, occupancy status, and deviation from current set point.

See ASHRAE Guideline 13 for best practices in locating zone-group operating mode programming logic based on network architecture.

5.4.6.1 Occupied Mode. A zone group is in the occupied mode when any of the following is true:

a. The time of day is between the zone group's scheduled occupied start and stop times.
b. The schedules have been overridden by the occupant override system.

Occupant 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.

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

5.4.6.2 Warm-Up Mode. For each zone, the BAS shall calculate the required warm-up time based on the zone's occupied heating set point, 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 BAS. 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.

5.4.6.3 Cooldown Mode. For each zone, the BAS shall calculate the required cooldown time based on the zone's occupied cooling set point, 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 BAS. 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. Cooldown mode shall start based on the zone with the longest calculated cooldown 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.

Warm-up and cooldown modes are used to bring the zone groups up to temperature based on their scheduled occupancy period. The algorithms used in these modes (often referred to as "optimal start") predict the shortest time to achieve occupied set point to reduce the central system energy use based on past performance.

It's recommended to use a global outdoor air temperature not associated with any AHU to determine warm-up start time. This is because unit-mounted OA sensors, which are usually placed in the outdoor air intake stream, are often inaccurate (reading high) when the unit is OFF due to air leakage from the space through the OA damper.

5.4.6.4 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 set points, or if the average zone temperature of the zone group falls below the average unoccupied heating set point, the zone group shall enter setback mode until all spaces in the zone group are 1°C (2°F) above their unoccupied set points.

Table 5.5.4 Set Points as a Function of Zone Group Mode

Set Point	Occupied	Cooldown	Setup	Warm-Up	Setback	Unoccupied
Cooling maximum	Vcool-max	Vcool-max	Vcool-max	0	0	0
Minimum	Vmin*	0	0	0	0	0
Heating maximum	Vmin*	0	0	0	0	0

5.4.6.5 Freeze Protection Setback Mode. During unoccupied mode, if any single zone falls below 4°C (40°F), the zone group shall enter setback mode until all zones are above 7°C (45°F), and a Level 3 alarm shall be set.

5.4.6.6 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 set points, or if the average zone temperature of the zone group rises above the average unoccupied cooling set point, the zone group shall enter setup mode until all spaces in the zone group are 1°C (2°F) below their unoccupied set points. Zones where the window switch indicates that a window is open shall be ignored.

Setback and setup modes are used to keep zone temperatures (and mass) from straying excessively far from occupied set points so that the cooldown and warm-up modes can achieve set point 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.

5.4.6.7 Unoccupied Mode. When the zone group is not in any other mode.

5.5 VAV Terminal Unit—Cooling Only

5.5.1 See "Generic Thermal Zones" (Section 5.3) for set points, loops, control modes, alarms, etc.

5.5.2 See "Generic Ventilation Zones" (Section 5.2) for calculation of zone minimum outdoor airflow.

CO_2 DCV for cooling-only zones can lead to overcooling due to the faster rise in CO_2 levels from people in the room versus the increase in cooling loads from people. Including heat in all zones with CO_2 DCV is therefore recommended.

5.5.3 See Section 3.1.2.1 for zone minimum airflow set point Vmin and zone cooling maximum design airflow set point Vcool-max.

If the minimum ventilation rate is more than 25% or so of the cooling maximum, or DCV is used, a reheat box is recommended to avoid overcooling. DCV logic is not provided for cooling-only boxes, because doing so results in periods of overcooling, as the CO_2 levels due to occupants rises much faster than the cooling load due to occupants because of thermal mass.

5.5.4 Active maximum and minimum set points shall vary depending on the mode of the zone group the zone is a part of (see Table 5.5.4).

5.5.5 Control logic is depicted schematically in Figure 5.5.5 and described in the following subsections. Relative levels of various set points are depicted for occupied mode operation.

5.5.5.1 When the zone state is cooling, the cooling-loop output shall be mapped to the active airflow set point from the minimum to the cooling maximum airflow set points.

a. If supply air temperature from the air handler is greater than room temperature, cooling supply airflow set point shall be no higher than the minimum.

5.5.5.2 When the zone state is deadband or heating, the active airflow set point shall be the minimum airflow set point.

5.5.6 The VAV damper shall be modulated by a control loop to maintain the measured airflow at the active set point.

5.5.7 Alarms

5.5.7.1 Low Airflow

a. If the measured airflow is less than 70% of set point for 5 minutes while set point is greater than zero, generate a Level 3 alarm.
b. If the measured airflow is less than 50% of set point for 5 minutes while set point is greater than zero, generate a Level 2 alarm.
c. If a zone has an importance multiplier of 0 (see Section 5.1.14.2[a][1]) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.

5.5.7.2 Airflow Sensor Calibration. If the fan serving the zone has been OFF for 10 minutes, and airflow sensor reading is above 10% of the cooling maximum airflow set point, generate a Level 3 alarm.

5.5.7.3 Leaking Damper. If the damper position is 0%, and airflow sensor reading is above 10% of the cooling maximum airflow set point for 10 minutes while the fan serving the zone is proven ON, generate a Level 4 alarm.

5.5.8 Testing/Commissioning Overrides. Provide software switches that interlock to a system-level point to

a. force zone airflow set point to zero,
b. force zone airflow set point to Vcool-max,
c. force zone airflow set point to Vmin,
d. force damper full closed/open, and
e. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

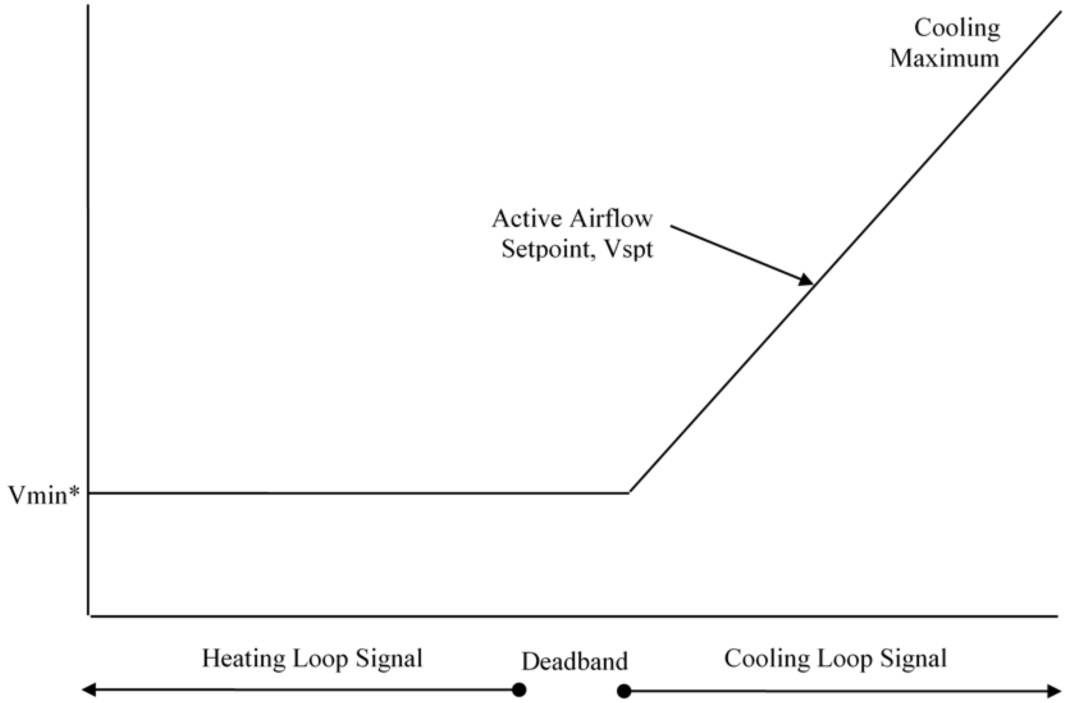

Figure 5.5.5 Control logic for cooling-only VAV zone.

Per Section 5.1.11, all *hardware points can be overridden through the BAS. Each of the following points is interlocked so that they can be overridden together at a zone-group level, per Section 5.4.5.*

For example, the commissioning authority (CxA) can check for leaking dampers by forcing all VAV boxes in a zone group closed and then recording airflow at the AHU.

5.5.9 System Requests

5.5.9.1 Cooling SAT Reset Requests

a. If the zone temperature exceeds the zone's cooling set point by 3°C (5°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 3 requests.
b. Else if the zone temperature exceeds the zone's cooling set point by 2°C (3°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 2 requests.
c. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
d. Else if the cooling loop is less than 95%, send 0 requests.

5.5.9.2 Static Pressure Reset Requests

a. If the measured airflow is less than 50% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 3 requests.
b. Else if the measured airflow is less than 70% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 2 requests.
c. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
d. Else if the damper position is less than 95%, send 0 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.

5.6 VAV Terminal Unit with Reheat

5.6.1 See "Generic Thermal Zones" (Section 5.3) for set points, loops, control modes, alarms, etc.

5.6.2 See "Generic Ventilation Zones" (Section 5.2) for calculation of zone minimum outdoor airflow.

5.6.3 See Section 3.1.2.2 for zone minimum airflow set points Vmin, zone maximum cooling airflow set point Vcool-max, zone maximum heating design airflow set point Vheat-max, and the maximum DAT rise above heating set point MaxΔT.

5.6.4 Active maximum and minimum set points shall vary depending on the mode of the zone group the zone is a part of (see Table 5.6.4).

These sequences use different maximum airflow set points for heating and cooling. This dual-max logic allows the minimum airflow set point to be lower than in a conventional sequence where the minimum airflow equals the heating airflow.

Heating is nonzero in cooldown to allow for individual zones within a zone group that may need heating while the zone group is in cooldown.

The warm-up and setback minimum set point is set to zero to ensure spaces that do not want heat during these modes receive no air; because the supply air temperature can be warm in these modes if the AHU has a heating coil, any minimum could cause overheating. The heating minimum is set to

Table 5.6.4 Set Points as a Function of Zone Group Mode

Set Point	Occupied	Cooldown	Setup	Warm-Up	Setback	Unoccupied
Cooling maximum	Vcool-max	Vcool-max	Vcool-max	0	0	0
Cooling minimum	Vmin*	0	0	0	0	0
Minimum	Vmin*	0	0	0	0	0
Heating minimum	Max (Vheat-min, Vmin*)	Vheat-min	0	Vheat-max	Vheat-max	0
Heating maximum	Max (Vheat-max, Vmin*)	Vheat-max	0	Vcool-max	Vcool-max	0

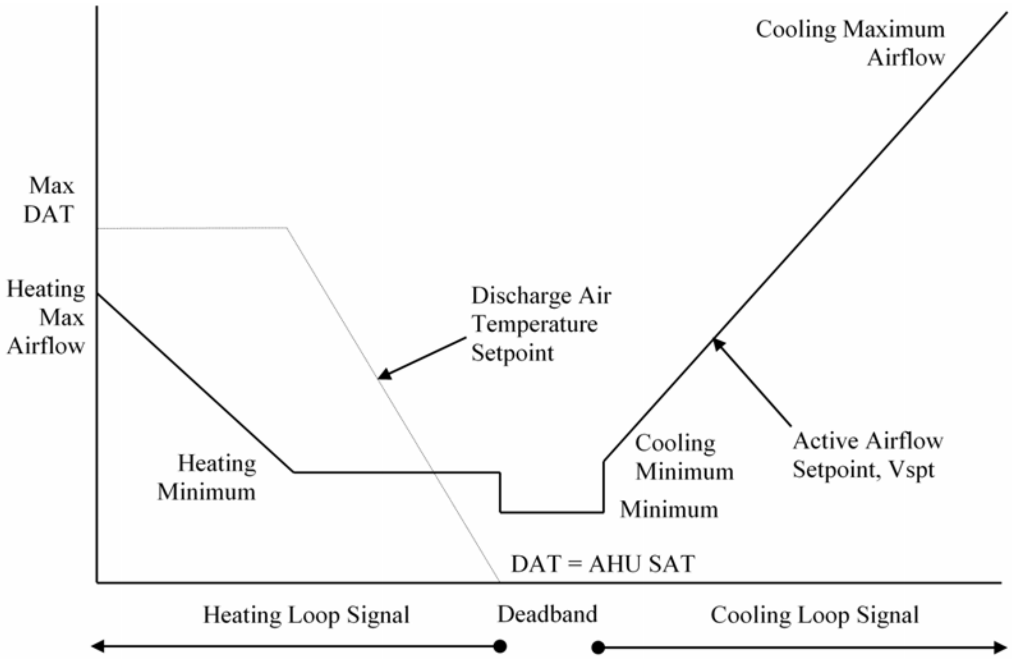

Figure 5.6.5 Control logic for VAV reheat zone.

Vheat-max and the heating maximum is set to Vcool-max to provide faster response. This also ensures nonzero flow for the first half of the heating loop, avoiding instabilities.

5.6.5 Control logic is depicted schematically in Figure 5.6.5 and described in the following subsections. Relative levels of various set points are depicted for occupied mode operation.

5.6.5.1 When the zone state is cooling, the cooling-loop output shall be mapped to the airflow set point from the cooling minimum to the cooling maximum airflow set points. Heating coil is disabled unless the DAT is below the minimum set point (see Section 5.6.5.4).

a. If supply air temperature from the air handler is greater than room temperature, cooling supply airflow set point shall be no higher than the minimum.

5.6.5.2 When the zone state is deadband, the active airflow set point shall be the minimum airflow set point. Heating coil is disabled unless the DAT is below the minimum set point (see Section 5.6.5.4).

5.6.5.3 When the zone state is heating, the heating loop shall maintain space temperature at the heating set point 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.

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a. From 0% to 50%, the heating-loop output shall reset the discharge temperature set point from the current AHU SAT set point to a maximum of MaxΔT above space temperature set point. The airflow set point shall be the heating minimum.
b. From 51% to 100%, if the DAT is greater than room temperature plus 3°C (5°F), the heating-loop output shall reset the airflow set point from the heating minimum airflow set point to the heating maximum airflow set point.
c. The heating coil shall be modulated to maintain the discharge temperature at set point. (Directly controlling heating off the zone temperature control loop is not acceptable).

1. When the airflow set point is pulse-width modulated per Section 5.2.2, the heating coil and PID loop shall be disabled, with output set to 0 during closed periods.

5.6.5.4 In occupied mode, the heating coil shall be modulated to maintain a DAT no lower than 10°C (50°F).

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

5.6.6 Alarms

5.6.6.1 Low Airflow

a. If the measured airflow is less than 70% of set point for 5 minutes while set point is greater than zero, generate a Level 3 alarm.
b. If the measured airflow is less than 50% of set point for 5 minutes while set point is greater than zero, generate a Level 2 alarm.
c. If a zone has an Importance-Multiplier of 0 (see Section 5.1.14.2[a][1]) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.

5.6.6.2 Low-Discharge Air Temperature

a. If heating hot-water plant is proven ON, and the DAT is 8°C (15°F) less than set point for 10 minutes, generate a Level 3 alarm.
b. If heating hot-water plant is proven ON, and the DAT is 17°C (30°F) less than set point for 10 minutes, generate a Level 2 alarm.
c. If a zone has an Importance-Multiplier of 0 (see Section 5.1.14.2[a][1]) for its hot-water reset T&R control loop, low-DAT alarms shall be suppressed for that zone.

5.6.6.3 Airflow Sensor Calibration. If the fan serving the zone has been OFF for 10 minutes, and airflow sensor reading is above 10% of the cooling maximum airflow set point, generate a Level 3 alarm.

5.6.6.4 Leaking Damper. If the damper position is 0%, and airflow sensor reading is above 10% of the cooling maximum airflow set point for 10 minutes while the fan serving the zone is proven ON, generate a Level 4 alarm.

5.6.6.5 Leaking Valve. If the valve position is 0% for 15 minutes, DAT is above AHU SAT by 3°C (5°F), and the fan serving the zone is proven ON, generate a Level 4 alarm.

5.6.7 Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to

a. force zone airflow set point to zero,
b. force zone airflow set point to Vcool-max,
c. force zone airflow set point to Vmin,
d. force zone airflow set point to Vheat-max,
e. force damper full closed/open,
f. force heating to OFF/closed, and
g. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 5.1.11, all hardware points can be overridden through the BAS. Each of the following points is interlocked so that they can be overridden together at a zone-group level, per Section 5.4.5.

For example, the CxA can check for leaking dampers by forcing all VAV boxes in a zone group closed and then recording airflow at the AHU.

Central plant sequences are not part of the initial scope of Guideline 36, but control logic for plant requests are being included for future use, when central plant sequences are added.

Typically, the heating hot-water 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.

Hot-water reset requests are used in T&R loops to control supply water temperature and/or pump DP set points based on zone and AHU demands.

5.6.8 System Requests

5.6.8.1 Cooling SAT Reset Requests

a. If the zone temperature exceeds the zone's cooling set point by 3°C (5°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 3 requests.
b. Else if the zone temperature exceeds the zone's cooling set point by 2°C (3°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 2 requests.
c. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
d. Else if the cooling loop is less than 95%, send 0 requests.

5.6.8.2 Static Pressure Reset Requests

a. If the measured airflow is less than 50% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 3 requests.
b. Else if the measured airflow is less than 70% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 2 requests.
c. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
d. Else if the damper position is less than 95%, send 0 requests.

5.6.8.3 If There Is a Hot-Water Coil, Hot-Water Reset Requests

a. If the DAT is 17°C (30°F) less than set point for 5 minutes, send 3 requests.
b. Else if the DAT is 8°C (15°F) less than set point for 5 minutes, send 2 requests.
c. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
d. Else if the HW valve position is less than 95%, send 0 requests.

5.6.8.4 If There Is a Hot-Water Coil and Heating Hot-Water Plant, Heating Hot-Water Plant Requests. Send the heating hot-water plant that serves the zone a heating hot-water plant request as follows:

a. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.

Table 5.7.4 Set Points as a Function of Zone Group Mode

Set Point	Occupied	Cooldown	Setup	Warm-Up	Setback	Unoccupied
Cooling maximum	Vcool-max	Vcool-max	Vcool-max	0	0	0
Minimum	Vmin*	0	0	0	0	0

b. Else if the HW valve position is less than 95%, send 0 requests.

5.7 Parallel Fan-Powered Terminal Unit—Constant-Volume Fan

5.7.1 See "Generic Thermal Zones" (Section 5.3) for set points, loops, control modes, alarms, etc.

5.7.2 See "Generic Ventilation Zones" (Section 5.2) for calculation of zone minimum outdoor airflow.

5.7.3 See Section 3.1.2.2.5 for zone minimum airflow set point Vmin, zone maximum cooling airflow set point Vcool-max, and the maximum DAT rise above heating set point MaxΔT.

5.7.4 Active maximum and minimum primary air set points shall vary depending on the mode of the zone group the zone is a part of (see Table 5.7.4).

5.7.5 Control logic is depicted schematically in Figures 5.7.5-1 and 5.7.5-2 and described in the following subsections. In Figures 5.7.5-1 and 5.7.5-2, OA-min is Voz (if using ASHRAE Standard 62.1 ventilation logic) or Zone-Abs-OA-min (if using California Title 24 ventilation logic).

5.7.5.1 When the Zone State Is Cooling

a. The cooling-loop output shall be mapped to the primary airflow set point from the minimum to the cooling maximum airflow set points.
   1. If supply air temperature from the air handler is greater than room temperature, cooling supply airflow set point shall be no higher than the minimum.
b. Heating coil is OFF.

5.7.5.2 When the Zone State Is Deadband

a. The primary airflow set point shall be the minimum airflow set point.
b. Heating coil is OFF.

5.7.5.3 When Zone State Is Heating

a. As the heating-loop output increases from 0% to 100%, it shall reset the discharge temperature from the current AHU SAT set point to a maximum of MaxΔT above space temperature set point.

ASHRAE/IES Standard 90.1-2016 limits overhead supply air to 11°C (20°F) above space temperature (e.g., 32°C [90°F] at 21°C [70°F] space temperature set point) to minimize stratification.

b. The heating coil shall be modulated to maintain the discharge temperature at set point. (Directly controlling heat off zone temperature control loop is not acceptable).

5.7.5.4 The VAV damper shall be modulated to maintain the measured primary airflow at set point.

5.7.5.5 Fan Control

a. Fan shall run whenever zone state is heating.
b. If ventilation is according to ASHRAE Standard 62.1-2016, the fan shall run in Deadband and Cooling when the primary air volume is less than Voz for 1 minute, and shall shut off when primary air volume is above Voz by 10% for 3 minutes.
c. If ventilation is according to California Title 24, the fan shall run in Deadband and Cooling when the primary air volume is less than Zone-Abs-OA-min for 1 minute, and shall shut off when primary air volume is above Zone-Abs-OA-min by 10% for 3 minutes.

The designer must ensure that the sum of the indirect ventilation provided by the fan plus the ventilation provided by the primary air at minimum set point meet Standard 62.1 requirements.

5.7.6 Alarms

5.7.6.1 Low Primary Airflow

a. If the measured airflow is less than 70% of set point for 5 minutes while set point is greater than zero, generate a Level 3 alarm.
b. If the measured airflow is less than 50% of set point for 5 minutes while set point is greater than zero, generate a Level 2 alarm.
c. If a zone has an Importance-Multiplier of 0 (see Section 5.1.14.2[a][1]) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.

5.7.6.2 Low-Discharge Air Temperature

a. If heating hot-water plant is proven ON, and the DAT is 8°C (15°F) less than set point for 10 minutes, generate a Level 3 alarm.
b. If heating hot-water plant is proven ON, and the DAT is 17°C (30°F) less than set point for 10 minutes, generate a Level 2 alarm.
c. If a zone has an Importance-Multiplier of 0 (see Section 5.1.14.2[a][1]) for its hot-water reset T&R control loop, low-DAT alarms shall be suppressed for that zone.

5.7.6.3 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.

a. Commanded ON, status OFF: Level 2
b. Commanded OFF, status ON: Level 4

5.7.6.4 Airflow Sensor Calibration. If the fan serving the zone has been OFF for 10 minutes, and airflow sensor reading is above 10% of the cooling maximum airflow set point, generate a Level 3 alarm.

5.7.6.5 Leaking Damper. If the damper position is 0%, and airflow sensor reading is above 10% of the cooling maximum airflow set point for 10 minutes while the fan serving the zone is proven ON, generate a Level 4 alarm.

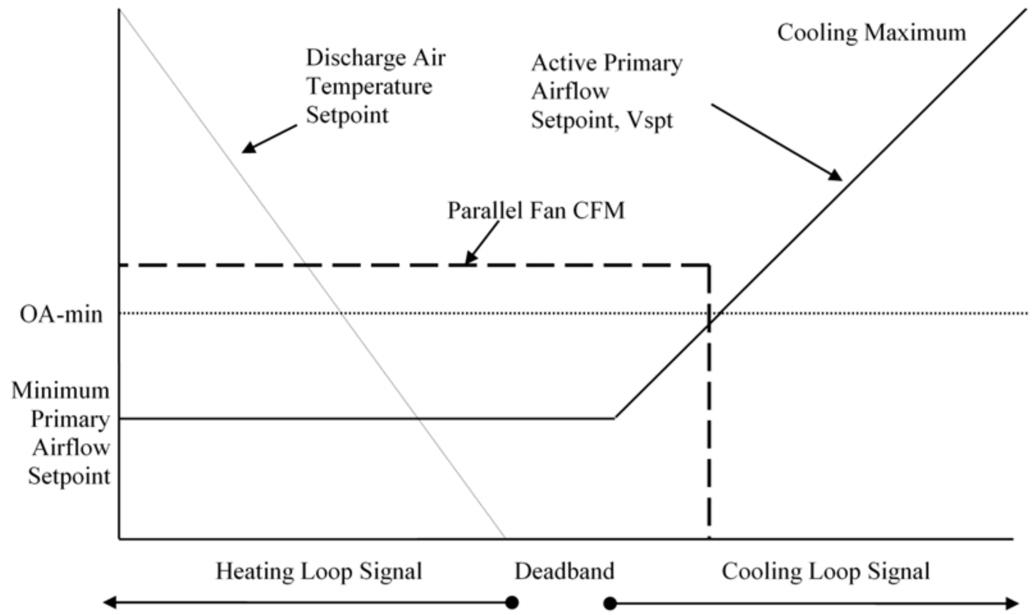

Figure 5.7.5-1 Control logic for constant-volume parallel fan-powered VAV zone (OA-min > Vmin).

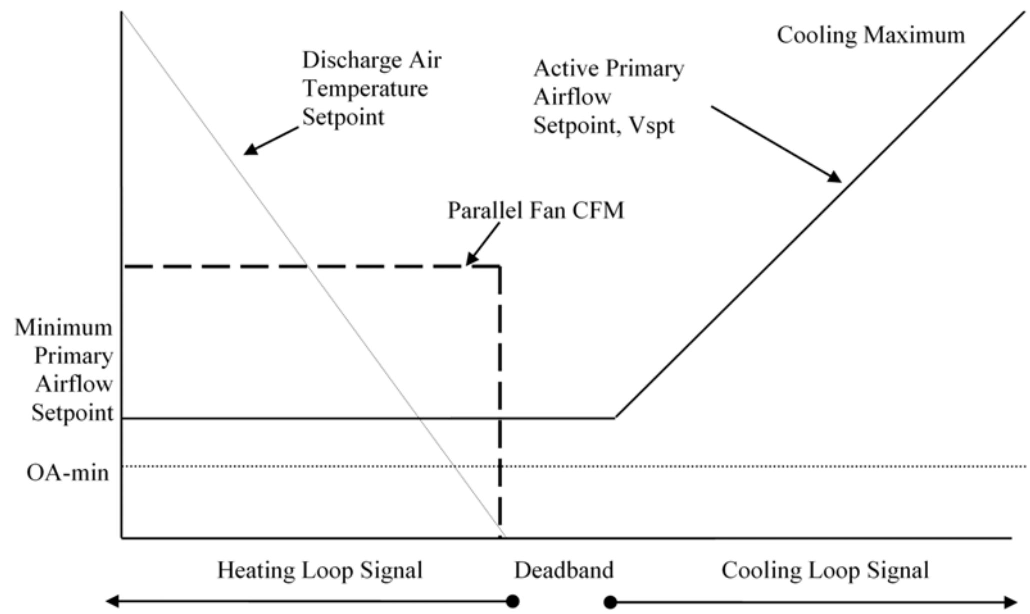

Figure 5.7.5-2 Control logic for constant-volume parallel fan-powered VAV zone (OA-min < Vmin).

5.7.6.6 Leaking Valve. If the valve position is 0% for 15 minutes, DAT is above AHU SAT by 3°C (5°F), and the fan serving the zone is proven ON, generate a Level 4 alarm.

5.7.7 Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to

a. force zone airflow set point to zero,
b. force zone airflow set point to Vcool-max,
c. force zone airflow set point to Vmin,
d. force damper full closed/open,
e. force heating to OFF/closed,
f. turn fan ON/OFF, and
g. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 5.1.11, all hardware points can be overridden through the BAS. Each of the following points is interlocked so that they can be overridden together at a zone-group level, per Section 5.4.5.

For example, the CxA can check for leaking dampers by forcing all VAV boxes in a zone group closed and then recording airflow at the AHU.

Central plant sequences are not part of the initial scope of Guideline 36, but control logic for plant requests are being

Table 5.8.5 Set Points as a Function of Zone Group Mode

Set Point	Occupied	Cooldown	Setup	Warm-Up	Setback	Unoccupied
Cooling maximum	Vcool-max	Vcool-max	Vcool-max	0	0	0
Minimum	Vmin*	0	0	0	0	0

included for future use, when central plant sequences are added.

Typically, the heating hot-water 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.

Hot-water reset requests are used in T&R loops to control supply water temperature and/or pump DP set points based on zone and AHU demands.

5.7.8 System Requests

5.7.8.1 Cooling SAT Reset Requests

a. If the zone temperature exceeds the zone's cooling set point by 3°C (5°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 3 requests.
b. Else if the zone temperature exceeds the zone's cooling set point by 2°C (3°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 2 requests.
c. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
d. Else if the cooling loop is less than 95%, send 0 requests.

5.7.8.2 Static Pressure Reset Requests

a. If the measured airflow is less than 50% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 3 requests.
b. Else if the measured airflow is less than 70% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 2 requests.
c. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
d. Else if the damper position is less than 95%, send 0 requests.

5.7.8.3 If There Is a Hot-Water Coil, Hot-Water Reset Requests

a. If the DAT is 17°C (30°F) less than set point for 5 minutes, send 3 requests.
b. Else if the DAT is 8.3°C (15°F) less than set point for 5 minutes, send 2 requests.
c. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
d. Else if the HW valve position is less than 95%, send 0 requests.

5.7.8.4 If There Is a Hot-Water Coil and a Heating Hot-Water Plant, Heating Hot-Water Plant Requests. Send the heating hot-water plant that serves the zone a heating hot-water plant request as follows:

a. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.
b. Else if the HW valve position is less than 95%, send 0 requests.

5.8 Parallel Fan-Powered Terminal Unit—Variable-Volume Fan

5.8.1 See "Generic Thermal Zones" (Section 5.3) for set points, loops, control modes, alarms, etc.

5.8.2 See "Generic Ventilation Zones" (Section 5.2) for calculation of zone minimum outdoor airflow.

5.8.3 See Section 3.1.2.4 for zone minimum airflow set point Vmin, zone maximum cooling airflow set point Vcool-max, the parallel fan maximum heating airflow set point Pfan-htg-max, and the maximum DAT rise above heating set point MaxΔT.

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

5.8.5 Active maximum and minimum primary air set points shall vary depending on the mode of the zone group the zone is a part of (see Table 5.8.5).

Control logic is depicted schematically in Figure 5.8.5 and described in the following subsections. Relative levels of various set points are depicted for occupied mode operation. In Figure 5.8.5, OA-min is Voz (if using ASHRAE Standard 62.1 ventilation logic) or Zone-Abs-OA-min (if using California Title 24 ventilation logic).

In the heating zone state, the logic keeps the fan airflow rate low while supply air temperature is increased as the first heating stage. This presumes that the temperature of the air the fan is supplying is neutral or below the space temperature, as it would be if the fan draws air directly from the space, and as it might be if the fan draws air from a return air plenum that is cooled by roof and wall heat losses. In the past, return air plenums were warmed by recessed light fixtures, but pendent lights are increasingly common, so the potential for free heating from the plenum is smaller than it was. Because there is the potential that the plenum is colder than the space due to envelope loads, the logic leads with the supply air temperature rather than with an increase in fan speed. If the designer is confident that the plenum will always be warmer, the logic can be reversed.

5.8.5.1 When the Zone State Is Cooling

a. The cooling-loop output shall be mapped to the airflow set point from the minimum to the cooling maximum airflow set points.
    1. If supply air temperature from the air handler is greater than room temperature, cooling supply airflow set point shall be no higher than the minimum.
b. Heating coil is OFF.

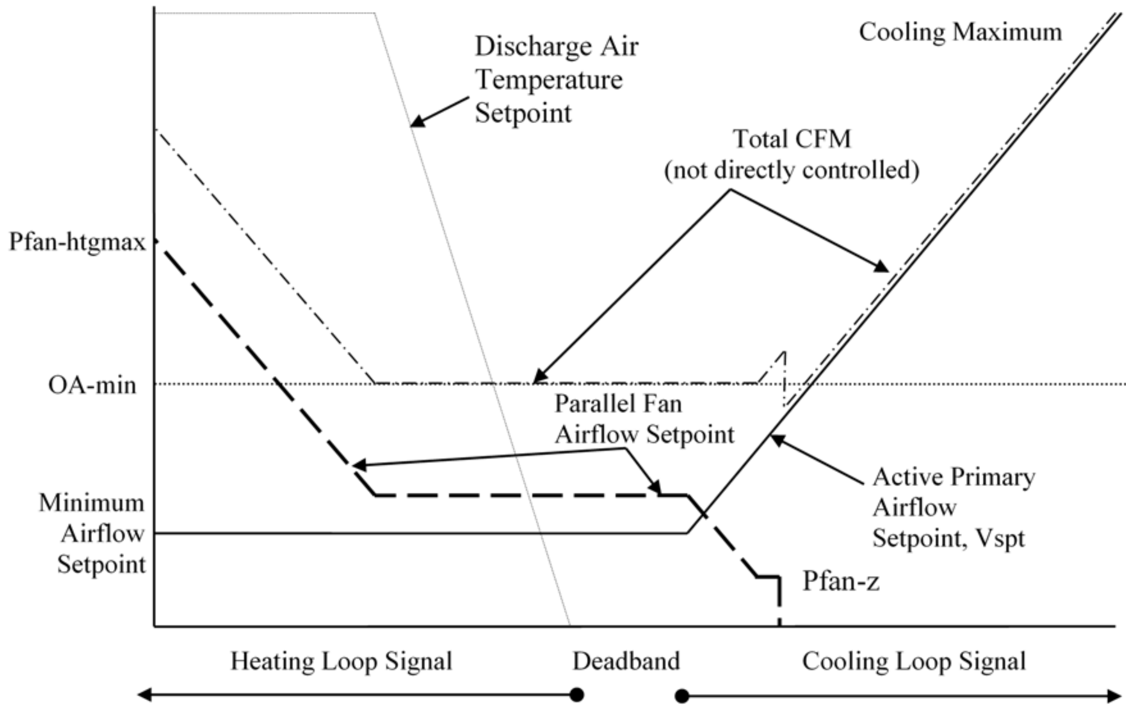

Figure 5.8.5 Control logic for variable-volume parallel fan-powered VAV zone.

c. If ventilation is according to ASHRAE Standard 62.1-2016, in occupied mode only, parallel fan starts when primary airflow drops below Voz minus one half of Pfan-z and shuts off when primary airflow rises above Voz. Fan airflow rate set point is equal to Voz minus the current primary airflow set point.

d. If ventilation is according to California Title 24, in occupied mode only, parallel fan starts when primary airflow drops below Zone-Abs-OA-min minus one half of Pfan-z and shuts off when primary airflow rises above Zone-Abs-OA-min. Fan airflow rate set point is equal to Zone-Abs-OA-min minus the current primary airflow set point.

The designer must ensure that the sum of the indirect ventilation provided by the fan plus the ventilation provided by the primary air at minimum set point meet Standard 62.1 requirements.

5.8.5.2 When the Zone State Is Deadband

a. The airflow set point shall be the minimum airflow set point.

b. Heating coil is OFF.

c. If ventilation is according to ASHRAE Standard 62.1-2016, parallel fan runs if primary airflow set point is below Voz. Fan airflow rate set point is equal to Voz minus the current primary airflow set point.

d. If ventilation is according to California Title 24, in occupied mode only, parallel fan runs if primary airflow set point is below Zone-Abs-OA-min. Fan airflow rate set point is equal to Zone-Abs-OA-min minus the current primary airflow set point.

The designer must ensure that the sum of the indirect ventilation provided by the fan plus the ventilation provided by the primary air at minimum set point meet Standard 62.1 requirements.

5.8.5.3 When Zone State is Heating

For systems with electric reheat, ensure that the minimum airflow provided by the parallel fan at minimum speed exceeds the minimum required airflow for the electric heater.

a. Parallel fan shall run.

b. From 0% to 50%, the heating loop output shall reset the discharge temperature from the current AHU SAT set point to a maximum of MaxΔT above space temperature set point.

ASHRAE/IES Standard 90.1-2016 limits overhead supply air to 11°C (20°F) above space temperature (e.g., 32°C [90°F] at 21°C [70°F] space temperature set point) to minimize stratification.

c. From 50% to 100%, the heating loop output shall reset the parallel fan airflow set point from the airflow set point required in deadband (see above; this is Pfan-z if deadband set point is less than Pfan-z) proportionally up to the maximum heating-fan airflow set point (Pfan-htgmax).

5.8.5.4 The heating coil shall be modulated to maintain the discharge temperature at set point. (Directly controlling heating off zone temperature control loop is not acceptable).

5.8.5.5 The VAV damper shall be modulated to maintain the measured primary airflow at the primary airflow set point.

5.8.6 Alarms

5.8.6.1 Low Primary Airflow

a. If the measured airflow is less than 70% of set point for 5 minutes while set point is greater than zero, generate a Level 3 alarm.
b. If the measured airflow is less than 50% of set point for 5 minutes while set point is greater than zero, generate a Level 2 alarm.
c. If a zone has an Importance-Multiplier of 0 (see Section 5.1.14.2[a][1]) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.

5.8.6.2 Low-Discharge Air Temperature

a. If heating hot-water plant is proven ON, and the DAT is 8.3°C (15°F) less than set point for 10 minutes, generate a Level 3 alarm.
b. If heating hot-water plant is proven ON, and the DAT is 17°C (30°F) less than set point for 10 minutes, generate a Level 2 alarm.
c. If a zone has an Importance-Multiplier of 0 (see Section 5.1.14.2[a][1]) for its hot-water reset T&R control loop, low-DAT alarms shall be suppressed for that zone.

5.8.6.3 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.

a. Commanded ON, status OFF Level 2
b. Commanded OFF, status ON: Level 4

5.8.6.4 Airflow Sensor Calibration. If the fan serving the zone has been OFF for 10 minutes, and airflow sensor reading is above 10% of the cooling maximum airflow set point, generate a Level 3 alarm.

5.8.6.5 Leaking Damper. If the damper position is 0%, and airflow sensor reading is above 10% of the cooling maximum airflow set point for 10 minutes while fan serving the zone is proven ON, generate a Level 4 alarm.

5.8.6.6 Leaking Valve. If the valve position is 0% for 15 minutes, and DAT is above AHU SAT by 3°C (5°F), generate a Level 4 alarm.

5.8.7 Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to

a. force zone airflow set point to zero,
b. force zone airflow set point to Vcool-max,
c. force zone airflow set point to Vmin,
d. force damper full closed/open,
e. force heating to off/closed,
f. turn fan on/off, and
g. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 5.1.11, all *hardware points can be overridden through the BAS. Each of the following points is interlocked so that they can be overridden together at a zone-group level, per Section 5.4.5.*

For example, the CxA can check for leaking dampers by forcing all VAV boxes in a zone group closed and then recording airflow at the AHU.

Central plant sequences are not part of the initial scope of Guideline 36, but control logic for plant requests are being included for future use, when central plant sequences are added.

Typically, the heating hot-water 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.

Hot-water reset requests are used in T&R loops to control supply water temperature and/or pump DP set points based on zone and AHU demands.

5.8.8 System Requests

5.8.8.1 Cooling SAT Reset Requests

a. If the zone temperature exceeds the zone's cooling set point by 3°C (5°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 3 requests.
b. Else if the zone temperature exceeds the zone's cooling set point by 2°C (3°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 2 requests.
c. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
d. Else if the cooling loop is less than 95%, send 0 requests.

5.8.8.2 Static Pressure Reset Requests

a. If the measured airflow is less than 50% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 3 requests.
b. Else if the measured airflow is less than 70% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 2 requests.
c. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
d. Else if the damper position is less than 95%, send 0 requests.

5.8.8.3 If There Is a Hot-Water Coil, Hot-Water Reset Requests

a. If the DAT is 17°C (30°F) less than set point for 5 minutes, send 3 requests.
b. Else if the DAT is 8.3°C (15°F) less than set point for 5 minutes, send 2 requests.
c. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
d. Else if the HW valve position is less than 95%, send 0 requests.

5.8.8.4 If There Is a Hot-Water Coil and a Heating Hot-Water Plant, Heating-Hot Water Plant Requests. Send the heating hot-water plant that serves the zone a heating hot-water plant request as follows:

a. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.
b. Else if the HW valve position is less than 95%, send 0 requests.

Table 5.9.4 Set Points as a Function of Zone Group Mode

Set Point	Occupied	Cooldown	Setup	Warm-Up	Setback	Unoccupied
Cooling maximum	Vcool-max	Vcool-max	Vcool-max	0	0	0
Minimum	Vmin*	0	0	0	0	0

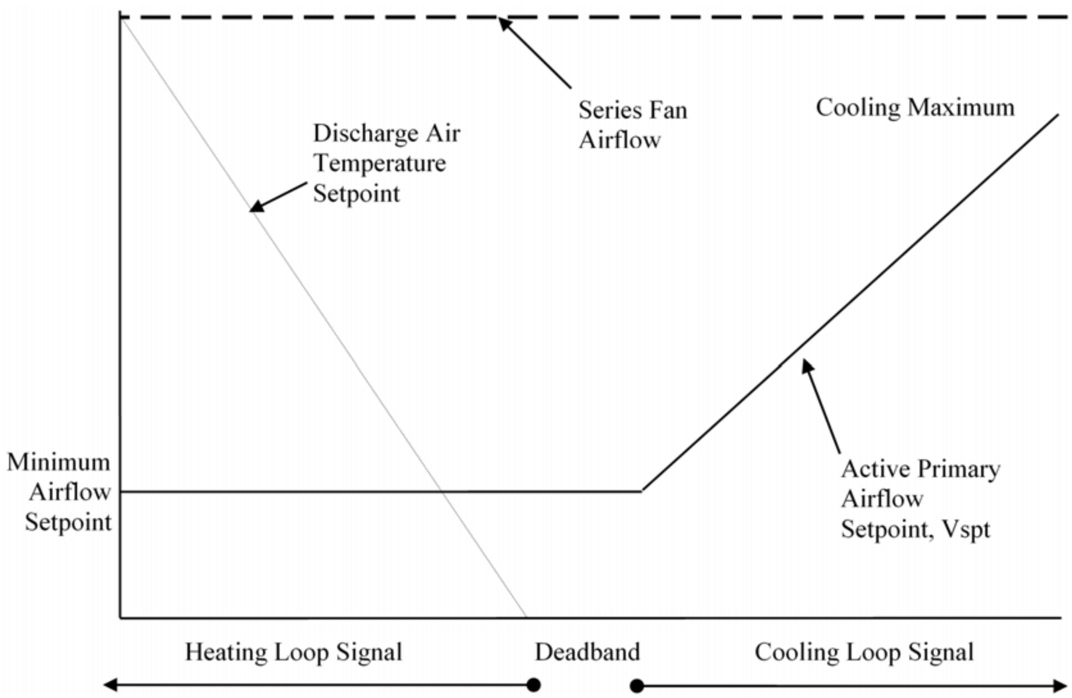

Figure 5.9.5 Control logic for constant-volume series fan-powered VAV zone.

5.9 Series Fan-Powered Terminal Unit—Constant-Volume Fan

5.9.1 See "Generic Thermal Zones" (Section 5.3) for set points, loops, control modes, alarms, etc.

5.9.2 See "Generic Ventilation Zones" (Section 5.2) for calculation of zone minimum outdoor airflow.

5.9.3 See Section 3.1.2.5 for zone minimum airflow set points Vmin, zone maximum cooling airflow set point Vcool-max, and the maximum DAT rise above heating set point MaxΔT.

5.9.4 Active maximum and minimum primary air set points shall vary depending on the mode of the zone group the zone is a part of (see Table 5.9.4).

5.9.5 Control logic is depicted schematically in Figure 5.9.5 and described in the following subsections.

5.9.5.1 When the Zone State Is Cooling

a. The cooling-loop output shall be mapped to the primary airflow set point from the minimum to the cooling maximum airflow set points.
   1. If supply air temperature from the air handler is greater than room temperature, cooling supply airflow set point shall be no higher than the minimum.
b. Heating coil is OFF.

5.9.5.2 When the Zone State Is Deadband

a. The primary airflow set point shall be the minimum airflow set point.
b. Heating coil is OFF.

5.9.5.3 When Zone State Is Heating

ASHRAE/IES Standard 90.1-2016 limits overhead supply air to 11°C (20°F) above space temperature (e.g., 32°C [90°F] at 21°C [70°F] space temperature set point) to minimize stratification.

a. The heating-loop shall reset the discharge temperature from the current AHU SAT set point to a maximum of MaxΔT above space temperature set point.
b. The heating coil shall be modulated to maintain the discharge temperature at set point. (Directly controlling heating off zone temperature control loop is not acceptable).

5.9.5.4 The VAV damper shall be modulated to maintain the measured airflow at set point.

5.9.5.5 Fan Control. Fan shall run whenever zone is in heating or cooling zone state, or if the associated zone group is in occupied mode. Prior to starting the fan, the damper is first driven fully closed to ensure that the fan is not rotating backward. Once the fan is proven ON for a fixed time delay (15 seconds), the damper override is released.

5.9.6 Alarms

5.9.6.1 Low Primary Airflow

a. If the measured airflow is less than 70% of set point for 5 minutes while set point is greater than zero, generate a Level 3 alarm.
b. If the measured airflow is less than 50% of set point for 5 minutes while set point is greater than zero, generate a Level 2 alarm.
c. If a zone has an Importance-Multiplier of 0 (see Section 5.1.14.2[a][1]) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.

5.9.6.2 Low-Discharge Air Temperature

a. If heating hot-water plant is proven ON, and the DAT is 8.3°C (15°F) less than set point for 10 minutes, generate a Level 3 alarm.
b. If heating hot-water plant is proven ON, and the DAT is 17°C (30°F) less than set point for 10 minutes, generate a Level 2 alarm.
c. If a zone has an Importance-Multiplier of 0 (see Section 5.1.14.2[a][1]) for its hot-water reset T&R control loop, low-DAT alarms shall be suppressed for that zone.

5.9.6.3 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.

a. Commanded ON, status OFF: Level 2
b. Commanded OFF, status ON: Level 4

5.9.6.4 Airflow Sensor Calibration. If the fan serving the zone has been OFF for 10 minutes, and airflow sensor reading is above 10% of the cooling maximum airflow set point, generate a Level 3 alarm.

5.9.6.5 Leaking Damper. If the damper position is 0%, and airflow sensor reading is above 10% of the cooling maximum airflow set point for 10 minutes while the fan serving the zone is proven ON, generate a Level 4 alarm.

5.9.6.6 Leaking Valve. If the valve position is 0% for 15 minutes, and DAT is above AHU SAT by 3°C (5°F), generate a Level 4 alarm.

5.9.7 Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to

a. force zone airflow set point to zero,
b. force zone airflow set point to Vcool-max,
c. force zone airflow set point to Vmin,
d. force damper full closed/open,
e. force heating to ON/closed,
f. turn fan ON/OFF, and
g. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 5.1.11, all hardware points can be overridden through the BAS. Each of the following points is interlocked so that they can be overridden together at a zone-group level, per Section 5.4.5.

For example, the CxA can check for leaking dampers by forcing all VAV boxes in a zone group closed and then recording airflow at the AHU.

Central plant sequences are not part of the initial scope of Guideline 36, but control logic for plant requests are being included for future use, when central plant sequences are added.

Typically, the heating hot-water 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.

Hot-water reset requests are used in T&R loops to control supply water temperature and/or pump DP set points based on zone and AHU demands.

5.9.8 System Requests

5.9.8.1 Cooling SAT Reset Requests

a. If the zone temperature exceeds the zone's cooling set point by 3°C (5°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 3 requests.
b. Else if the zone temperature exceeds the zone's cooling set point by 2°C (3°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 2 requests.
c. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
d. Else if the cooling loop is less than 95%, send 0 requests.

5.9.8.2 Static Pressure Reset Requests

a. If the measured airflow is less than 50% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 3 requests.
b. Else if the measured airflow is less than 70% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 2 requests.
c. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
d. Else if the damper position is less than 95%, send 0 requests.

5.9.8.3 If There Is a Hot-Water Coil, Hot-Water Reset Requests

a. If the DAT is 17°C (30°F) less than set point for 5 minutes, send 3 requests.
b. Else if the DAT is 8.3°C (15°F) less than set point for 5 minutes, send 2 requests.
c. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
d. Else if the HW valve position is less than 95%, send 0 requests.

5.9.8.4 If There Is a Hot-Water Coil and a Heating Hot-Water Plant, Heating Hot-Water Plant Requests. Send the heating hot-water plant that serves the zone a heating hot-water plant request as follows:

a. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.
b. Else if the HW valve position is less than 95%, send 0 requests.

Table 5.10.4 Set Points as a Function of Zone Group Mode

Set Point	Occupied	Cooldown	Setup	Warm-Up	Setback	Unoccupied
Cooling maximum	Vcool-max	Vcool-max	Vcool-max	0	0	0
Minimum	Vmin*	0	0	0	0	0

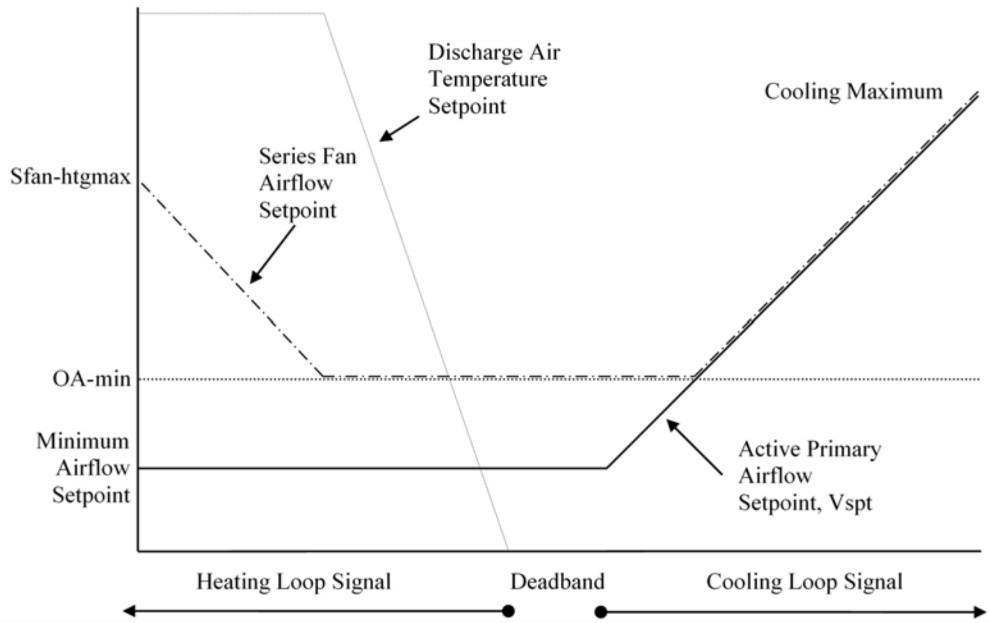

Figure 5.10.5 Control logic for variable-volume series fan-powered VAV zone.

5.10 Series Fan-Powered Terminal Unit—Variable-Volume Fan

5.10.1 See "Generic Thermal Zones" (Section 5.3) for set points, loops, control modes, alarms, etc.

5.10.2 See "Generic Ventilation Zones" (Section 5.2) for calculation of zone minimum outdoor airflow.

5.10.3 See Section 3.1.2.6 for zone minimum airflow set point Vmin, zone maximum cooling airflow set point Vcool-max, the series fan maximum heating airflow Sfan-htgmax, and the maximum DAT rise above heating set point MaxΔT.

5.10.4 Active maximum and minimum primary air set points shall vary depending on the mode of the zone group the zone is a part of (see Table 5.10.4).

5.10.5 Control logic is depicted schematically in Figure 5.10.5 and described in the following subsections. Relative levels of various set points are depicted for occupied mode operation. In Figure 5.10.5, OA-min is Voz (if using ASHRAE Standard 62.1 ventilation logic) or Zone-Abs-OA-min (if using California Title 24 ventilation logic).

In the heating zone state, the logic keeps the fan airflow rate low while supply air temperature is increased as the first heating stage. This presumes that the temperature of the air the fan is supplying is neutral or below the space temperature, as it would be if the fan draws air directly from the space, and as it might be if the fan draws air from a return air plenum that is cooled by roof and wall heat losses. In the past, return air plenums were warmed by recessed light fixtures, but pendent lights are increasingly common, so the potential for free heating from the plenum is smaller than it was. Because there is the potential that the plenum is colder than the space due to envelope loads, the logic leads with the supply air temperature rather than with an increase in fan speed. If the designer is confident that the plenum will always be warmer, the logic can be reversed.

5.10.5.1 When the Zone State Is Cooling

a. The cooling-loop output shall be mapped to the primary airflow set point from the cooling minimum to the cooling maximum airflow set points.
   1. If supply air temperature from the air handler is greater than room temperature, primary airflow set point shall be no higher than the minimum and the series fan airflow set point shall be no higher than OA-min.
b. The series fan airflow set point shall be the larger of OA-min and the primary airflow set point.
c. Heating coil is OFF.

5.10.5.2 When the Zone State Is Deadband

a. The primary airflow set point shall be the minimum airflow set point.
b. The series fan airflow set point shall be equal to OA-min.
c. Heating coil is OFF.

5.10.5.3 When Zone State Is Heating

ASHRAE/IES Standard 90.1-2016 limits overhead supply air to 11°C (20°F) above space temperature (e.g., 32°C [90°F] at 21°C [70°F] space temperature set point) to minimize stratification.

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a. From 0% to 50%, the heating loop output shall reset the discharge temperature set point from the current AHU SAT set point to a maximum of MaxΔT above space temperature set point. The primary airflow set point shall be the minimum airflow set point, and the series fan airflow set point shall be OA-min.
b. From 50% to 100%, the heating loop output shall reset the series fan airflow set point from OA-min to a Sfan-htgmax. The primary airflow set point shall be the minimum airflow set point.
c. The heating coil shall be modulated to maintain the discharge temperature at set point. (Directly controlling heating off zone temperature control loop is not acceptable).

5.10.5.4 The VAV damper shall be modulated to maintain the measured airflow at set point.

5.10.5.5 Fan Control. Fan shall run whenever zone is in heating or cooling zone state, or if the associated zone group is in occupied mode. Prior to starting the fan, the damper is first driven fully closed to ensure that the fan is not rotating backward. Once the fan is proven ON for a fixed time delay (15 seconds), the damper override is released.

5.10.6 Alarms

5.10.6.1 Low Primary Airflow

a. If the measured airflow is less than 70% of set point for 5 minutes while set point is greater than zero, generate a Level 3 alarm.
b. If the measured airflow is less than 50% of set point for 5 minutes while set point is greater than zero, generate a Level 2 alarm.
c. If a zone has an Importance-Multiplier of 0 (see Section 5.1.14.2[a][1] for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.

5.10.6.2 Low-Discharge Air Temperature

a. If heating hot-water plant is proven ON, and the DAT is 8.3°C (15°F) less than set point for 10 minutes, generate a Level 3 alarm.
b. If heating hot-water plant is proven ON, and the DAT is 17°C (30°F) less than set point for 10 minutes, generate a Level 2 alarm.
c. If a zone has an Importance-Multiplier of 0 (see 5.1.14.2[a][1]) for its hot-water reset T&R control loop, low-DAT alarms shall be suppressed for that zone.

5.10.6.3 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.

a. Commanded ON, status OFF: Level 2
b. Commanded OFF, status ON: Level 4

5.10.6.4 Airflow Sensor Calibration. If the fan serving the zone has been OFF for 10 minutes, and airflow sensor reading is above 10% of the cooling maximum airflow set point, generate a Level 3 alarm.

5.10.6.5 Leaking Damper. If the damper position is 0%, and airflow sensor reading is above 10% of the cooling maximum airflow set point for 10 minutes while the fan serving the zone is proven ON, generate a Level 4 alarm.

5.10.6.6 Leaking Valve. If the valve position is 0% for 15 minutes, and DAT is above AHU SAT by 3°C (5°F), generate a Level 4 alarm.

5.10.7 Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to

a. force zone airflow set point to zero,
b. force zone airflow set point to Vcool-max,
c. force zone airflow set point to Vmin,
d. force damper full closed/open,
e. force heating to OFF/closed,
f. turn fan ON/OFF, and
g. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 5.1.11, all hardware points can be overridden through the BAS. Each of the following points is interlocked so that they can be overridden together at a Zone Group level, per Section 5.4.5.

For example, the CxA can check for leaking dampers by forcing all VAV boxes in a zone group closed and then recording airflow at the AHU.

Central plant sequences are not part of the initial scope of Guideline 36, but control logic for plant requests are being included for future use, when central plant sequences are added.

Typically, the heating hot-water 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.

Hot-water reset requests are used in T&R loops to control supply water temperature and/or pump DP set points based on zone and AHU demands.

5.10.8 System Requests

5.10.8.1 Cooling SAT Reset Requests

a. If the zone temperature exceeds the zone's cooling set point by 3°C (5°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 3 requests.
b. Else if the zone temperature exceeds the zone's cooling set point by 2°C (3°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 2 requests.
c. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
d. Else if the cooling loop is less than 95%, send 0 requests.

Table 5.11.4 Set Points as a Function of Zone Group Mode

Set Point	Occupied	Cooldown	Setup	Warm-Up	Setback	Unoccupied
Cooling maximum	Vcool-max	Vcool-max	Vcool-max	0	0	0
Minimum	Vmin*	0	0	0	0	0
Heating maximum	Vheat-max	0	0	Vheat-max	Vheat-max	0

5.10.8.2 Static Pressure Reset Requests

a. If the measured airflow is less than 50% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 3 requests.
b. Else if the measured airflow is less than 70% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 2 requests.
c. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
d. Else if the damper position is less than 95%, send 0 requests.

5.10.8.3 If There Is a Hot-Water Coil, Hot Water Reset Requests

a. If the DAT is 17°C (30°F) less than set point for 5 minutes, send 3 requests.
b. Else if the DAT is 8.3°C (15°F) less than set point for 5 minutes, send 2 requests.
c. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
d. Else if the HW valve position is less than 95%, send 0 requests.

5.10.8.4 If There Is a Hot-Water Coil and a Heating Hot-Water Plant, Heating Hot-Water Plant Requests. Send the heating hot-water plant that serves the zone a heating hot-water plant request as follows:

a. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.
b. Else if the HW valve position is less than 95%, send 0 requests.

5.11 Dual-Duct VAV Terminal Unit—Snap-Acting Control

Snap-acting control logic is the first choice among the various DD control schemes, as it is the most efficient and does not require DD boxes with mixing sections that 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_2 control because it can cause the zone to oscillate between cooling and heating. This occurs when the CO_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_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 that may occur on systems with high outdoor airflows and no preheat coil. So a preheat coil is likely to be required on such systems if mixed air temperature can fall below 7°C (45°F) or so in winter.

Note that snap-acting logic can also be problematic for zones with high minimums, because 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 overventilated spaces on the same system. Refer to Standard 62.1-2016 and Standard 62.1 User's Manual.

5.11.1 See "Generic Thermal Zones" (Section 5.3) for set points, loops, control modes, alarms, etc.

5.11.2 See "Generic Ventilation Zones" (Section 5.2) for calculation of zone minimum outdoor airflow.

5.11.3 See Section 3.1.2.7 for zone minimum airflow set point Vmin, maximum cooling airflow set point Vcool-max, and the zone maximum heating airflow set point Vheat-max.

5.11.4 Active maximum and minimum set points shall vary depending on the mode of the zone group the zone is a part of (see Table 5.11.4).

5.11.5 Control logic is depicted schematically in Figures 5.11.5-1 and 5.11.5-2 and described in the following subsections. Relative levels of various set points are depicted for occupied mode operation.

The engineer must select between ventilation logic options:

- **If there are airflow sensors at both inlets to the box, use Section 5.11.5.1 and delete Section 5.11.5.2.**
- **If there is a single airflow sensor at the box discharge, use Section 5.11.5.2 and delete Section 5.11.5.1.**

5.11.5.1 Temperature and Damper Control with Dual Inlet Airflow Sensors

a. When the zone state is cooling, the cooling-loop output shall reset the cooling supply airflow set point from the minimum to cooling maximum set points. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at set point. The heating damper shall be closed.
   1. If cold-deck supply air temperature from the air handler is greater than room temperature, cooling supply airflow set point shall be no higher than the minimum.
b. When the zone state is deadband, the cooling and heating airflow set points shall be their last set points just before entering deadband. In other words, when going from cooling to deadband, the cooling airflow set point is equal to

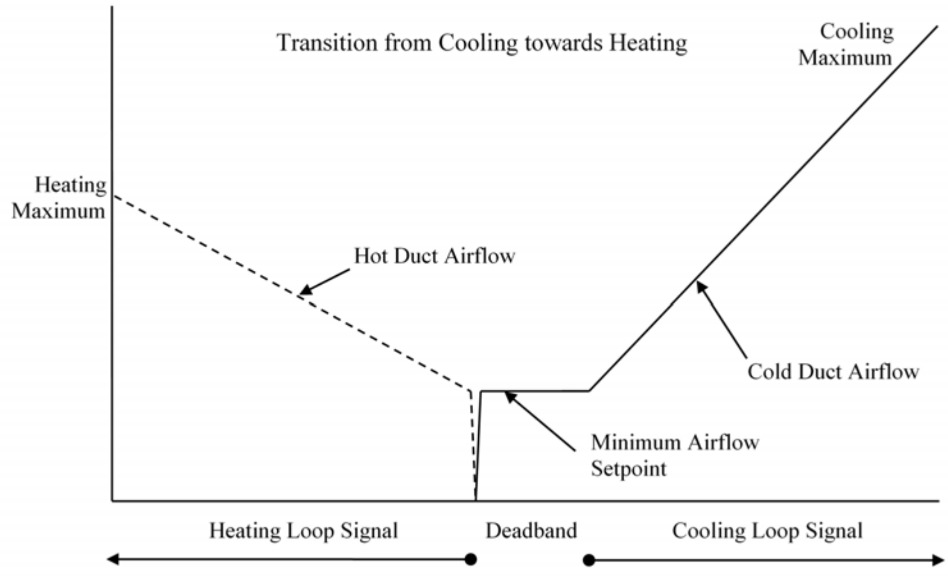

Figure 5.11.5-1 Control logic for snap-acting dual-duct VAV zone (transition to cooling).

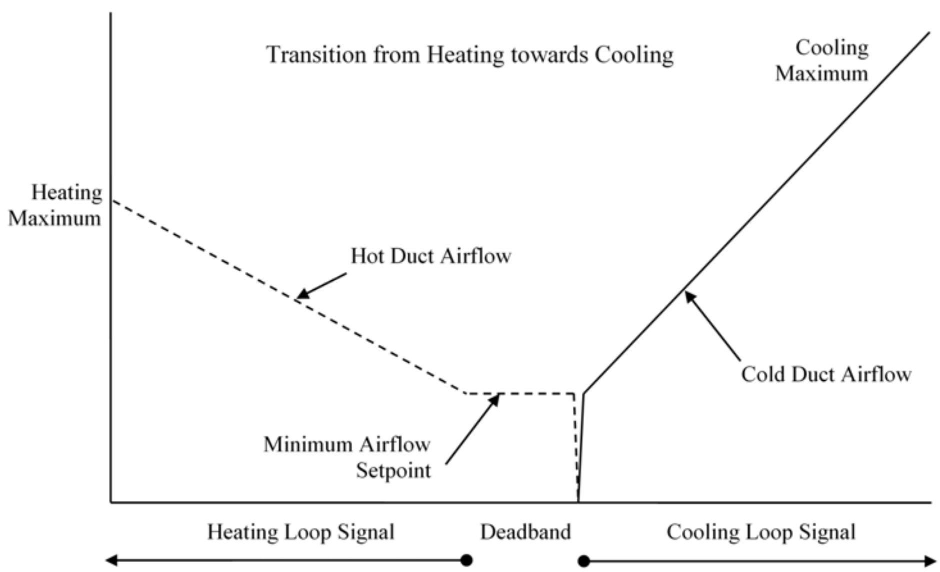

Figure 5.11.5-2 Control logic for snap-acting dual-duct VAV zone (transition to heating).

the zone minimum, and the heating set point is zero. When going from heating to deadband, the heating airflow set point is equal to the zone minimum, and the cooling set point is zero. This results in a snap-action switch in the damper set point as indicated in Figures 5.11.5-1 and 5.11.5-2.

With snap-acting logic, the deadband airflow is maintained by the damper from the last mode, rather than always using the cold deck, as per the mixing sequences below. This is to avoid instability when transitioning from heating to deadband.

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c. When the zone state is heating, the heating-loop output shall reset the heating supply airflow set point from the minimum to heating maximum set points. The heating damper shall be modulated by a control loop to maintain the measured heating airflow at set point. The cooling damper shall be closed.

1. If hot-deck supply air temperature from the air handler is less than room temperature, heating supply airflow set point shall be no higher than the minimum.

The engineer must select between airflow sensor configuration options:

- **If there is a single airflow sensor at the box discharge, use Section 5.11.5.2 and delete Section 5.11.5.1.**
- **If there are airflow sensors at both inlets to the box, use Section 5.11.5.1 and delete Section 5.11.5.2.**

5.11.5.2 Temperature and Damper Control with a Single Discharge Airflow Sensor

a. When the zone states is cooling, the cooling-loop output shall reset the discharge airflow set point from the minimum to cooling maximum set points. The cooling damper shall be modulated by a control loop to maintain the measured discharge airflow at set point. The heating damper shall be closed.
b. When the zone state is deadband, the discharge airflow set point 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 set point, 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 set point, and the cooling damper shall be closed. This results in a snap-action switch in the damper set point as indicated in Figures 5.11.5-1 and 5.11.5-2.
c. When the zone state is heating, the heating-loop output shall reset the discharge airflow set point from the minimum to heating maximum set points. The heating damper shall be modulated by a control loop to maintain the measured discharge airflow at set point. The cooling damper shall be closed.

This concludes the section where the airflow sensor configuration is selected.

When the sequences are complete, only one of Section 5.11.5.1 and Section 5.11.5.2 should remain. The other section should be deleted, along with these flag notes.

5.11.5.3 Overriding Sections 5.11.5.1 and 5.11.5.2 Logic (to Avoid Backflow from One Duct to the Other)

a. If heating air handler is not proven ON, the heating damper shall be closed.
b. If cooling air handler is not proven ON, the cooling damper shall be closed.

5.11.6 Alarms

5.11.6.1 Low Airflow

a. If the measured airflow is less than 70% of set point for 5 minutes while set point is greater than zero, generate a Level 3 alarm.
b. If the measured airflow is less than 50% of set point for 5 minutes while set point is greater than zero, generate a Level 2 alarm.
c. If a zone has an Importance-Multiplier of 0 (see Section 5.1.14.2[1][a]) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.

5.11.6.2 Airflow Sensor Calibration. If the fan serving the zone has been off for 10 minutes, and airflow sensor reading is above 10% of the maximum airflow set point, generate a Level 3 alarm.

5.11.6.3 Leaking Damper. If the damper position is 0%, and airflow sensor reading is above 10% of the cooling maximum airflow set point for 10 minutes while the fan serving the damper is proven ON, generate a Level 4 alarm.

5.11.7 Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to

a. force zone airflow set point to zero,
b. force zone airflow set point to Vcool-max,
c. force zone airflow set point to Vmin,
d. force zone airflow set point to Vheat-max,
e. force cooling damper full closed/open,
f. force heating damper full closed/open, and
g. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 5.1.11, all hardware points can be overridden through the BAS. Each of the following points is interlocked so that they can be overridden together at a Zone Group level, per Section 5.4.5.

For example, the CxA can check for leaking dampers by forcing all VAV boxes in a zone group closed and then recording airflow at the AHU.

5.11.8 System Requests

5.11.8.1 Cooling SAT Reset Requests

a. If the zone temperature exceeds the zone's cooling set point by 3°C (5°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 3 requests.
b. Else if the zone temperature exceeds the zone's cooling set point by 2°C (3°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 2 requests.
c. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
d. Else if the cooling loop is less than 95%, send 0 requests.

5.11.8.2 Cold-Duct Static Pressure Reset Requests

a. If the measured airflow is less than 50% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 3 requests.
b. Else if the measured airflow is less than 70% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 2 requests.
c. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
d. Else if the damper position is less than 95%, send 0 requests.

5.11.8.3 Heating SAT Reset Requests

a. If the zone temperature is below the zone's heating set point by 3°C (5°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 3 requests.
b. Else if the zone temperature is below the zone's heating set point by 2°C (3°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 2 requests.

c. Else if the heating loop is greater than 95%, send 1 request until the heating loop is less than 85%.
d. Else if the heating loop is less than 95%, send 0 requests

5.11.8.4 Hot-Duct Static Pressure Reset Requests

a. If the measured airflow is less than 50% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 3 requests.
b. Else if the measured airflow is less than 70% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 2 requests.
c. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
d. Else if the damper position is less than 95%, send 0 requests.

5.11.8.5 Heating-Fan Requests. Send the heating fan that serves the zone a heating-fan request as follows:

a. If the heating loop is greater than 15%, send 1 request until the heating loop is less than 1%.
b. Else if the heating loop is less than 15%, send 0 requests.

5.12 Dual-Duct VAV Terminal Unit—Mixing Control with Inlet Airflow Sensors

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Mixing control logic is the preferred option for use with DCV. 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 uses 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 most of the heating mode, the heating system must include ventilation air either with direct outdoor air intake or indirectly via transfer air from overventilated spaces on the same system. Refer to Standard 62.1-2016 and Standard 62.1 User's Manual.

5.12.1 See "Generic Thermal Zones" (Section 5.3) for set points, loops, control modes, alarms, etc.

5.12.2 See "Generic Ventilation Zones" (Section 5.2) for calculation of zone minimum outdoor airflow.

5.12.3 See Section 3.1.2.7 for zone minimum airflow set point Vmin, zone maximum cooling airflow set point Vcool-max, and the zone maximum heating airflow set point Vheat-max.

5.12.4 Active maximum and minimum set points shall vary depending on the mode of the zone group the zone is a part of (see Table 5.12.4).

5.12.5 Control logic is depicted schematically in Figure 5.12.5 and described in the following sections. Relative levels of various set points are depicted for occupied mode operation.

5.12.5.1 Temperature Control

a. When the zone state is cooling, the cooling loop output shall reset the cooling supply airflow set point from minimum to the maximum cooling set point. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at set point.
   1. If cold-deck supply air temperature from the air handler is greater than room temperature, cooling supply airflow set point shall be no higher than the minimum.
b. When the zone state is deadband, the cooling airflow set point shall be the minimum set point. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at set point. The heating damper shall be closed.

The deadband airflow is maintained by the cooling damper, as the cooling system has a definite source of ventilation. With dual-fan dual-duct, the heating fan generally has no direct ventilation source; typically, ventilation is indirect via return air from interior zones that are overventilated due to the outdoor air economizer.

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c. When the zone state is heating, the heating-loop output shall reset the heating supply airflow set point from zero to the maximum heating set point. The heating damper shall be modulated by a control loop to maintain the measured heating airflow at set point. The cooling damper shall be controlled to maintain the sum of the measured inlet airflows at the minimum airflow set point.
   1. If hot-deck supply air temperature from air handler is less than room temperature, heating supply airflow set point shall be no higher than the minimum.

5.12.5.2 Overriding Section 5.12.5.1 Logic (to Avoid Backflow from One Duct to the Other)

a. If heating air handler is not proven ON, the heating damper shall be closed.
b. If cooling air handler is not proven ON, the cooling damper shall be closed.

5.12.6 Alarms

5.12.6.1 Low Airflow

a. If the measured airflow is less than 70% of set point for 5 minutes while set point is greater than zero, generate a Level 3 alarm.
b. If the measured airflow is less than 50% of set point for 5 minutes while set point is greater than zero, generate a Level 2 alarm.
c. If a zone has an Importance-Multiplier of 0 (see Section 5.1.14.2.[a][1]) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.

Table 5.12.4 Set Points as a Function of Zone Group Mode

Set Point	Occupied	Cooldown	Setup	Warm-Up	Setback	Unoccupied
Cooling maximum	Vcool-max	Vcool-max	Vcool-max	0	0	0
Minimum	Vmin*	0	0	0	0	0
Heating maximum	Vheat-max	0	0	Vheat-max	Vheat-max	0

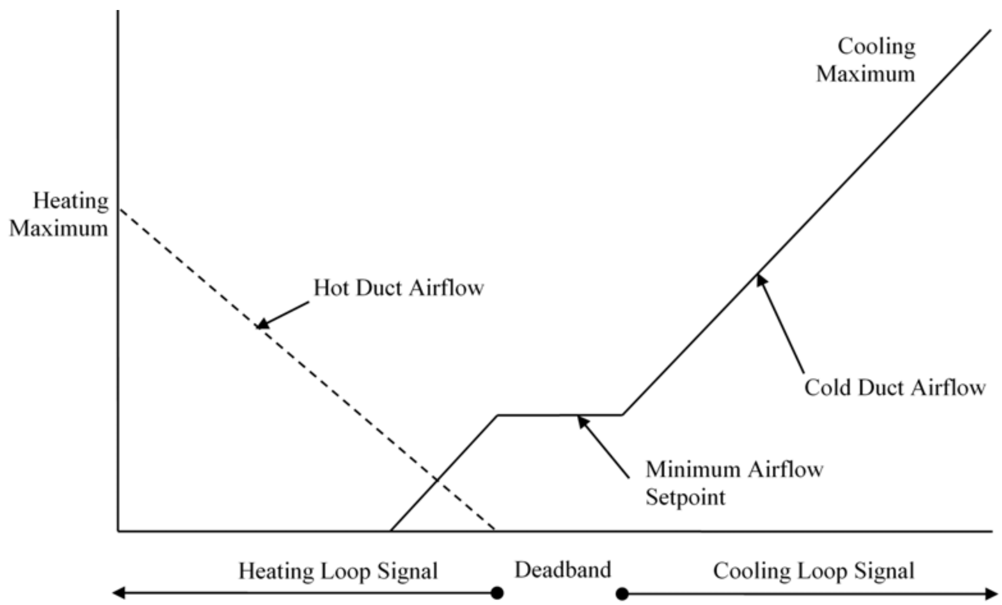

Figure 5.12.5 Control logic for mixing dual-duct VAV zone with inlet sensors.

5.12.6.2 Airflow Sensor Calibration. If the fan serving the zone has been OFF for 10 minutes, and airflow sensor reading is above 10% of the maximum airflow set point, generate a Level 3 alarm.

5.12.6.3 Leaking Damper. If the damper position is 0%, and airflow sensor reading is above 10% of the cooling maximum airflow set point for 10 minutes while the fan serving the damper is proven ON, generate a Level 4 alarm.

5.12.7 Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to

a. force zone airflow set point to zero,
b. force zone airflow set point to Vcool-max,
c. force zone airflow set point to Vmin,
d. force zone airflow set point to Vheat-max,
e. force cooling damper full closed/open,
f. force heating damper full closed/open, and
g. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 5.1.11, all hardware points can be overridden through the BAS. Each of the following points is interlocked so that they can be overridden together at a zone-group level, per Section 5.4.5.

For example, the CxA can check for leaking dampers by forcing all VAV boxes in a zone group closed and then recording airflow at the AHU.

5.12.8 System Requests

5.12.8.1 Cooling SAT Reset Requests

a. If the zone temperature exceeds the zone's cooling set point by 3°C (5°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 3 requests.
b. Else if the zone temperature exceeds the zone's cooling set point by 2°C (3°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 2 requests.
c. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
d. Else if the cooling loop is less than 95%, send 0 requests.

5.12.8.2 Cold-Duct Static Pressure Reset Requests

a. If the measured airflow is less than 50% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 3 requests.
b. Else if the measured airflow is less than 70% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 2 requests.
c. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
d. Else if the damper position is less than 95%, send 0 requests.

5.12.8.3 Heating SAT Reset Requests

a. If the zone temperature is below the zone's heating set point by 3°C (5°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 3 requests.
b. Else if the zone temperature is below the zone's heating set point by 2°C (3°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 2 requests.
c. Else if the heating loop is greater than 95%, send 1 request until the heating loop is less than 85%.
d. Else if the heating loop is less than 95%, send 0 requests.

5.12.8.4 Hot-Duct Static Pressure Reset Requests

a. If the measured airflow is less than 50% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 3 requests.
b. Else if the measured airflow is less than 70% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 2 requests.
c. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
d. Else if the damper position is less than 95%, send 0 requests.

5.12.8.5 Heating-Fan Requests. Send the heating fan that serves the zone a heating-fan request as follows:

a. If the heating loop is greater than 15%, send 1 request until the heating loop is less than 1%.
b. Else if the heating loop is less than 15%, send 0 requests.

5.13 Dual-Duct VAV Terminal Unit—Mixing Control with Discharge Airflow Sensor

Mixing control logic is the preferred option for use with DCV. 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 uses 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 of a legacy approach from when adding a second airflow sensor was much more expensive. As dual-airflow-sensor controllers are now more common, the previous 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 overventilated spaces on the same system. Refer to Standard 62.1-2016 and Standard 62.1 User's Manual.

5.13.1 See "Generic Thermal Zones" (Section 5.3) for set points, loops, control modes, alarms, etc.

5.13.2 See "Generic Ventilation Zones" (Section 5.2) for calculation of zone minimum outdoor airflow.

5.13.3 See Section 3.1.2.7 for zone minimum airflow set point Vmin, zone maximum cooling airflow set point Vcool-max, and the zone maximum heating airflow set point Vheat-max.

5.13.4 Active maximum and minimum set points shall vary depending on the mode of the zone group the zone is a part of (see Table 5.13.4).

5.13.5 Control logic is depicted schematically in Figure 5.13.5 and described in the following subsections. Relative levels of various set points are depicted for occupied mode operation.

5.13.5.1 Temperature Control

Because there is only a single airflow sensor on the combined discharge, typical pressure-independent control will not work for both dampers. Instead, the cooling damper is controlled using pressure-independent control, while the heating damper position equals the heating loop signal (i.e., pressure-dependent control).

a. When the zone state is cooling, the cooling-loop output shall reset the cooling supply airflow set point from minimum to the maximum cooling set point. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at set point.
   1. If cold-deck supply air temperature from the air handler is greater than room temperature, cooling supply airflow set point shall be no higher than the minimum.
b. When the zone state is deadband, the cooling airflow set point shall be the minimum set point. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at set point. The heating damper shall be closed.

The deadband airflow is maintained by the cooling damper, as the cooling system has a definite source of ventilation. With dual-fan dual-duct, the heating fan generally has no direct ventilation source; typically, ventilation is indirect via return air from interior zones that are overventilated due to the outdoor air economizer.

c. When the zone state is heating, the heating loop output shall be mapped to the heating damper position. The cooling damper is modulated to maintain measured discharge airflow at the minimum airflow set point.
   1. If hot-deck supply air temperature from the air handler is less than room temperature, the heating damper shall be closed.
   2. Maximum heating airflow shall be limited by a reverse-acting P-only loop whose set point is Vheat-max and whose output is maximum heating damper position ranging from 0% to 100%.

Because the heating damper is operating in a pressure-dependent manner, a loop must be added to limit heating damper position to Vheat-max. When this comes into play, the only air passing through the discharge airflow sensor is heating air.

Table 5.13.4 Set Points as a Function of Zone Group Mode

Set Point	Occupied	Cooldown	Setup	Warm-Up	Setback	Unoccupied
Cooling maximum	Vcool-max	Vcool-max	Vcool-max	0	0	0
Minimum	Vmin*	0	0	0	0	0
Heating maximum	Vheat-max	0	0	Vheat-max	Vheat-max	0

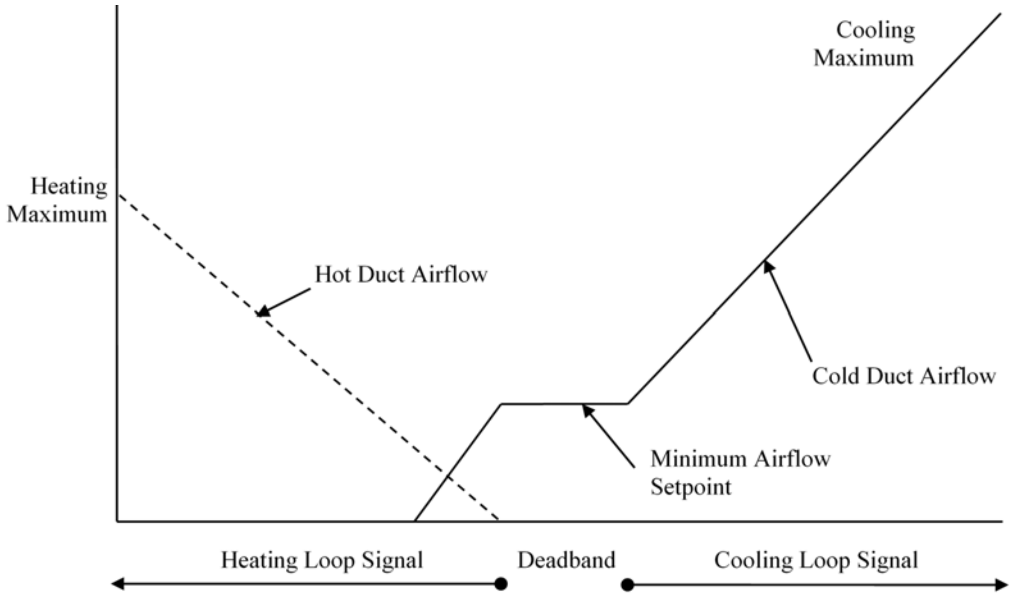

Figure 5.13.5 Control logic for mixing dual-duct VAV zone with discharge sensor.

5.13.5.2 Overriding Section 5.13.5.1 Logic (to Avoid Backflow from One Duct to the Other)

a. If heating air handler is not proven ON, the heating damper shall be closed.
b. If cooling air handler is not proven ON, the cooling damper shall be closed.

5.13.6 Alarms

5.13.6.1 Low Airflow

a. If the measured airflow is less than 70% of set point for 5 minutes while set point is greater than zero, generate a Level 3 alarm.
b. If the measured airflow is less than 50% of set point for 5 minutes while set point is greater than zero, generate a Level 2 alarm.
c. If a zone has an Importance-Multiplier of 0 (see Section 5.1.14.2[a][1]) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.

5.13.6.2 Airflow Sensor Calibration. If the fan serving the zone has been OFF for 10 minutes, and airflow sensor reading is above 10% of the maximum airflow set point, generate a Level 3 alarm.

5.13.6.3 Leaking Damper. If the damper position is 0%, and airflow sensor reading is above 10% of the cooling maximum airflow set point for 10 minutes while the fan serving the damper is proven ON, generate a Level 4 alarm.

5.13.7 Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to

a. force zone airflow set point to zero,
b. force zone airflow set point to Vcool-max,
c. force zone airflow set point to Vmin,
d. force zone airflow set point to Vheat-max,
e. force cooling damper full closed/open,
f. force heating damper full closed/open, and
g. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 5.1.11, all hardware points can be overridden through the BAS. Each of the following points is interlocked so that they can be overridden together at a Zone Group level, per Section 5.4.5.

For example, the CxA can check for leaking dampers by forcing all VAV boxes in a zone group closed and then recording airflow at the AHU.

5.13.8 System Requests

5.13.8.1 Cooling SAT Reset Requests

a. If the zone temperature exceeds the zone's cooling set point by 3°C (5°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 3 requests.

b. Else if the zone temperature exceeds the zone's cooling set point by 2°C (3°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 2 requests.
c. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
d. Else if the cooling loop is less than 95%, send 0 requests.

5.13.8.2 Cold-Duct Static Pressure Reset Requests

a. If the measured airflow is less than 50% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 3 requests.
b. Else if the measured airflow is less than 70% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 2 requests.
c. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
d. Else if the damper position is less than 95%, send 0 requests.

5.13.8.3 Heating SAT Reset Requests

a. If the zone temperature is below the zone's heating set point by 3°C (5°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 3 requests.
b. Else if the zone temperature is below the zone's heating set point by 2°C (3°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 2 requests.
c. Else if the heating loop is greater than 95%, send 1 request until the heating loop is less than 85%.
d. Else if the heating loop is less than 95%, send 0 requests.

5.13.8.4 Hot-Duct Static Pressure Reset Requests

a. If the measured airflow is less than 50% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 3 requests.
b. Else if the measured airflow is less than 70% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 2 requests.
c. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
d. Else if the damper position is less than 95%, send 0 requests.

5.13.8.5 Heating-Fan Requests. Send the heating fan that serves the zone a heating-fan request as follows:

a. If the heating loop is greater than 15%, send 1 request until the heating loop is less than 1%
b. Else if the heating loop is less than 15%, send 0 requests.

5.14 Dual-Duct VAV Terminal Unit—Cold-Duct Minimum Control

Cold-duct minimum control logic is the most conventional, but least efficient, dual-duct control strategy. It ensures ventilation rates without Standard 62.1-2016 generalized multiple spaces considerations, because only the cold duct has ventilation air with DFDD systems.

This strategy uses dual airflow sensors, one at each inlet. It may be used with or without DCV.

The designer must ensure that the minimum and heating maximum sum to less than the cooling maximum to avoid oversupplying the diffusers.

5.14.1 See "Generic Thermal Zones" (Section 5.3) for set points, loops, control modes, alarms, etc.

5.14.2 See "Generic Ventilation Zones" (Section 5.2) for calculation of zone minimum outdoor airflow.

5.14.3 See Section 3.1.2.7 for zone minimum airflow set point Vmin, zone maximum cooling airflow set point Vcool-max, and the zone maximum heating airflow set point Vheat-max.

5.14.4 Active maximum and minimum set points shall vary depending on the mode of the zone group the zone is a part of (see Table 5.14.4).

5.14.5 Control logic is depicted schematically in Figure 5.14.5 and described in the following subsections. Relative levels of various set points are depicted for occupied mode operation.

5.14.5.1 Temperature and Damper Control

a. When the zone state is cooling, the cooling loop output shall reset the cooling supply airflow set point from the minimum to cooling maximum set points. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at set point. The heating damper shall be closed.
    1. If cold-deck supply air temperature from air handler is greater than room temperature, cooling supply airflow set point shall be no higher than the minimum.
b. When the zone state is deadband, the cooling airflow set point shall be the minimum set point. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at set point. The heating damper shall be closed.
c. When the zone state is heating:
    1. The heating loop output shall reset the heating supply airflow set point from zero to heating maximum set point. The heating damper shall be modulated by a control loop to maintain the measured heating airflow at set point.
    2. The cooling airflow set point shall be the minimum set point. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at set point.
    3. If hot-deck supply air temperature from the air handler is less than room temperature, the heating damper shall be closed.

5.14.5.2 Overriding Section 5.14.5.1 Logic (to Avoid Backflow from One Duct to the Other)

a. If heating air handler is not proven ON, the heating damper shall be closed.
b. If cooling air handler is not proven ON, the cooling damper shall be closed.

Table 5.14.4 Set Points as a Function of Zone Group Mode

Set Point	Occupied	Cooldown	Setup	Warm-Up	Setback	Unoccupied
Cooling maximum	Vcool-max	Vcool-max	Vcool-max	0	0	0
Minimum	Vmin*	0	0	0	0	0
Heating maximum	Vheat-max	0	0	Vheat-max	Vheat-max	0

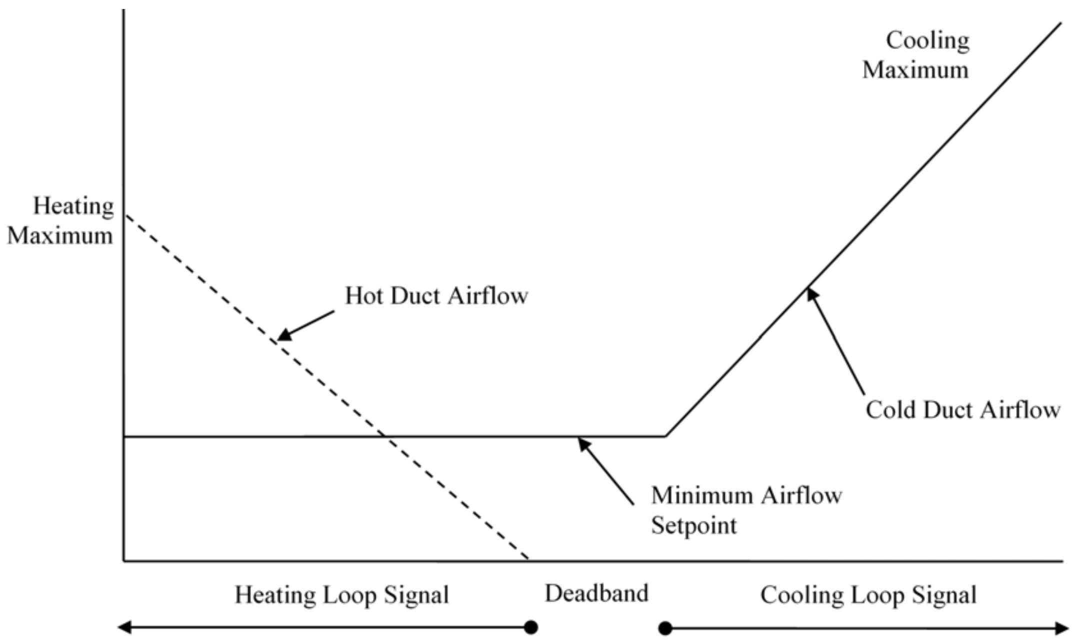

Figure 5.14.5 Control logic for mixing dual-duct VAV zone with cold-duct minimum.

5.14.6 Alarms

5.14.6.1 Low Airflow

a. If the measured airflow is less than 70% of set point for 5 minutes while set point is greater than zero, generate a Level 3 alarm.
b. If the measured airflow is less than 50% of set point for 5 minutes while set point is greater than zero, generate a Level 2 alarm.
c. If a zone has an Importance-Multiplier of 0 (see Section 5.1.14.2[a][1]) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.

5.14.6.2 Airflow Sensor Calibration. If the fan serving the zone has been off for 10 minutes, and airflow sensor reading is above 10% of the maximum airflow set point, generate a Level 3 alarm.

5.14.6.3 Leaking Damper. If the damper position is 0%, and airflow sensor reading is above 10% of the cooling maximum airflow set point for 10 minutes while the fan serving the damper is proven ON, generate a Level 4 alarm.

5.14.7 Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to

a. force zone airflow set point to zero,
b. force zone airflow set point to Vcool-max,
c. force zone airflow set point to Vmin,
d. force zone airflow set point to Vheat-max,
e. force cooling damper full closed/open,
f. force heating damper full closed/open, and
g. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 5.1.11, all hardware points can be overridden through the BAS. Each of the following points is interlocked so that they can be overridden together at a zone-group level, per Section 5.4.5.

For example, the CxA can check for leaking dampers by forcing all VAV boxes in a zone group closed and then recording airflow at the AHU.

5.14.8 System Requests

5.14.8.1 Cooling SAT Reset Requests

a. If the zone temperature exceeds the zone's cooling set point by 3°C (5°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 3 requests.
b. Else if the zone temperature exceeds the zone's cooling set point by 2°C (3°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 2 requests.

c. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
d. Else if the cooling loop is less than 95%, send 0 requests.

5.14.8.2 Cold-Duct Static Pressure Reset Requests

a. If the measured airflow is less than 50% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 3 requests.
b. Else if the measured airflow is less than 70% of set point while set point is greater than zero and the damper position is greater than 95% for 1 minute, send 2 requests.
c. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
d. Else if the damper position is less than 95%, send 0 requests.

5.14.8.3 Heating SAT Reset Requests

a. If the zone temperature is below the zone's heating set point by 3°C (5°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 3 requests.
b. Else if the zone temperature is below the zone's heating set point by 2°C (3°F) for 2 minutes and after suppression period due to set point change per Section 5.1.19, send 2 requests.
c. Else if the heating loop is greater than 95%, send 1 request until the heating loop is less than 85%.
d. Else if the heating loop is less than 95%, send 0 requests.

5.14.8.4 Hot-Duct Static Pressure Reset Requests

a. If the measured airflow is less than 50% of set point while set point is greater than zero for 1 minute, send 3 requests.
b. Else if the measured airflow is less than 70% of set point while set point is greater than zero for 1 minute, send 2 requests.
c. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
d. Else if the damper position is less than 95%, send 0 requests.

5.14.8.5 Heating-Fan Requests. Send the heating fan that serves the zone a heating-fan request as follows:

a. If the heating loop is greater than 15%, send 1 request until the heating loop is less than 1%.
b. Else if the heating loop is less than 15%, send 0 requests.

5.15 Air-Handling Unit System Modes

5.15.1 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. Cooldown mode
c. Setup mode
d. Warm-up mode
e. Setback mode
f. Freeze protection setback mode
g. Unoccupied mode

Table 5.16.1.2 Trim & Respond Variables

Variable	Value
Device	Supply fan
SP0	120 Pa (0.5 in. of water)
SPmin	25 Pa (0.1 in. of water)
SPmax	Max_DSP (see Section 3.2.1.1)
Td	10 minutes
T	2 minutes
I	2
R	Zone static pressure reset requests
SPtrim	–12 Pa (–0.05 in. of water)
SPres	15 Pa (+0.06 in. of water)
SPres-max	32 Pa (+0.13 in. of water)

5.16 Multiple-Zone VAV Air-Handling Unit

This section applies primarily to a cooling VAV air-handling system. It can be adapted to apply to a heating air handler serving a dual-duct VAV system by editing out logic that does not apply and by adjusting supply air temperature set points.

5.16.1 Supply Fan Control

5.16.1.1 Supply Fan Start/Stop

a. Supply fan shall run when system is in the cooldown mode, setup mode, or occupied mode.
b. If there are any VAV-reheat boxes on perimeter zones, supply fan shall also run when system is in setback mode or warm-up mode (i.e., all modes except unoccupied).

Delete the following paragraph if the air-handler serves dual-duct boxes that do not have hot-duct inlet airflow sensors, i.e., those that have only a box discharge airflow sensor. This paragraph may also be deleted if there is a supply AFMS.

c. Totalize current airflow rate from VAV boxes to a software point Vps.

VAV box airflow rates are summed to obtain overall supply air rate without the need for an airflow measuring station (AFMS) at the air-handler discharge. This is used for ventilation rate calculations and may also be used for display and diagnostics.

5.16.1.2 Static Pressure Set-Point Reset

a. **Static pressure set point.** Set point shall be reset using T&R logic (see Section 5.1.14) using the parameters shown in Table 5.16.1.2.

The T&R reset parameters in Table 5.16.1.2 are suggested as a starting point; they will most likely require adjustment during the commissioning/tuning phase.

5.16.1.3 Static Pressure Control

a. Supply fan speed is controlled to maintain DSP at set point when the fan is proven ON. 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.).

High-pressure trips may occur if all VAV boxes are closed (as in unoccupied mode) or if fire/smoke dampers are closed (in some fire/smoke damper (FSD) designs, the dampers are interlocked to the fan status rather than being controlled by smoke detectors). Multiple sets of gains are used to provide control loop stability as system characteristics change.

5.16.2 Supply Air Temperature Control

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

5.16.2.2 Supply Air Temperature Set Point

The default range of outdoor air temperatures [21°C (70°F) –16°C (60°F)] used to reset the occupied mode SAT set point was chosen to maximize economizer hours. It may be preferable to use a lower range of OATs (e.g., 18°C [65°F] – 13°C [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, or*
- *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 do not drive the T&R block to the minimum SAT set point.

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a. See Section 3.1.4.1 for Min_ClgSAT, Max_ClgSAT, OAT_Min, and OAT_Max set points.

b. During occupied mode and setup mode, set point shall be reset from Min_ClgSAT when the outdoor air temperature is OAT_Max and above, proportionally up to T-max when the outdoor air temperature is OAT_Min and below.

   1. T-max shall be reset using T&R logic (see Section 5.1.14) between Min_ClgSAT and Max_ClgSAT. The parameters shown in Table 5.16.2.2 are suggested as a starting place, but they will require adjustment during the commissioning/tuning phase.

      The net result of this SAT reset strategy is depicted in the Figure 5.16.2.2 for Min_ClgSAT = 12°C (55°F), Max_ClgSAT = 18°C (65°F), OAT_Max = 21°C (70°F), and OAT_Min = 16°C (60°F).

The T&R reset parameters in Table 5.16.2.2 are suggested as a starting place; they will most likely require adjustment during the commissioning/tuning phase.

Table 5.16.2.2 Trim & Respond Variables

Variable	Value
Device	Supply fan
SP0	SPmax
SPmin	Min_ClgSAT
SPmax	Max_ClgSAT
Td	10 minutes
T	2 minutes
I	2
R	Zone cooling SAT requests
SPtrim	+0.1°C (+0.2°F)
SPres	–0.2°C (–0.3°F)
SPres-max	–0.6°C (–1.0°F)

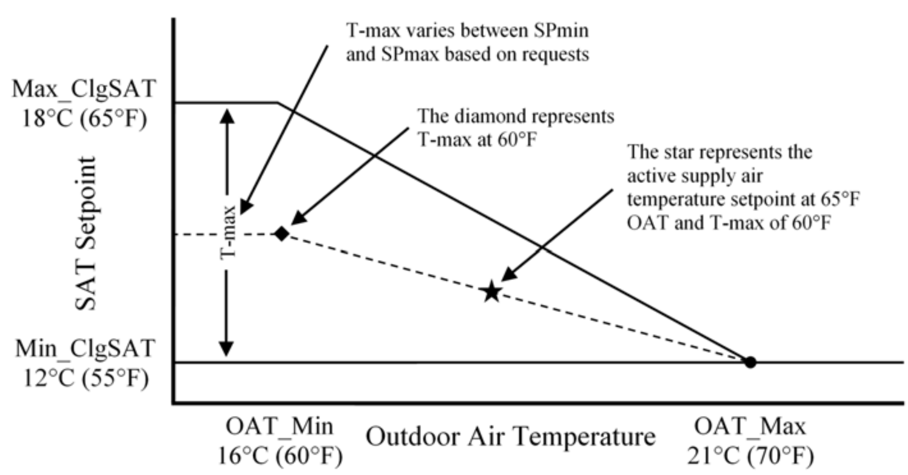

Figure 5.16.2.2 Example supply air temperature reset diagram.

c. During cooldown mode, set point shall be Min_ClgSAT.
d. During warm-up and setback modes, set point shall be 35°C (95°F).

Raising the SAT set point in warm-up will effectively lock out the economizer and cooling coil, which is desirable for warm-up 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 warm-up and setback.

5.16.2.3 Supply air temperature shall be controlled to set point using a control loop whose output is mapped to sequence the heating coil (if applicable), outdoor air damper, return air damper, and cooling coil as shown in Figure 5.16.2.3-1.

a. Economizer damper maximum position MaxOA-P is limited for economizer high-limit lockout (see Section 5.16.8.1).

The engineer must specify whether minimum outdoor air and economizer functions use separate dedicated dampers or a single common damper.

- **If there are separate dedicated dampers, keep subsection (b) and delete subsection (c).**
- **If there is a single common damper, keep subsection (c) and delete subsection (b).**

Note that a single common damper requires an outdoor air AFMS. It is not a valid choice if minimum outdoor air control is being done by DP (i.e., if is being used).

Delete this flag note after selection has been made.

---

b. For units with a separate minimum outdoor air damper, economizer damper minimum position MinOA-P is 0%, and return air damper maximum position MaxRA-P is modulated to control minimum outdoor air volume (see Sections 5.16.4 and 5.16.5).
c. For units with a single common minimum outdoor air and economizer damper, return air damper maximum position MaxRA-P and economizer damper minimum position MinOA-P are modulated to control minimum outdoor air volume (see Section 5.16.6).
d. The points of transition along the x-axis shown and described in Figure 5.16.2.3-1 are representative. Separate gains shall be provided for each section of the control map (heating coil, economizer, cooling coil) that is determined by the contractor to provide stable control. Alternatively, the contractor shall adjust the precise value of the x-axis thresholds shown in Figure 5.16.2.3-1 to provide stable control. Damper control depends on the type of building pressure control system.

The engineer should indicate which of the following three diagrams apply and delete the others.

---

1. Relief damper or relief fan (Figure 5.16.2.3-1)

Outdoor air and return air dampers are sequenced rather than complementary (as per traditional sequences) to reduce fan power at part loads.

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2. Return-fan control with airflow tracking (Figure 5.16.2.3-2)
3. Return-fan control with direct building pressure controls (Figure 5.16.2.3-3)

For AHUs with return fans, the outdoor air damper remains fully open whenever the AHU is on, while the return air damper modulates to maintain supply air temperature and minimum outdoor airflow at set point. For return-fan systems using airflow tracking building pressure control logic, the relief/exhaust damper inversely tracks the return air damper. Outdoor air dampers on air handlers with return fans have no impact on the outdoor airflow rate into the mixing plenum. Instead, the return-fan and return-damper controls dictate outdoor air flow. See ASHRAE Guideline 16.

5.16.3 Minimum Outdoor Airflow Set Points

The engineer must select between options for determining the outdoor airflow set point based on the ventilation logic being used.

- **If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 5.16.3.1 and delete Section 5.16.3.2.**
- **If the project is to comply with California Title 24 ventilation requirements, keep Section 5.16.3.2 and delete Section 5.16.3.1.**

5.16.3.1 Outdoor Airflow Set Point for ASHRAE Standard 62.1-2016 Ventilation

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CO_2 DCV at the system level is not yet implemented for Standard 62.1 compliance, pending the results of RP-1747.

---

a. See Section 5.2.1.3.5 for zone outdoor air requirement Voz.
b. See Section 3.1.4.2.1 for set points DesVou and DesVot.

The following logic solves the Standard 62.1 multiple-spaces equation dynamically. This is required prescriptively by ASHRAE/IES Standard 90.1 for single-duct VAV systems. The logic does not strictly apply to VAV systems with multiple recirculation paths, such as dual-fan dual-duct systems and systems with fan-powered terminals, nor is it required by Standard 90.1 for these systems. Logic for dynamic reset for these systems has yet to be developed.

---

c. Outdoor air absolute minimum and design minimum set points are recalculated continuously based on the mode of the zones being served.

Some diversity factor is included in Vou, calculated below, because the ventilation requirements have been zeroed out for unoccupied zones and those with open window switches. But there is additional diversity in areas with occupancy sensors

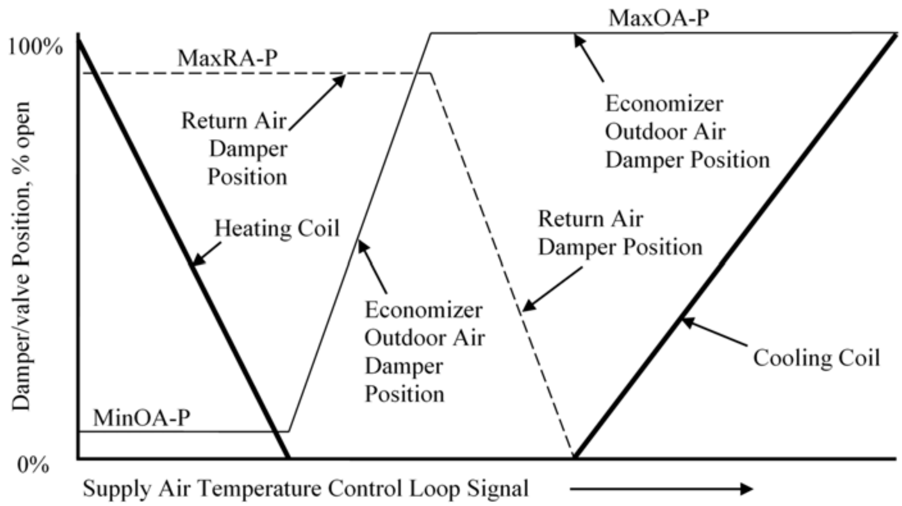

Figure 5.16.2.3-1 SAT loop mapping with relief damper or relief fan.

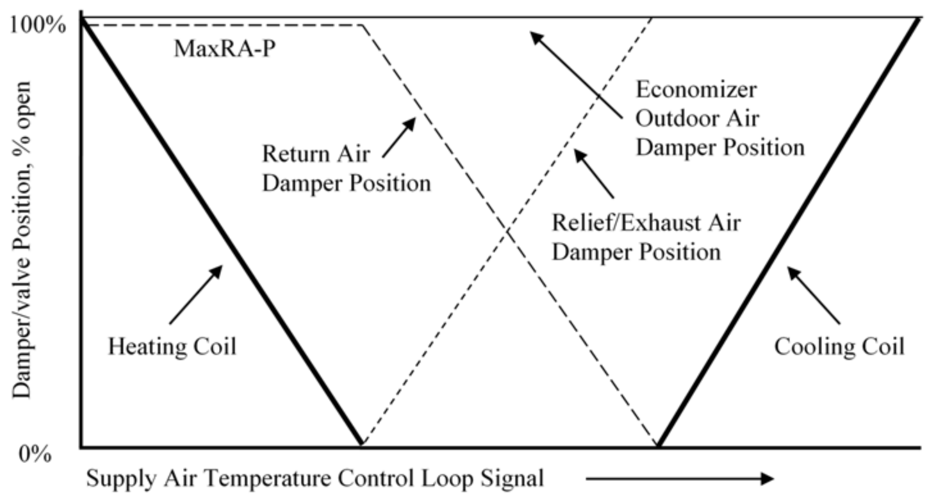

Figure 5.16.2.3-2 SAT loop mapping with return-fan control with airflow tracking.

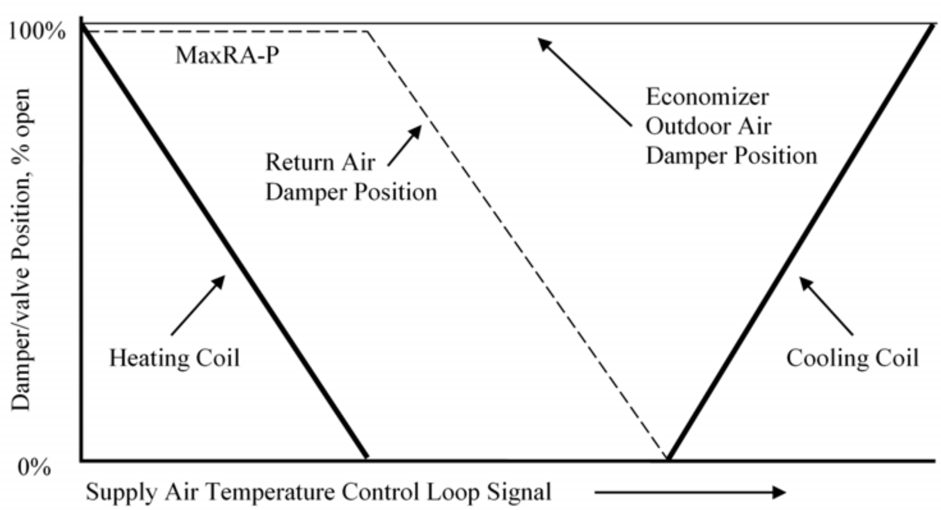

Figure 5.16.2.3-3 SAT loop mapping with return-fan control with direct building pressure controls.

because only one person in the room will trigger the sensor. There is also diversity in other areas without occupancy sensors. Therefore operating Vou is limited to design Vou, and the diversity value of D in the calculation of DesVou is not required.

---

1. Calculate the uncorrected outdoor air rate Vou for all zones in all zone groups that are in occupied mode, but note that Vou shall be no larger than the design uncorrected outdoor air rate DesVou.

$$\text{Vou} = \text{MIN}[\text{DesVou} \mid (\sum \text{Vbz-A} + \sum \text{Vbz-P})]$$

d. Vps is the sum of the zone primary airflow rates Vpz as measured by VAV boxes for all zones in all zone groups that are in occupied mode.

e. For each zone in occupied mode, calculate the zone primary outdoor air fraction Zpz:

$$\text{Zpz} = \text{Voz/Vpz}$$

See ASHRAE Guideline 13 for best practices in locating programming logic for the zone primary outdoor air fraction calculation based on network architecture.

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f. Calculate the maximum zone outdoor air fraction Zp:

$$\text{Zp} = \max(\text{Zpz})$$

g. Calculate the current system ventilation efficiency Ev:

$$\text{Ev} = 1 + (\text{Vou/Vps}) - \text{Zp}$$

h. Calculate the effective minimum outdoor air set point MinOAsp as the uncorrected outdoor air intake divided by the system ventilation efficiency, but no larger than the design total outdoor air rate DesVot:

$$\text{MinOAs} = \text{MIN}\left(\frac{\text{Vou}}{\text{Ev}} \mid \text{DesVot}\right)$$

- **If the project is to comply with California Title 24 ventilation requirements, keep Section 5.16.3.2 and delete Section 5.16.3.1.**
- **If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 5.16.3.1 and delete Section 5.16.3.2.**

5.16.3.2 Outdoor Airflow Set Point for California Title 24 Ventilation

a. See Section 5.2.1.4.2 for zone outdoor air rates Zone-Abs-OA-min and Zone-Des-OA-min.

b. See Section 3.1.4.2.2 for set points AbsMinOA and DesMinOA.

c. Effective outdoor air absolute minimum and design minimum set points are recalculated continuously based on the mode of the zones being served.

   1. 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.
   2. 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.

This concludes the section where the method for determining the outdoor airflow set point is selected.

When the sequences are complete, only one of Section 5.16.3.1 or Section 5.16.3.2 should remain. The other subsection should be deleted along with these flag notes.

The engineer must select among options for minimum outdoor air control logic based on two criteria:

- **Do the minimum outdoor air and economizer functions use separate dedicated dampers or a single common damper?**
- **Is outdoor air volume measured by DP ΔP or an airflow measurement station (AFMS)?**

Control logic selections should be made as follows:

- **For AHUs with separate dedicated dampers and OA measurement by ΔP, use Section 5.16.4 and delete Sections 5.16.5 and 5.16.6.**
- **For AHUs with separate dedicated dampers and OA measurement by AFMS, use Section 5.16.5 and delete Sections 5.16.4 and 5.16.6.**
- **For AHUs with a single common damper and OA measurement by AFMS, use Section 5.16.6 and delete Sections 5.16.4 and 5.16.5.**
- **AHUs with a single common damper and OA measurement by ΔP are not supported because OA measurements are not accurate in this configuration.**

DCV is supported in all three options but only for California Title 24 ventilation.

5.16.4 Minimum Outdoor Air Control with a Separate Minimum Outdoor Air Damper and Differential Pressure Control

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The engineer must select between ventilation logic options:

- **If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 5.16.4.1 and delete Section 5.16.4.2.**
- **If the project is to comply with California Title 24 ventilation requirements, keep Section 5.16.4.2 and delete Section 5.16.4.1.**

5.16.4.1 DP Set Point for ASHRAE Standard 62.1 Ventilation

a. See Section 3.2.1.5 for design OA DP set points.

b. See Section 5.16.3.1 for calculation of current outdoor air set point MinOAsp.

c. The minimum outdoor air DP set point MinDPsp shall be calculated as

$$\mathrm{MinDPsp} = \mathrm{DesMinDP}\left[\frac{\mathrm{MinOAsp}}{\mathrm{DesVot}}\right]^2$$

- **If the project is to comply with California Title 24 ventilation requirements, keep Section 5.16.4.2 and delete Section 5.16.4.1.**
- **If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 5.16.4.1 and delete Section 5.16.4.2.**

5.16.4.2 DP set point for California Title 24 Ventilation

a. See Section 3.2.1.5 for design OA DP set points.
b. See Section 5.16.3.2.3 for calculation of current set points AbsMinOA* and DesMinOA*.
c. See zone CO_2 control logic under terminal unit sequences.
d. The active minimum DP set points AbsDPsp* and DesDPsp* shall be determined by the following equations:

$$\mathrm{AbsDPsp}^* = \mathrm{AbsMinDP}\left[\frac{\mathrm{AbsMinOA}^*}{\mathrm{AbsMinOA}}\right]^2$$

$$\mathrm{DesDPsp}^* = \mathrm{DesMinDP}\left[\frac{\mathrm{DesMinOA}^*}{\mathrm{DesMinOA}}\right]^2$$

This equation prevents excess outdoor air from being supplied during periods of partial occupancy.

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e. The minimum outdoor air DP set point MinDPsp shall be reset based on the highest zone CO_2 control-loop signal from AbsDPsp* at 50% signal to DesDPsp* at 100% signal.
f. The minimum outdoor air set point MinOAsp shall be reset based on the highest zone CO_2 control-loop signal from AbsMinOA* at 50% signal to DesMinOA* at 100% signal.

This concludes the section where the ventilation logic option is selected.

When the sequences are complete, only one of Section 5.16.4.1 and Section 5.16.4.2 should remain. The other section should be deleted along with these flag notes.

5.16.4.3 Open minimum outdoor air damper when the supply air fan is proven ON and the system is in occupied mode and MinDPsp is greater than zero. Damper shall be closed otherwise.

5.16.4.4 Return Air Dampers

a. Return air damper minimum outdoor air control is enabled when the minimum outdoor air damper is open and the economizer outdoor air damper is less than MOA-P, where MOA-P is 5% when supply-fan speed is at 100% design speed proportionally up to 80% when the fan is at minimum speed.
b. Return air damper minimum outdoor air control is disabled when the minimum outdoor air damper is closed or the economizer outdoor air damper is 10% above MOA-P as determined above.
c. When enabled, the maximum RA damper set point MaxRA-P is modulated from 100% to 0% to maintain DP across the minimum outdoor air damper at set point MinDPsp.

The economizer outdoor air damper enabling set point assumes the minimum outdoor air can be maintained by a combination of outdoor air coming through the economizer outdoor air damper as well as the minimum outdoor air damper. Higher damper position set points ensure minimum outdoor airflow will be maintained but at the expense of fan energy. These set points could be determined empirically during TAB work as well.

The engineer must select among options for minimum outdoor air control logic based on two criteria:

- **Do the minimum outdoor air and economizer functions use separate dedicated dampers or a single common damper?**
- **Is outdoor air volume measured by DP ΔP or an airflow measurement station (AFMS)?**

Control logic selections should be made as follows:

- **For AHUs with separate dedicated dampers and OA measurement by AFMS, use Section 5.16.5 and delete Sections 5.16.4 and 5.16.6.**
- **For AHUs with separate dedicated dampers and OA measurement by ΔP, use Section 5.16.4 and delete Sections 5.16.5 and 5.16.6.**
- **For AHUs with a single common damper and OA measurement by AFMS, use Section 5.16.6 and delete Sections 5.16.4 and 5.16.5.**
- **AHUs with a single common damper and OA measurement by ΔP are not supported because OA measurements are not accurate in this configuration.**

DCV is supported in all three options but only for California Title 24 ventilation.

5.16.5 Minimum Outdoor Air Control with a Separate Minimum Outdoor Air Damper and Airflow Measurement

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The engineer must select between ventilation logic options:

- **If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 5.16.5.1 and delete Section 5.16.5.2.**
- **If the project is to comply with California Title 24 ventilation requirements, keep Section 5.16.5.2 and delete Section 5.16.5.1.**

5.16.5.1 Outdoor Airflow Set Point for ASHRAE Standard 62.1-2016 Ventilation

a. See Section 5.16.3.1 for calculation of current outdoor air set point MinOAsp.

- **If the project is to comply with California Title 24 ventilation requirements, keep Section 5.16.5.2 and delete Section 5.16.5.1.**
- **If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 5.16.5.1 and delete Section 5.16.5.2.**

5.16.5.2 Outdoor Airflow Set Point for California Title 24 Ventilation

a. See Section 5.16.3.2.3 for calculation of current set points AbsMinOA* and DesMinOA*.
b. See zone CO_2 control logic under terminal unit sequences.
c. The minimum outdoor air set point MinOAsp shall be reset based on the highest zone CO_2 control-loop signal from AbsMinOA* at 50% signal to DesMinOA* at 100% signal.

This concludes the section where the ventilation logic option is selected.

When the sequences are complete, only one of Section 5.16.5.1 and Section 5.16.5.2 should remain. The other section should be deleted along with these flag notes.

5.16.5.3 Minimum Outdoor Air Control Loop

a. Minimum outdoor air control loop is enabled when the supply fan is proven ON and in occupied mode, and disabled and output set to zero otherwise.
b. The minimum outdoor airflow rate shall be maintained at the minimum outdoor air set point MinOAsp by a reverse-acting control loop whose output is 0% to 100%. From 0% to 50% loop output, the minimum outdoor air damper is opened from 0% to 100%.
c. Return air dampers
    1. Return air damper minimum outdoor air control is enabled when the minimum outdoor air damper is 100% open and the economizer outdoor air damper is less than MOA-P, where MOA-P is 5% when supply-fan speed is at 100% design speed proportionally up to 80% when the fan is at minimum speed.

The economizer outdoor air damper enabling set point assumes the minimum outdoor air can be maintained by a combination of outdoor air coming through the economizer outdoor air damper as well as the minimum outdoor air damper. Higher damper position set points ensure minimum outdoor airflow will be maintained but at the expense of fan energy. These set points could be determined empirically during TAB work as well.

    2. Return air damper minimum outdoor air control is disabled when the minimum outdoor air damper is less than 100% open or the economizer outdoor air damper is 10% above MOA-P, as determined above.
    3. When enabled, the maximum RA damper set point, MaxRA-P, is reduced from 100% to 0% as the minimum outdoor air loop output rises from 50% to 100%.

The engineer must select among options for minimum outdoor air control logic based on two criteria:

- **Do the minimum outdoor air and economizer functions use separate dedicated dampers or a single common damper?**
- **Is outdoor air volume measured by DP ΔP or an airflow measurement station (AFMS)?**

Control logic selections should be made as follows:

- **For AHUs with a single common damper and OA measurement by AFMS, use Section 5.16.6 and delete Sections 5.16.4 and 5.16.5.**
- **For AHUs with separate dedicated dampers and OA measurement by ΔP, use Section 5.16.4 and delete Sections 5.16.5 and 5.16.6.**
- **For AHUs with separate dedicated dampers and OA measurement by AFMS, use Section 5.16.5 and delete Sections 5.16.4 and 5.16.6.**
- **AHUs with a single common damper and OA measurement by ΔP are not supported because OA measurements are not accurate in this configuration.**

DCV is supported in all three options but only for California Title 24 ventilation.

5.16.6 Minimum Outdoor Air Control with a Single Common Damper for Minimum Outdoor Air and Economizer Functions and Airflow Measurement

The engineer must select between ventilation logic options:

- **If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 5.16.6.1 and delete Section 5.16.6.2.**
- **If the project is to comply with California Title 24 ventilation requirements, keep Section 5.16.6.2 and delete Section 5.16.6.1.**

5.16.6.1 Outdoor Airflow Set Point for ASHRAE Standard 62.1-2016 Ventilation

a. See Section 5.16.3.1 for calculation of current outdoor air set point MinOAsp.

- **If the project is to comply with California Title 24 ventilation requirements, keep Section 5.16.6.2 and delete Section 5.16.6.1.**
- **If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 5.16.6.1 and delete Section 5.16.6.2.**

5.16.6.2 Outdoor Airflow Set Point for California Title 24 Ventilation

a. See Section 5.16.3.2.3 for calculation of current set points AbsMinOA* and DesMinOA*.
b. See zone CO_2 control logic under terminal unit sequences.

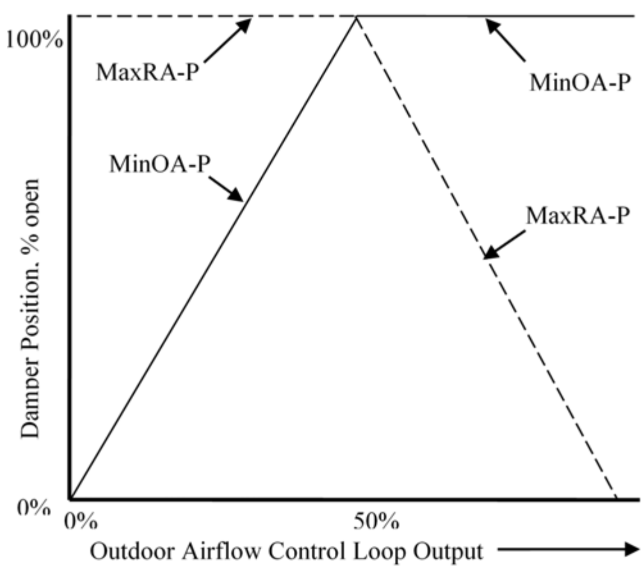

Figure 5.16.6.3 Minimum outdoor airflow control mapping with single damper.

c. The minimum outdoor air set point MinOAsp shall be reset based on the highest zone CO_2 control-loop signal from AbsMinOA* at 50% signal to DesMinOA* at 100% signal.

This concludes the section where the ventilation logic option is selected.

When the sequences are complete, only one of Section 5.16.6.1 and Section 5.16.6.2 should remain. The other section should be deleted along with these flag notes.

5.16.6.3 Minimum Outdoor Air Control Loop

a. Minimum outdoor air control loop is enabled when the supply fan is proven ON and the AHU is in occupied mode, and disabled and output set to zero otherwise.
b. The outdoor airflow rate shall be maintained at the minimum outdoor air set point MinOAsp by a reverse-acting control loop whose output is mapped to economizer damper minimum position MinOA-P and return air damper maximum position MaxRA-P as indicated in Figure 5.16.6.3.

This concludes the section where the minimum outdoor air control logic is selected.

When the sequences are complete, only one of Section 5.16.4, 5.16.5, and 5.16.6 should remain. The other two sections should be deleted along with these flag notes.

5.16.7 Economizer High-Limit Lockout

5.16.7.1 The normal sequencing of the economizer dampers in Sections 5.16.2 through 5.16.6 shall be disabled in accordance with Section 5.1.16.

5.16.7.2 When economizer is enabled, MaxOA-P = 100%.

5.16.7.3 Once the economizer is disabled, it shall not be reenabled within 10 minutes, and vice versa.

5.16.7.4 When the economizer is disabled,

a. return air damper shall be fully opened;
b. wait 15 seconds, then set MaxOA-P equal to MinOA-P; and
c. wait 3 minutes, then release return air damper for minimum outdoor air control.

The return air damper is at first opened to avoid drawing the mixing plenum too negative.

The 3-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 does not become unstable chasing a fluctuating pressure reading.

The engineer must select among control logic options for return/relief/exhaust. This decision is based on the AHU configuration.

Control logic selections should be made as follows:

- **For AHUs using actuated relief dampers with relief fan(s), use section Section 5.16.9 and delete sections 5.16.8, 5.16.10, and 5.16.11.**
- **For AHUs using actuated relief dampers without a fan, use section Section 5.16.8 and delete sections 5.16.9, 5.16.10, and 5.16.11.**
- **For AHUs using a return fan with direct building pressure control, use section Section 5.16.10 and delete sections 5.16.8, 5.16.9, and 5.16.11.**
- **For AHUs using a return fan with airflow tracking control, use section use section Section 5.16.11 and delete sections 5.16.8, 5.16.9, and 5.16.10.**
- **For AHUs using nonactuated barometric relief only, delete all four Sections 5.16.8, 5.16.9, 5.16.10, and 5.16.11.**

A building pressure sensor is required for options in Sections 5.16.8, 5.16.9, 5.16.10.

5.16.8 Control of Actuated Relief Dampers without Fans

5.16.8.1 Relief dampers shall be enabled when the associated supply fan is proven ON, and disabled otherwise.

5.16.8.2 When enabled, use a P-only control loop to modulate relief dampers to maintain 12 Pa (0.05 in. of water) building static pressure. Close damper when disabled.

The engineer must select among control logic options for return/relief/exhaust. This decision is based on the AHU configuration.

Control logic selections should be made as follows:

- **For AHUs using actuated relief dampers without a fan, use section Section 5.16.8 and delete sections 5.16.9, 5.16.10, and 5.16.11.**
- **For AHUs using actuated relief dampers with relief fan(s), use section Section 5.16.9 and delete sections 5.16.8, 5.16.10, and 5.16.11.**

- **For AHUs using a return fan with direct building pressure control, use section Section 5.16.10 and delete sections 5.16.8, 5.16.9, and 5.16.11.**
- **For AHUs using a return fan with airflow tracking control, use section use section Section 5.16.11 and delete sections 5.16.8, 5.16.9, and 5.16.10.**
- **For AHUs using nonactuated barometric relief only, delete all four Sections 5.16.8, 5.16.9, 5.16.10, and 5.16.11.**

A building pressure sensor is required for options in Sections 5.16.8, 5.16.9, 5.16.10.

5.16.9 Relief-Fan Control

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. 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 AHUs.

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.

5.16.9.1 All operating relief fans that serve a common/shared air volume shall be grouped and 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 AHUs.

5.16.9.2 A relief fan shall be enabled when its associated supply fan is proven ON, and shall be disabled otherwise.

5.16.9.3 Building static pressure shall be time averaged with a sliding 5-minute window and 15 second sampling rate (to dampen fluctuations). The averaged value shall be that displayed and used for control.

5.16.9.4 A P-only control loop maintains the building pressure at a set point of 12 Pa (0.05 in. of water) with an output ranging from 0% to 100%. The loop is disabled and output set to zero when all fans in the relief system group are disabled.

The following is intended to use barometric relief as the first stage and then maintain many fans on at low speed to minimize noise and reduce losses through discharge dampers and louvers. Fans are staged OFF only when minimum speed is reached.

For best results, fan speed minimums should be set as low as possible.

5.16.9.5 Fan speed signal to all operating fans in the relief system group shall be the same and shall be equal to the PID signal but no less than the minimum speed. Except for Stage 0, discharge dampers of all relief fans shall be open only when fan is commanded ON.

a. **Stage 0 (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 relief system group that are enabled; close the dampers when the loop output drops to 0% for 5 minutes.
b. **Stage Up.** When control loop is above minimum speed plus 15%, start stage-up timer. Each time the timer reaches 7 minutes, start the next relief fan (and open the associated damper) in the relief system group, per staging order, and reset the timer to 0. The timer is reset to 0 and frozen if control loop is below minimum speed plus 15%. Note, when staging from Stage 0 (no relief fans) to Stage 1 (one relief fan), the discharge dampers of all nonoperating relief fans must be closed.
c. **Stage Down.** When PID loop is below minimum speed, start stage-down timer. Each time the timer reaches 5 minutes, shut off lag fan per staging order and reset the timer to 0. The timer is reset to 0 and frozen if PID loop rises above minimum speed or all fans are OFF. If all fans are OFF, go to Stage 0 (all dampers open and all fans OFF).

5.16.9.6 For fans in a Level 2 alarm and status is OFF, discharge damper shall be closed when stage is above Stage 0.

The engineer must select among control logic options for return/relief/exhaust. This decision is based on the AHU configuration.

Control logic selections should be made as follows:

- **For AHUs using a return fan with direct building pressure control, use section Section 5.16.10 and delete sections 5.16.8, 5.16.9, and 5.16.11.**
- **For AHUs using actuated relief dampers without a fan, use section Section 5.16.8 and delete sections 5.16.9, 5.16.10, and 5.16.11.**
- **For AHUs using actuated relief dampers with relief fan(s), use section Section 5.16.9 and delete sections 5.16.8, 5.16.10, and 5.16.11.**
- **For AHUs using a return fan with airflow tracking control, use section use section Section 5.16.11 and delete sections 5.16.8, 5.16.9, and 5.16.10.**
- **For AHUs using nonactuated barometric relief only, delete all four Sections 5.16.8, 5.16.9, 5.16.10, and 5.16.11.**

A building pressure sensor is required for options in Sections 5.16.8, 5.16.9, 5.16.10.

5.16.10 Return-Fan Control—Direct Building Pressure

5.16.10.1 Return fan operates whenever the associated supply fan is proven ON and shall be off otherwise.

5.16.10.2 Return fans shall be controlled to maintain return-fan discharge static pressure at set point (Section 5.16.10.5).

5.16.10.3 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.

5.16.10.4 Building static pressure shall be time averaged with a sliding 5-minute window (to dampen fluctua-

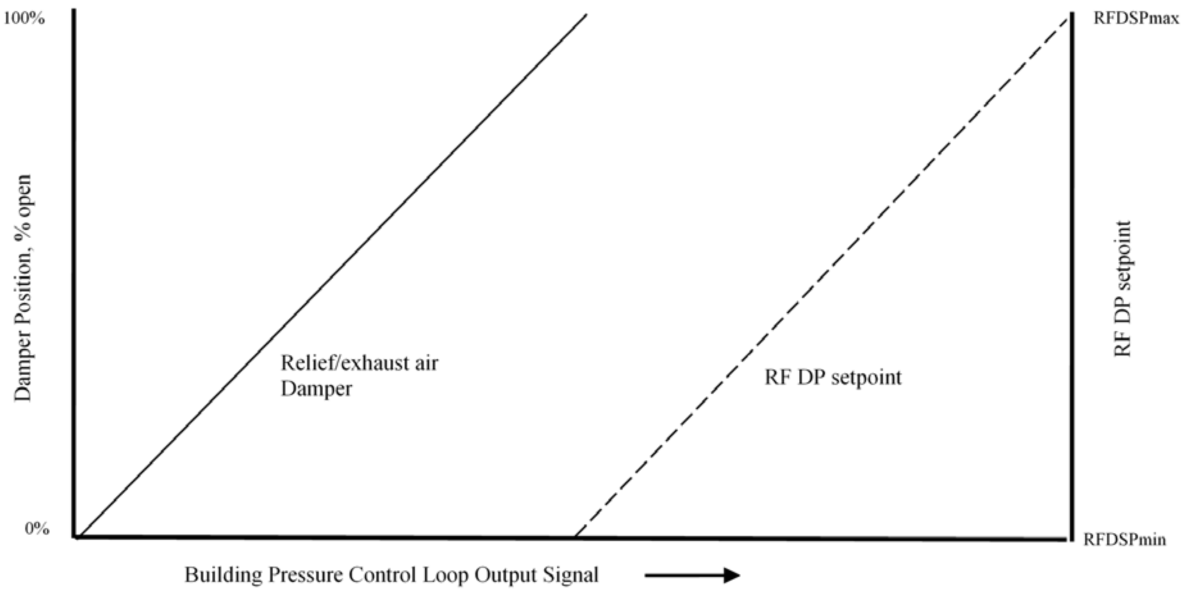

Figure 5.16.10.5 Exhaust damper position and return-fan DP reset

tions). The averaged value shall be that displayed and used for control.

Due to 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 control loop.

5.16.10.5 When exhaust dampers are enabled, a control loop shall modulate exhaust dampers in sequence with the return-fan static pressure set point, as shown in Figure 5.16.10.5, to maintain the building pressure at a set point of 12 Pa (0.05 in. of water).

a. From 0% to 50%, the building pressure control loop shall modulate the exhaust dampers from 0% to 100% open.
b. From 51% to 100%, the building pressure control loop shall reset the return-fan discharge static pressure set point from RFDSPmin at 50% loop output to RFDSPmax at 100% of loop output. See Section 3.2.1.4 for RFDSPmin and RFDSPmax.

The engineer must select among control logic options for return/relief/exhaust. This decision is based on the AHU configuration.

Control logic selections should be made as follows:

- **For AHUs using a return fan with airflow tracking control, use section use section Section 5.16.11 and delete sections 5.16.8, 5.16.9, and 5.16.10.**
- **For AHUs using actuated relief dampers without a fan, use section Section 5.16.8 and delete sections 5.16.9, 5.16.10, and 5.16.11.**
- **For AHUs using actuated relief dampers with relief fan(s), use section Section 5.16.9 and delete sections 5.16.8, 5.16.10, and 5.16.11.**
- **For AHUs using a return fan with direct building pressure control, use section Section 5.16.10 and delete sections 5.16.8, 5.16.9, and 5.16.11.**
- **For AHUs using nonactuated barometric relief only, delete all four Sections 5.16.8, 5.16.9, 5.16.10, and 5.16.11.**

A building pressure sensor is required for options in Sections 5.16.8, 5.16.9, 5.16.10.

5.16.11 Return-Fan Control— Airflow Tracking

5.16.11.1 Return fan operates whenever associated supply fan is proven ON.

5.16.11.2 Return-fan speed shall be controlled to maintain return airflow equal to supply airflow less differential S-R-DIFF, as determined per Section 3.2.1.5.

5.16.11.3 Relief/exhaust dampers shall be enabled when the associated supply and return fans are proven ON and closed otherwise. Exhaust dampers shall modulate as the inverse of the return air damper per Section 5.16.2.3.4.

Airflow tracking requires a measurement of supply airflow and return airflow. Figure 6.9 shows AFMS at both fans. These are actually not mandatory, although they may improve accuracy if properly installed. The supply airflow can be calculated by summing VAV box airflow rates. Return airflow can be approximated by return-fan speed if there are no dampers in the return air path (the geometry of the return air system must be static for speed to track airflow.)

S-R-DIFF is determined empirically during the TAB phase. If there are intermittent or variable-flow exhaust fans, this set point should be dynamically adjusted based on exhaust fan status or airflow/speed.

This concludes the section where the control logic for return/relief/exhaust is selected.

When the sequences are complete, *at most*, one of Sections 5.16.8, 5.16.9, 5.16.10, and 5.16.11 should remain. If relief is barometric (without actuators) only, then all four subsections should be deleted. Delete these flag notes after the decision has been made.

There are three stages of freeze protection. The first stage modulates the heating valve to maintain a safe SAT. The second stage eliminates outdoor air ventilation in case heating is not available for whatever reason. The third stage shuts down the unit and activates coil valves and pumps to circulate water in case the second stage does not work (e.g., stuck economizer damper).

If a freeze-stat is present, it may be hardwired to perform some or all of these functions. In that case, delete those functions from sequence logic in Section 5.16.12 but maintain the alarms. Delete this flag note when sequences are complete.

5.16.12 Freeze Protection

There are three stages of freeze protection. The first stage modulates the heating valve to maintain a safe SAT. The second stage eliminates outdoor air ventilation in case heating is not available for whatever reason. The third stage shuts down the unit and activates coil valves and pumps to circulate water in case the second stage does not work (e.g., stuck economizer damper).

5.16.12.1 If the supply air temperature drops below 4.4°C (40°F) for 5 minutes, send two (or more, as required to ensure that heating plant is active) heating hot-water plant requests, override the outdoor air damper to the minimum position, and modulate the heating coil to maintain a supply air temperature of at least 6°C (42°F). Disable this function when supply air temperature rises above 7°C (45°F) for 5 minutes.

The first stage of freeze protection locks out the economizer. Most likely this has already occurred by this time, but this logic provides insurance.

5.16.12.2 If the supply air temperature drops below 3.3°C (38°F) for 5 minutes, fully close both the economizer damper and the minimum outdoor air damper for 1 hour and set a Level 3 alarm noting that minimum ventilation was interrupted. After 1 hour, the unit shall resume minimum outdoor air ventilation and enter the previous stage of freeze protection (see Section 5.16.12.1).

A timer is used (rather than an OAT threshold) to exit the second stage of freeze protection because a bad OAT sensor could lock out ventilation indefinitely; whereas a timer should just work and thus avoid problems with the unit becoming stuck in this mode with no ventilation.

Upon timer expiration, the unit will reenter the previous stage of freeze protection (MinOA ventilation, with heating to maintain SAT of 6°C [42°F]), after which one of three possibilities will occur:

a. *If it is warm enough that the SAT rises above 7°C (45°F) with minimum ventilation, the unit will remain in Stage 1 freeze protection for 5 minutes then resume normal operation.*
b. *If it is cold enough that SAT remains between 3.3°C (38°F) and 7°C (45°F) with heating and minimum ventilation, the unit will remain in Stage 1 freeze protection indefinitely until outdoor conditions warm up.*
c. *If it is so cold that SAT is less than 3.3°F (38°F) with minimum ventilation, despite heating, then the unit will revert to Stage 2 freeze protection where it will remain for 1 hour. This process will then repeat.*

5.16.12.3 Upon signal from the freeze-stat (if installed), or if supply air temperature drops below 3.3°C (38F) for 15 minutes or below 1°C (34°F) for 5 minutes, shut down supply and return/relief fan(s), close outdoor air damper, open the cooling-coil valve to 100%, and energize the CHW pump system. Also send two (or more, as required to ensure that heating plant is active) heating hot-water plant requests, modulate the heating coil to maintain the higher of the supply air temperature or the mixed air temperature at 27°C (80°F), and set a Level 2 alarm indicating the unit is shut down by freeze protection.

a. If a freeze-protection shutdown is triggered by a low air temperature sensor reading, 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.)

Stage 3 can be triggered by either of two conditions. The second condition is meant to respond to an extreme and sudden cold snap.

Protecting the cooling coil in this situation will require water movement through the coil, which means that the CHW pumps need to be energized.

Heating coil is controlled to an air temperature set point. The sensors will not read accurately with the fan OFF, but they will be influenced by proximity to the heating coil. A temperature of 27°C (80°F) at either of these sensors indicates that the interior of the unit is sufficiently warm. This avoids the situation where a fixed valve position leads to very high (and potentially damaging) temperatures inside the unit.

5.16.13 Alarms

5.16.13.1 Maintenance interval alarm when fan has operated for more than 1500 hours: Level 4. Reset interval count when alarm is acknowledged.

5.16.13.2 Fan alarm is indicated by the status being different from the command for a period of 15 seconds.

a. Commanded ON, status OFF: Level 2
b. Commanded OFF, status ON: Level 4

5.16.13.3 Filter pressure drop exceeds alarm limit: Level 4. The alarm limit shall vary with total airflow (if available; use fan speed if total airflow is not known) as follows:

$$DPx = DP100(x)^{1.4}$$

where DP100 is the high-limit pressure drop at design airflow (determine limit from filter manufacturer) and DPx is the high limit at the current airflow rate x (expressed as a fraction). For instance, the set point at 50% of design airflow would be $(0.5)^{1.4}$, or 38% of the design high-limit pressure drop.

5.16.13.4 High building pressure (more than 25 Pa [0.10 in. of water]): Level 3.

5.16.13.5 Low building pressure (less than 0 Pa [0.0 in. of water], i.e., negative): Level 4.

Automatic fault detection and diagnostics (AFDD) is a sophisticated system for detecting and diagnosing air-handler faults.

To function correctly, AFDD requires specific sensors and data be available, as detailed in the sequences below. If this information is not available, AFDD tests that do not apply should be deleted.

5.16.14 Automatic Fault Detection and Diagnostics

The AFDD routines for AHUs continually assess AHU performance by comparing the values of BAS 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 (OS) 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 that 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.

5.16.14.1 AFDD conditions are evaluated continuously and separately for each operating AHU.

5.16.14.2 The 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 Table 5.16.14.2 and Figure 5.16.14.2.

The OS 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 through OS#4 (see Table 5.16.14.2) represent normal operation during which a fault may nevertheless occur if so determined by the fault condition tests in Section 5.16.14.6. By contrast, OS#5 may represent 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 or during warm-up.

5.16.14.3 The following points must be available to the AFDD routines for each AHU:

For the AFDD routines to be effective, an averaging sensor is recommended for SAT. An averaging sensor is essential for MAT, as the environment of the mixing box will be subject to nonuniform 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.

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a. SAT = supply air temperature
b. MAT = mixed air temperature
c. RAT = return air temperature
d. OAT = outdoor air temperature
e. DSP = duct static pressure
f. SATSP = supply air temperature set point
g. DSPSP = duct static pressure set point
h. HC = heating-coil valve position command; 0% ≤ HC ≤ 100%
i. CC = cooling-coil valve position command; 0% ≤ CC ≤ 100%
j. FS = fan speed command; 0% ≤ FS ≤ 100%
k. CCET = cooling-coil entering temperature (Depending on the AHU configuration, this could be the MAT or a separate sensor for this specific purpose.)
l. CCLT = cooling-coil leaving temperature (Depending on the AHU configuration, this could be the SAT or a separate sensor for this specific purpose.)
m. HCET = heating-coil entering temperature (Depending on the AHU configuration, this could be the MAT or a separate sensor for this specific purpose.)
n. HCLT = heating-coil leaving temperature (Depending on the AHU configuration, this could be the SAT or a separate sensor for this specific purpose.)

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

a. Five-minute rolling averages with 1-minute sampling time of the following point values; operator shall have the ability to adjust the averaging window and sampling period for each point independently.
   1. SATavg = rolling average of supply air temperature
   2. MATavg = rolling average of mixed air temperature
   3. RATavg = rolling average of return air temperature
   4. OATavg = rolling average of outdoor air temperature
   5. DSPavg = rolling average of duct static pressure
   6. CCETavg = rolling average of cooling-coil entering temperature
   7. CCLTavg = rolling average of cooling-coil leaving temperature
   8. HCETavg = rolling average of heating-coil entering temperature
   9. HCLTavg = rolling average of heating-coil leaving temperature

Table 5.16.4.2 VAV AHU Operating States

Operating State	Heating Valve Position	Cooling Valve Position	Outdoor Air Damper Position
#1: Heating	> 0	= 0	= min
#2: Free cooling, modulating OA	= 0	= 0	min < x < 100%
#3: Mechanical + economizer cooling	= 0	> 0	= 100%
#4: Mechanical cooling, minimum OA	= 0	> 0	= min
#5: Unknown or dehumidification	No other OS applies		

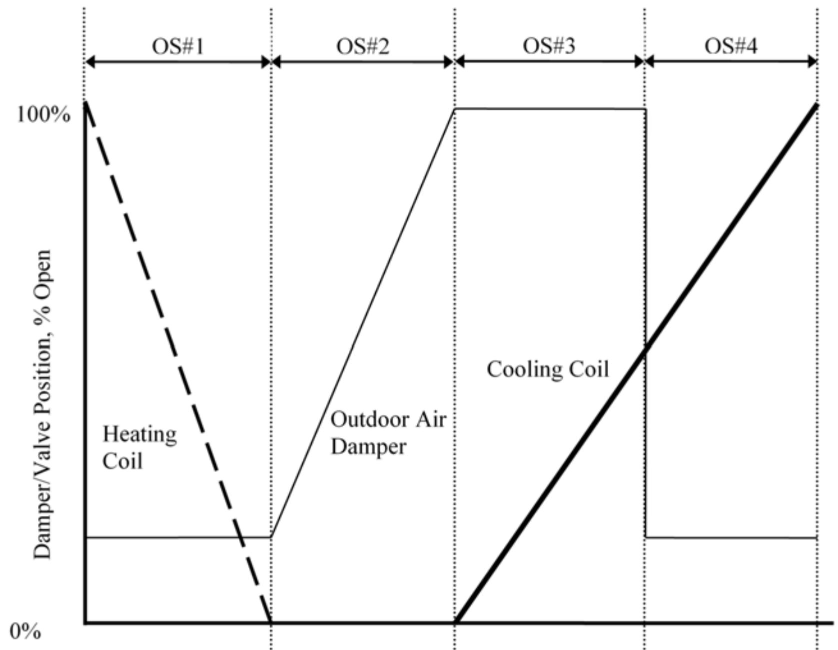

Figure 5.16.14.2 VAV AHU operating states.

b. %OA = actual outdoor air fraction as a percentage = (MAT – RAT)/(OAT – RAT), or per airflow measurement station if available.
c. %OAmin = active minimum OA set point (MinOAsp) divided by actual total airflow (from sum of VAV box flows or by airflow measurement station) as a percentage.
d. OS = number of changes in operating state during the previous 60 minutes (moving window)

5.16.14.5 The internal variables shown in Table 5.16.14.5 shall be defined for each AHU. All parameters are adjustable by the operator, with initial values as shown.

Default values are derived from NISTIR 7365 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 toward 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 trend logs. 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.

The purpose of ΔTmin 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.

The purpose of TestModeDelay is to ensure that normal fault reporting occurs after the testing and commissioning process is completed as prescribed in Section 5.16.14.12.

Table 5.16.14.5 VAV AHU AFDD Internal Variables

Variable Name	Description	Default Value
ΔTSF	Temperature rise across supply fan	1°C (2°F)
ΔTmin	Minimum difference between OAT and RAT to evaluate economizer error conditions (FC#6)	6°C (10° F)
εSAT	Temperature error threshold for SAT sensor	1°C (2°F)
εRAT	Temperature error threshold for RAT sensor	1°C (2°F)
εMAT	Temperature error threshold for MAT sensor	3°C (5°F)
εOAT	Temperature error threshold for OAT sensor	1°C (2°F) if local sensor @ unit. 3°C (5°F) if global sensor.
εF	Airflow error threshold	30%
εVFDSPD	VFD speed error threshold	5%
εDSP	DSP error threshold	25 Pa (0.1")
εCCET	CCET sensor error; equal to εMAT or dedicated sensor error	Varies; see description.
εCCLT	CCLT sensor error; equal to εSAT or dedicated sensor error	
εHCET	Heating-coil entering temperature sensor error; equal to εMAT or dedicated sensor error	
εHCLT	Heating-coil leaving temperature sensor error; equal to εSAT or dedicated sensor error	
ΔOSmax	Maximum number of changes in OS during the previous 60 minutes (moving window)	7
ModeDelay	Time in minutes to suspend fault condition evaluation after a change in mode	30
AlarmDelay	Time in minutes to that a fault condition must persist before triggering an alarm	30
TestModeDelay	Time in minutes that test mode is enabled	120

5.16.14.6 Table 5.16.14.6 shows 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 OS of the AHU.

The equations in Table 5.16.14.6 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.

To detect the required economizer faults in California Title 24 section 120.2(i)7, use FC#2, #3, and #5 through #13 at a minimum. Other Title 24 AFDD requirements, including acceptance tests, are not met through these fault conditions.

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

a. In OS#1 (heating), the following fault conditions shall be evaluated:
   1. FC#1: DSP too low with fan at full speed
   2. FC#2: MAT too low; should be between RAT and OAT
   3. FC#3: MAT too high; should be between RAT and OAT
   4. FC#4: Too many changes in OS
   5. FC#5: SAT too low; should be higher than MAT
   6. FC#6: OA fraction too low or too high; should equal %OAmin
   7. FC#7: SAT too low in full heating
   8. FC#14: Temperature drop across inactive cooling coil
b. In OS#2 (modulating economizer), the following fault conditions shall be evaluated:
   1. FC#1: DSP too low with fan at full speed
   2. FC#2: MAT too low; should be between RAT and OAT
   3. FC#3: MAT too high; should be between RAT and OAT
   4. FC#4: Too many changes in OS
   5. FC#8: SAT and MAT should be approximately equal
   6. FC#9: OAT too high for free cooling without mechanical cooling
   7. FC#14: Temperature drop across inactive cooling coil
   8. FC#15: Temperature rise across inactive heating coil
c. In OS#3 (mechanical + 100% economizer cooling), the following fault conditions shall be evaluated:
   1. FC#1: DSP too low with fan at full speed
   2. FC#2: MAT too low; should be between RAT and OAT

Table 5.16.14.6 VAV AHU Fault Conditions

FC#1	**Equation**	$DSP < DSPSP - \varepsilon DSP$ **AND** $VFDSPD \geq 99\% - \varepsilon VFDSPD$	**Applies to OS#1 through OS#5**
	Description	Duct static pressure too low with fan at full speed	
	Possible Diagnosis	• Problem with VFD • Mechanical problem with fan • Fan undersized • SAT set point too high (too much zone demand)	
FC#2 (omit if no MAT sensor)	**Equation**	$MATavg + \varepsilon MAT < \min[(RATavg - \varepsilon RAT), (OATavg - \varepsilon OAT)]$	**Applies to OS#1 through OS#5**
	Description	MAT too low; should be between OAT and RAT	
	Possible Diagnosis	• RAT sensor error • MAT sensor error • OAT sensor error	
FC#3 (omit if no MAT sensor)	**Equation**	$MATavg - \varepsilon MAT > \max[(RATavg + \varepsilon RAT), (OATavg + \varepsilon OAT)]$	**Applies to OS#1 through OS#5**
	Description	MAT too high; should be between OAT and RAT	
	Possible Diagnosis	• RAT sensor error • MAT sensor error • OAT sensor error	
FC#4	**Equation**	$\Delta OS > \Delta OSmax$	**Applies to OS#1 through OS#5**
	Description	Too many changes in OS	
	Possible Diagnosis	Unstable control due to poorly tuned loop or mechanical problem	
FC#5 (omit if no MAT sensor)	**Equation**	$SATavg + \varepsilon SAT \leq MATavg - \varepsilon MAT + \Delta TSF$	**Applies to OS#1**
	Description	SAT too low; should be higher than MAT	
	Possible Diagnosis	• 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 • HW temperature too low or HW unavailable • Gas or electric heat unavailable • DX cooling stuck ON	
FC#6	**Equation**	$\lvert RATavg - OATavg \rvert \geq \Delta Tmin$ **AND** $\lvert \%OA - \%OAmin \rvert > \varepsilon F$	**Applies to OS#1 and OS#4**
	Description	OA fraction too low or too high; should equal %OAmin	
	Possible Diagnosis	• RAT sensor error • MAT sensor error • OAT sensor error • Leaking or stuck economizer damper or actuator	
FC#7	**Equation**	$SATavg < SATSP - \varepsilon SAT$ **AND** $HC \geq 99\%$	**Applies to OS#1**
	Description	SAT too low in full heating	
	Possible Diagnosis	• SAT sensor error • Cooling-coil valve leaking or stuck open • Heating-coil valve stuck closed or actuator failure • Fouled or undersized heating coil • HW temperature too low or HW unavailable • Gas or electric heat unavailable • DX cooling stuck ON • Leaking or stuck economizer damper or actuator	
FC#8 (omit if no MAT sensor)	**Equation**	$\lvert SATavg - \Delta TSF - MATavg \rvert > \sqrt{\varepsilon SAT^2 + \varepsilon MAT^2}$	**Applies to OS#2**
	Description	SAT and MAT should be approximately equal	
	Possible Diagnosis	• SAT sensor error • MAT sensor error • Cooling-coil valve leaking or stuck open • Heating-coil valve leaking or stuck open	

Table 5.16.14.6 VAV AHU Fault Conditions *(Continued)*

FC#9	**Equation**	$OATavg - \varepsilon OAT > SATSP - \Delta TSF + \varepsilon SAT$	**Applies to OS#2**
	Description	OAT too high for free cooling without additional mechanical cooling	
	Possible Diagnosis	• SAT sensor error • OAT sensor error • Cooling-coil valve leaking or stuck open	
FC#10 (omit if no MAT sensor)	**Equation**	$\lvert MATavg - OATavg \rvert > \sqrt{\varepsilon MAT2 + \varepsilon OAT^2}$	**Applies to OS#3**
	Description	OAT and MAT should be approximately equal	
	Possible Diagnosis	• MAT sensor error • OAT sensor error • Leaking or stuck economizer damper or actuator	
FC#11	**Equation**	$OATavg + \varepsilon OAT < SATSP - \Delta TSF - \varepsilon SAT$	**Applies to OS#3**
	Description	OAT too low for 100% OA cooling	
	Possible Diagnosis	• SAT sensor error • OAT sensor error • Heating-coil valve leaking or stuck open • Leaking or stuck economizer damper or actuator	
FC#12 (omit if no MAT sensor)	**Equation**	$SATavg - \varepsilon SAT - \Delta TSF \geq MATavg + \varepsilon MAT$	**Applies to OS#3 and OS#4**
	Description	SAT too high; should be less than MAT	
	Possible Diagnosis	• 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 • DX cooling unavailable • Gas or electric heat stuck ON • Heating-coil valve leaking or stuck open	
FC#13	**Equation**	$SATavg > SATSP + \varepsilon SAT$ **AND** $CC \geq 99\%$	**Applies to OS#3 and OS#4**
	Description	SAT too high in full cooling	
	Possible Diagnosis	• SAT sensor error • Cooling-coil valve stuck closed or actuator failure • Fouled or undersized cooling coil • CHW temperature too high or CHW unavailable • DX cooling unavailable • Gas or electric heat stuck ON • Heating-coil valve leaking or stuck open	
FC#14	**Equation**	$CCETavg - CCLTavg \geq \sqrt{\varepsilon CCET^2 + \varepsilon CCLT^2} + \Delta T_{SF}{}^{*}$ *Fan heat factor included or not, depending on location of sensors used for CCET and CCLT	**Applies to OS#1 and OS#2**
	Description	Temperature drop across inactive cooling coil	
	Possible Diagnosis	• CCET sensor error • CCLT sensor error • Cooling-coil valve stuck open or leaking • DX cooling stuck on	
FC#15	**Equation**	$HCLTavg - HCET_{avg} \geq \sqrt{\varepsilon HCET^2 + \varepsilon HCLT^2} + \Delta T_{SF}{}^{*}$ *Fan heat factor included or not, depending on location of sensors used for HCET and HCLT	**Applies to OS#2 through OS#4**
	Description	Temperature rise across inactive heating coil	
	Possible Diagnosis	• HCET sensor error • HCLT sensor error • Heating-coil valve stuck open or leaking.	

3. FC#3: MAT too high; should be between RAT and OAT
4. FC#4: Too many changes in OS
5. FC#10: OAT and MAT should be approximately equal
6. FC#11: OAT too low for 100% OA
7. FC#12: SAT too high; should be less than MAT
8. FC#13: SAT too high in full cooling
9. FC#15: Temperature rise across inactive heating coil

d. In OS#4 (mechanical Cooling, minimum OA), the following fault conditions shall be evaluated:
1. FC#1: DSP too low with fan at full speed
2. FC#2: MAT too low; should be between RAT and OAT
3. FC#3: MAT too high; should be between RAT and OAT
4. FC#4: Too many changes in OS
5. FC#6: OA fraction too low or too high; should equal%OAmin
6. FC#12: SAT too high; should be less than MAT
7. FC#13: SAT too high in full cooling
8. FC#15: Temperature rise across inactive heating coil

e. In OS#5 (other), the following fault conditions shall be evaluated:
1. FC#1: DSP too low with fan at full speed
2. FC#2: MAT too low; should be between RAT and OAT
3. FC#3: MAT too high; should be between RAT and OAT
4. FC#4: Too many changes in OS

5.16.14.8 For each air handler, the operator shall be able to suppress the alarm for any fault condition.

5.16.14.9 Evaluation of fault conditions shall be suspended under the following conditions:

a. When AHU is not operating
b. 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

5.16.14.10 Fault conditions that are not applicable to the current OS shall not be evaluated.

5.16.14.11 A fault condition that evaluates as TRUE must do so continuously for AlarmDelay minutes before it is reported to the operator.

5.16.14.12 Test mode shall temporarily set ModeDelay and AlarmDelay to 0 minutes for a period of TestModeDelay minutes to allow instant testing of the AFDD system, and ensure normal fault detection occurs after testing is complete.

5.16.14.13 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 Section 5.16.14.6.

5.16.15 Testing/Commissioning Overrides. Provide software switches that interlock to a CHW and hot-water plant level to

a. force HW valve full open if there is a hot-water coil,
b. force HW valve full closed if there is a hot-water coil,
c. force CHW valve full open, and
d. force CHW valve full closed.

Per Section 5.1.11, all hardware points can be overridden through the BAS. Each of the following points is interlocked so that they can be overridden together at a zone-group level, per Section 5.4.5.

For example, the CxA can check for leaking dampers by forcing all VAV boxes in a zone group closed and then recording airflow at the AHU.

Central plant sequences are not part of the initial scope of Guideline 36, but control logic for plant requests are being included for future use, when central plant sequences are added.

Typically, the chiller or heating hot-water 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.

Chilled-water and hot-water reset requests are used in T&R loops to control supply water temperature and/or pump DP set points based on zone and AHU demands.

5.16.16 Plant Requests

5.16.16.1 Chilled-Water Reset Requests

a. If the supply air temperature exceeds the supply air temperature set point by 3°C (5°F) for 2 minutes, send 3 requests.
b. Else if the supply air temperature exceeds the supply air temperature set point by 2°C (3°F) for 2 minutes, send 2 requests.
c. Else if the CHW valve position is greater than 95%, send 1 request until the CHW valve position is less than 85%.
d. Else if the CHW valve position is less than 95%, send 0 requests.

5.16.16.2 Chiller Plant Requests. Send the chiller plant that serves the system a chiller plant request as follows:

a. If the CHW valve position is greater than 95%, send 1 request until the CHW valve position is less than 10%.
b. Else if the CHW valve position is less than 95%, send 0 requests.

5.16.16.3 If There Is a Hot-Water Coil, Hot-Water Reset Requests

a. If the supply air temperature is 17°C (30°F) less than set point for 5 minutes, send 3 requests.
b. Else if the supply air temperature is 8°C (15°F) less than set point for 5 minutes, send 2 requests.
c. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
d. Else if the HW valve position is less than 95%, send 0 requests.

5.16.16.4 If There Is a Hot-Water Coil, Heating Hot Water Plant Requests. Send the heating hot-water plant that serves the AHU a heating hot-water plant request as follows:

a. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.
b. Else if the HW valve position is less than 95%, send 0 requests.

Table 5.17.1.2 Trim & Respond Variables

Variable	Value
Device	Supply fan
SP0	120 Pa (0.5 in. of water)
SPmin	25 Pa (0.1 in. of water)
SPmax	Max_DSP (See Section 3.2.1.1)
Td	10 min
T	2 min
I	2
R	Zone hot-duct static pressure reset requests
SPtrim	–12 Pa (–0.05 in. of water)
SPres	15 Pa (+0.06 in. of water)
SPres-max	32 Pa (+0.13 in. of water)

5.17 Dual-Fan Dual-Duct Heating VAV Air-Handling Unit

5.17.1 Supply Fan Control

5.17.1.1 Supply Fan Start/Stop

a. Fan shall run when system is in the warm-up mode and setback mode, and during occupied mode while there are any heating-fan requests with a minimum runtime of 15 minutes.

Delete the following paragraph if an air handler serves dual-duct boxes that do not have hot-duct inlet airflow sensors, i.e. those that have only a box discharge airflow sensor. This paragraph may also be deleted if there is a supply AFMS.

b. Totalize current airflow rate from VAV boxes to a software point.

VAV box airflow rates are summed to obtain overall supply air rate without the need for an AFMS at the air-handler discharge. This is used only for display and diagnostics and filter alarm.

5.17.1.2 Static Pressure Set-Point Reset

a. **Static pressure set point.** Set point shall be reset using T&R logic (see Section 5.1.14) using the parameters in Table 5.17.1.2.

The T&R reset parameters in Table 5.17.1.2 are suggested as a starting place; they will most likely require adjustment during the commissioning/tuning phase.

5.17.1.3 Static Pressure Control

a. Supply fan speed is controlled to maintain DSP at set point when the fan is proven ON. 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.).

Table 5.17.1.2 Trim & Respond Variables

Variable	Value
Device	Heating supply fan
SP0	SPmax
SPmin	21°C (70°F)
SPmax	Max_HtgSAT
Td	10 min
T	2 min
I	2
R	Zone heating SAT requests
SPtrim	–0.2°C (–0.4°F)
SPres	+0.3°C (+0.6°F)
SPres-max	+0.8°C (+1.4°F)

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).

5.17.2 Supply Air Temperature Control

5.17.2.1 Control loop is enabled when the supply air fan is proven ON, and disabled and output set to zero otherwise.

5.17.2.2 Supply Air Temperature Set Point

a. **During occupied mode (Table 5.17.2.2).** Set point shall be reset using T&R logic (see Section 5.1.14) between 21°C (70°F) and Max_HtgSAT. See Section 3.1.5.1 for Max_HtgSAT.

The T&R reset parameters in Table 5.17.2.2 are suggested as a starting place; they will most likely require adjustment during the commissioning/tuning phase.

b. **During warm-up and setback modes.** Set point shall be Max_HtgSAT.

5.17.2.3 Supply air temperature shall be maintained at set point by a PID loop modulating the heating coil.

5.17.3 Alarms

5.17.3.1 Maintenance interval alarm when fan has operated for more than 1500 hours: Level 4. Reset interval counter when alarm is acknowledged.

5.17.3.2 Fan alarm is indicated by the status being different from the command for a period of 15 seconds.

a. Commanded ON, status OFF: Level 2
b. Commanded OFF, status ON: Level 4

5.17.3.3 Filter pressure drop exceeds alarm limit: Level 4. The alarm limit shall vary with total airflow (if available; use fan speed if total airflow is not known) as follows:

$$DPx = DP100(x)^{1.4}$$

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 x (expressed as a fraction). For instance, the set point at 50% of design airflow would be $(0.5)^{1.4}$, or 38% of the design high limit pressure drop.

5.17.4 Automatic Fault Detection and Diagnostics

The AFDD routines for AHUs continually assess AHU performance by comparing the values of BAS inputs and outputs to a subset of potential fault conditions. Time delays are applied to the evaluation and reporting of fault conditions to suppress false alarms. Fault conditions that pass these filters are reported to the building operator along with a series of possible causes. The AFDD routines listed in this section are intended for heating ducts only; AFDD routines for cooling ducts are listed in Sections 5.16.14 and 5.18.13.

5.17.4.1 AFDD conditions are evaluated continuously and separately for each operating AHU.

5.17.4.2 The following points must be available to the AFDD routines for each AHU:

For the AFDD routines to be effective, an averaging sensor is recommended for supply air temperature.

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a. SAT = supply air temperature
b. RAT = return air temperature
c. DSP = duct static pressure
d. SATSP = supply air temperature set point
e. DSPSP = duct static pressure set point
f. HC = heating coil valve position command; 0% ≤ HC ≤ 100%
g. FS = fan speed command; 0% ≤ FS ≤ 100%

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

a. Five-minute rolling averages with 1-minute sampling time of the following point values; operator shall have the ability to adjust the averaging window and sampling period for each point independently

a. SATavg = rolling average of supply air temperature
b. RATavg = rolling average of return air temperature
c. DSPavg = rolling average of duct static pressure

5.17.4.4 The internal variables shown in Table 5.17.4.4 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 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 toward 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 trend logs. 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.

5.17.4.5 Table 5.17.4.5 shows potential fault conditions that can be evaluated by the AFDD routines. If the equation statement is TRUE, then the specified fault condition exists.

5.17.4.6 For each air handler, the operator shall be able to suppress the alarm for any fault condition.

5.17.4.7 Evaluation of fault conditions shall be suspended under the following conditions:

a. When AHU is not operating
b. 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

5.17.4.8 A fault condition that evaluates as TRUE must do so continuously for AlarmDelay minutes before it is reported to the operator.

5.17.4.9 Test mode shall temporarily set ModeDelay and AlarmDelay to 0 minutes for a period of TestModeDelay minutes to allow instant testing of the AFDD system and ensure normal fault detection occurs after testing is complete.

5.17.4.10 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 Table 5.16.14.6.

5.17.5 Testing/Commissioning Overrides. Provide software switches that interlock to a CHW and hot-water plant level to

a. force hot water valve full open and
b. force hot water valve full closed.

Per Section 5.1.11, all hardware points can be overridden through the BAS. Each of the following points is interlocked so that they can be overridden together at a zone-group level, per Section 5.4.5.

For example, the CxA can check for leaking dampers by forcing all VAV boxes in a zone group closed and then recording airflow at the AHU.

Central plant sequences are not part of the initial scope of Guideline 36, but control logic for plant requests are being included for future use, when central plant sequences are added.

Typically, the heating hot-water 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.

Hot-water reset requests are used in T&R loops to control supply water temperature and/or pump DP set points based on zone and AHU demands.

Table 5.17.4.4 DFDD Heating AHU AFDD Internal Variables

Variable Name	Description	Default Value
ΔTSF	Temperature rise across supply fan	1°C (2°F)
εSAT	Temperature error threshold for SAT sensor	1°C (2°F)
εRAT	Temperature error threshold for RAT sensor	1°C (2°F)
εVFDSPD	VFD speed error threshold	5%
εDSP	DSP error threshold	25 Pa (0.1in. of water)
ModeDelay	Time in minutes to suspend fault condition evaluation after a change in mode	30
AlarmDelay	Time in minutes that a fault condition must persist before triggering an alarm	30
TestModeDelay	Time in minutes that test mode is enabled	120

Table 5.17.4.5 DFDD Heating AHU Fault Conditions

FC#1	**Equation**	DSP < DSPSP – εDSP **AND** VFDSPD ≥ 99% – εVFDSPD
	Description	DSP too low with fan at full speed
	Possible Diagnosis	• Problem with VFD • Mechanical problem with fan • Fan undersized • SAT set point too high (too much zone demand)
FC#2	**Equation**	SATavg < SATSP – εSAT **AND** HC ≥ 99%
	Description	SAT too low in full heating
	Possible Diagnosis	• SAT sensor error • Heating-coil valve stuck closed or actuator failure • Fouled or undersized heating coil • HW temperature too low or HW unavailable • Gas or electric heat unavailable
FC#3	**Equation**	$RATavg - SATavg \geq \sqrt{\varepsilon SAT^2 + \varepsilon RAT^2} + \Delta TSF$ **AND** HC = 0%
	Description	Temperature rise across inactive heating coil
	Possible Diagnosis	• HCET sensor error • HCLT sensor error • Heating-coil valve stuck open or leaking • Gas or electric heat stuck ON

5.17.6 Plant Requests

5.17.6.1 Hot-Water Reset Requests

a. If the supply air temperature is 17°C (30°F) less than set point for 5 minutes, send 3 requests.
b. Else if the supply air temperature is 8°C (15°F) less than set point for 5 minutes, send 2 requests.
c. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
d. Else if the HW valve position is less than 95%, send 0 requests.

5.17.6.2 Heating Hot-Water Plant Requests. Send the heating hot-water plant that serves the AHU a heating hot-water plant request as follows:

a. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.
b. Else if the HW valve position is less than 95%, send 0 requests.

5.18 Single-Zone VAV Air-Handling Unit

5.18.1 See "Generic Thermal Zones" (Section 5.3) for set points, loops, control modes, alarms, etc.

5.18.2 See Section 3.1.6 for Cool_SAT, Heat_SAT, and MaxDPT.

5.18.3 See Section 3.2.2 for MinSpeed, MaxHeatSpeed, MaxCoolSpeed, MinPosMin, MinPosMax, DesPosMin, DesPosMax, MinRelief, MaxRelief, and S-R-DIFF.

5.18.4 Supply Fan Speed Control and Supply Air Temperature Set-Point Reset

These sequences use two supply air temperature set points SATsp and SATsp-C that are reset at different rates but are controlled using the same sensor and control loop, as well as a supply-fan speed reset that varies depending on outdoor air temperature. The goal of this scheme is to maximize free cooling and avoid chiller use when the outdoor air is cool, while avoiding excessive fan energy use and using the cooling coil when outdoor air is warm.

For this to work, it is essential that both SATsp and SATsp-C are controlled off the same physical SAT sensor.

It is also critical that the minimum value of the set point that controls the economizer SATsp is lower than the minimum value of the set point that controls the CHW valve SATsp-C. Otherwise, a brief temperature excursion due to the cooling coil will lead to short cycling of the economizer and subsequent unnecessary energy use by the cooling coil.

5.18.4.1 The supply fan shall run whenever the unit is in any mode other than unoccupied mode.

5.18.4.2 Provide a ramp function to prevent changes in fan speed of more than 10% per minute.

5.18.4.3 Minimum, medium, and maximum fan speeds shall be as follows:

a. Minimum speed MinSpeed, maximum cooling speed MaxCoolSpeed, and maximum heating speed MaxHeatSpeed shall be determined per Section 3.2.2.1.
b. Medium fan speed MedSpeed shall be reset linearly based on outdoor air temperature from MinSpeed when outdoor air temperature is greater or equal to Endpoint #1 to MaxCoolSpeed when outdoor air temperature is less than or equal to Endpoint #2.
    1. Endpoint #1: the lesser of zone temperature +0.5°C (1°F) and maximum supply air dew point MaxDPT.
    2. Endpoint #2: the lesser of zone temperature minus 6°C (10°F) and the maximum supply air dew point MaxDPT minus 1°C (2°F).

When outdoor air temperature is high, there is a potential for a high humidity ratio, and thus high space humidity, which can increase the risk of mold/mildew. Because dew point sensors are expensive and can quickly drift out of calibration, this sequence uses outdoor air dry-bulb temperature as a proxy for supply air dew point. When outdoor air temperature is above the maximum limit MaxDPT, the medium speed set point is kept at the minimum, which will reduce supply air temperature and thus lower supply air temperature set point.

5.18.4.4 Minimum and maximum supply air temperature set points shall be as follows:

a. The Deadband values of SATsp and SATsp-C shall be the average of the zone heating set point and the zone cooling set point but shall be no lower than 21°C (70°F) and no higher than 24°C (75°F).

The deadband set point is intended to provide neutral temperature air when the zone state is deadband. The values of this set point are limited to avoid the situation where an extreme value for zone temperature set point forces unnecessary heating or cooling, e.g., a cold-aisle set point of 32°C (90°F) in a datacenter could cause unnecessary heating if this limit were not in place.

5.18.4.5 When the supply fan is proven ON, fan speed and supply air temperature set points are controlled as shown in Figures 5.18.4.5-1 through 5.18.4.5-3. The points of transition along the x-axis shown and described are representative. Separate gains shall be provided for each section of the control map, that are determined by the contractor to provide stable control. Alternatively, the contractor shall adjust the precise value of the x-axis thresholds shown in Figure 5.18.4.5-1 to provide stable control.

Figure 5.18.4.5-2 separates Figure 5.18.4.5-1 in two for clarity and to illustrate the relative set points. However, both fan speed and supply air temperature set points are reset simultaneously and by the same signal: the value of the heating loop or cooling loop.

a. For a heating-loop signal of 100% to 50%, fan speed is reset from MaxHeatSpeed to MinSpeed.
b. For a heating-loop signal of 50% to 0%, fan speed set point is MinSpeed.
c. In deadband, fan speed set point is MinSpeed.
d. For a cooling-loop signal of 0% to 25%, fan speed is MinSpeed.
e. For a cooling-loop signal of 25% to 50%, fan speed is reset from MinSpeed to MedSpeed.
f. For a cooling-loop signal of 50% to 75%, fan speed is MedSpeed.
g. For a cooling-loop signal of 75% to 100%, fan speed is reset from MedSpeed to MaxCoolSpeed.
h. For a heating-loop signal of 100% to 50%, SATsp is Heat_SAT.
i. For a heating-loop signal of 50% to 0%, SATsp is reset from Heat_SAT to the deadband value.
j. In deadband, SATsp is the deadband value.
k. For a cooling-loop signal of 0% to 25%, SATsp is reset from the deadband value to Cool_SAT minus 1°C (2°F), while SATsp-C is the deadband value.
l. For a cooling-loop signal of 25% to 50%, SATsp and SATsp-C are unchanged.
m. For a cooling-loop signal of 50% to 75%, SATsp remains at Cool_SAT minus 1°C (2°F), SATsp-C is reset from the deadband value to Cool_SAT.
n. For a cooling-loop signal of 75% to 100%, SATsp and SATsp-C are unchanged.

In cooling, the economizer is controlled to a lower set point than the cooling coil (i.e., SATsp < SATsp-C) so that a low-temperature excursion does not cause the economizer to close inadvertently while cooling with mechanical cooling.

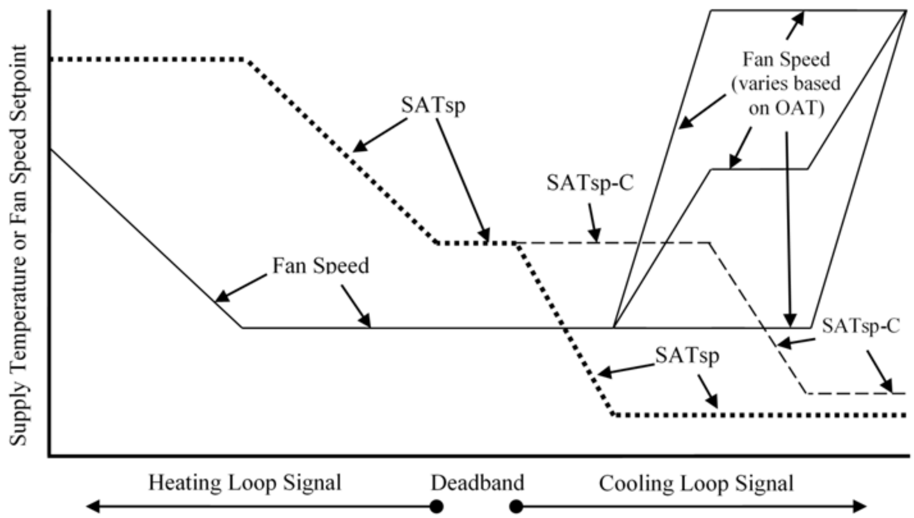

Figure 5.18.4.5-1 Control diagram for SZVAV AHU.

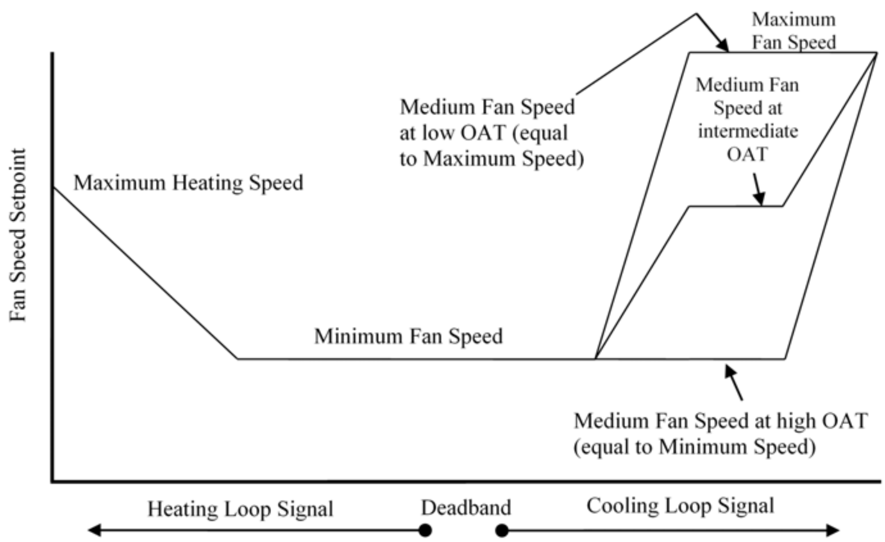

Figure 5.18.4.5-2 Control diagram for SZVAV AHU—fan speed.

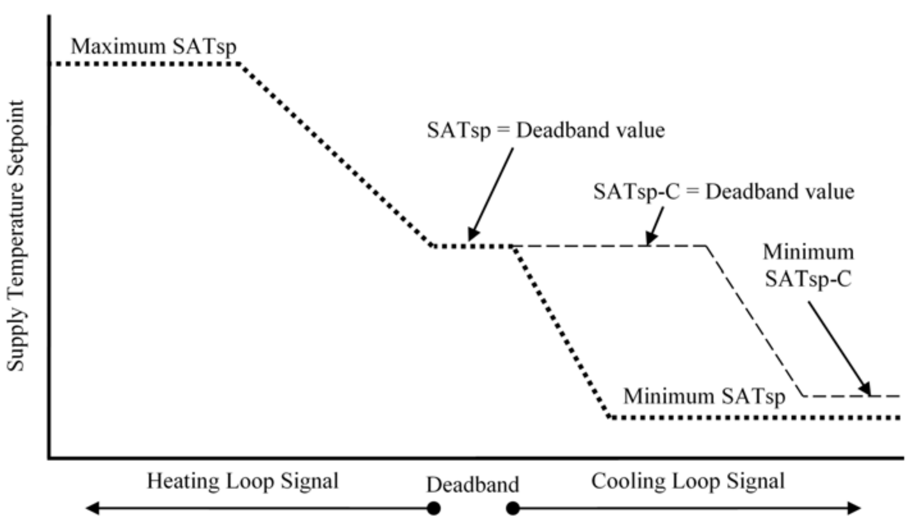

Figure 5.18.4.5-3 Control diagram for SZVAV AHU—supply air temperature.

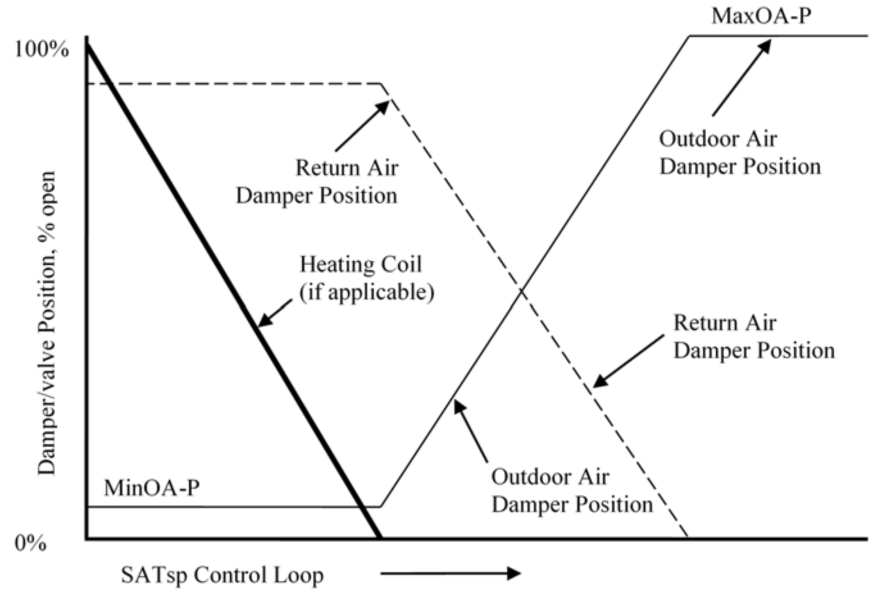

Figure 5.18.5.2 SZVAV AHU supply air temperature loop mapping.

5.18.5 Supply Air Temperature Control

5.18.5.1 There are two supply air temperature set points, SATsp and SATsp-C. Each set point is maintained by a separate control loop, but both loops use the same supply air temperature sensor.

5.18.5.2 The control loop for SATsp is enabled when the supply air fan is proven ON and disabled and set to neutral otherwise.

a. Supply air temperature shall be controlled to SATsp by a control loop whose output is mapped to sequence the heating coil (if applicable) and economizer dampers as shown in the Figure 5.18.5.2. Outdoor air damper minimum MinOA-P and maximum MaxOA-P positions are limited for economizer lockout and to maintain minimum outdoor airflow rate as described in Sections 5.18.6 and 5.18.7.

These sequences assume that the heat source can be modulated and thus control SAT to a set point in heating. If this is not the case (e.g., because heating is by multistage furnace or electric coil), then the following will need to be modified to add appropriate staging logic.

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b. The points of transition along the x-axis shown in Figure 5.18.5.2 are representative. Separate gains shall be provided for each section of the control map (heating coil, economizer) that are determined by the contractor to provide stable control. Alternatively, the contractor shall adjust the precise value of the x-axis thresholds shown in Figure 5.18.5.2 to provide stable control.

Dampers are complementary (rather than sequenced, as they are for multiple-zone VAV AHUs) to reduce equipment costs (avoiding multiple actuators) and to maintain a more-linear relationship between fan speed and outdoor air volume.

In order to make this relationship as linear as possible, the economizer should use parallel blade dampers.

5.18.5.3 The control loop for SATsp-C is enabled when the supply fan is proven ON and the zone state is cooling and disabled and set to neutral otherwise. When enabled, supply air temperature shall be controlled to SATsp-C by modulating the cooling coil.

5.18.6 Minimum Outdoor Air Control

This section describes minimum outdoor air control logic for a unit with a single common minimum OA and economizer damper (i.e., no separate minimum OA damper) and DCV.

This logic assumes that there is no airflow measurement station or DP sensor across the outdoor air intake and controls OA volume directly via damper position set points. This works for a single-zone unit because there are no downstream dampers that would change the relationship between OA damper position and OA airflow. This logic is not appropriate for a system with actuated dampers downstream of the AHU.

Other configurations are possible and would require modifications to the points list and the control logic.

5.18.6.1 See Section 5.2 for calculation of zone minimum outdoor airflow set point.

5.18.6.2 Outdoor Air Damper Control

a. See Section 3.2.2.2 for minimum damper position set points.
b. At least once per minute while the zone is in occupied mode, the BAS shall calculate MinPos* as a linear interpolation between MinPosMin and MinPosMax based on the current fan speed.
c. At least once per minute while the zone is in occupied mode, the BAS shall calculate DesPos* as a linear interpolation between DesPosMin and DesPosMax based on the current fan speed.

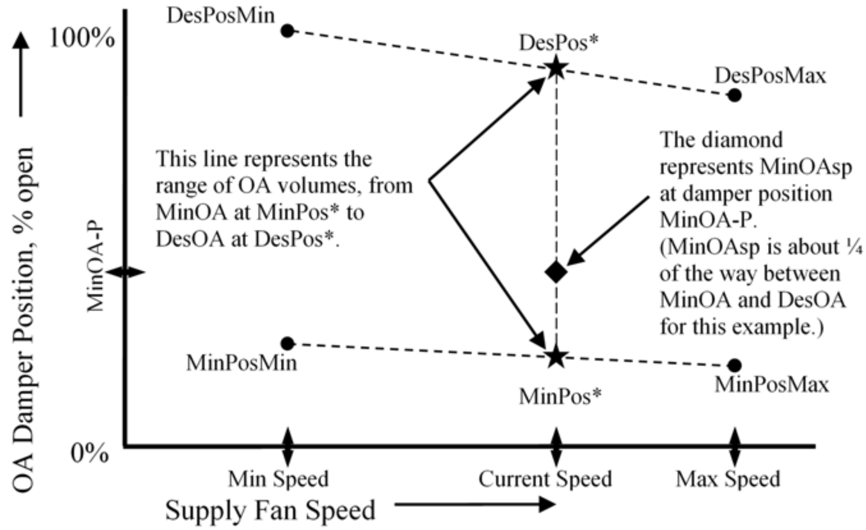

Figure 5.18.6.2 SZVAV AHU minimum outdoor air control.

d. If MinOAsp is zero, MinOA-P shall be zero (i.e., outdoor air damper fully closed).

e. If MinOAsp is nonzero, then the outdoor air damper minimum position MinOA-P shall be the value between MinPos* and DesPos* that is proportional to the value of MinOAsp between MinOA and DesOA. Figure 5.18.6.2 illustrates this (points are chosen arbitrarily and are not meant to be representative).

5.18.7 Economizer Lockout

This section describes economizer lockout logic for a unit with a common minimum OA and economizer damper (i.e., no separate minimum OA damper). Other configurations are possible, and would require modifications to the points list (above) and the control logic below.

5.18.7.1 The normal sequencing of the economizer dampers shall be disabled in accordance with Section 5.1.16.

5.18.7.2 Once the economizer is disabled, it shall not be reenabled within 10 minutes and vice versa.

5.18.7.3 When economizer is enabled, MaxOA-P = 100%. When economizer is disabled, set MaxOA-P equal to MinOA-P. See Section 5.18.5, “Supply Air Temperature Control,” and Section 5.18.6, “Minimum Outdoor Air Control,” for outdoor air damper minimum set point.

The engineer must select among control logic options for return/relief/exhaust. This decision is based on the AHU configuration.

Control logic selections should be made as follows:

- **For AHUs using actuated relief dampers without a fan, use Section 5.18.8 and delete Section 5.18.9 and Section 5.18.10.**
- **For AHUs using actuated relief dampers with relief fan(s), use Section 5.18.9 and delete Section 5.18.8 and Section 5.18.10.**
- **For AHUs using a return fan, use Section 5.18.10 and delete Section 5.18.8 and Section 5.18.9.**
- **For AHUs using nonactuated barometric relief only, delete *all three* Sections 5.18.8, 5.18.9, and 5.18.10.**
- **A building pressure sensor is required for the option in Section 5.18.9. One is not required for Sections 5.18.8 or 5.18.10.**

5.18.8 Control of Actuated Relief Dampers without Fans

5.18.8.1 See Section 3.2.2.2 for relief-damper position set points.

5.18.8.2 Relief dampers shall be enabled when the associated supply fan is proven ON and any outdoor air damper is open, and disabled and closed otherwise.

5.18.8.3 Relief-damper position shall be reset linearly from MinRelief to MaxRelief as the commanded economizer damper position goes from MinPos* to 100% open.

Relief-fan control logic is incorporated by reference in Section 5.18.9.1. If the project includes both single-zone and multiple-zone AHUs, then no change is required. However, if the project includes only single-zone AHUs, we recommend deleting Section 5.18.9 below and copying the full text of Section 5.16.9 in its place.

5.18.9 Relief-Fan Control

5.18.9.1 Refer to Section 5.16.9, “Relief-Fan Control” for multiple-zone air handlers.

5.18.10 Return-Fan Control

Exhaust damper may be barometric (no actuator). In that case, delete Sections 5.18.10.1 and 5.18.10.4.

5.18.10.1 Exhaust damper shall open whenever associated supply fan is proven ON.

5.18.10.2 Return fan shall run whenever associated supply fan is proven ON.

5.18.10.3 Return-fan speed shall be the same as supply-fan speed with a user adjustable offset S-R-DIFF.

5.18.10.4 Exhaust damper shall be closed when return fan is disabled.

This concludes the section where the control logic for return/relief/exhaust is selected.

When the sequences are complete, *at most* one of Sections 5.18.8, 5.18.9, or 5.18.10 should remain. If relief is barometric (without actuators) only, then all three subsections should be deleted. Delete these flag notes after the decision has been made.

If a freeze-stat is present, it may be hardwired to perform some or all of these functions. In that case, delete those functions from sequence logic but maintain the alarms. Delete this flag note when sequences are complete.

5.18.11 Freeze Protection

There are three stages of freeze protection. The first stage modulates the heating valve to maintain a safe SAT. The second stage eliminates outdoor air ventilation in case heating is not available for whatever reason. The third stage shuts down the unit and activates coil valves and pumps to circulate water in case the second stage does not work (e.g., stuck economizer damper).

5.18.11.1 If the supply air temperature drops below 4°C (40°F) for 5 minutes, send two (or more, as required to ensure that heating plant is active) heating hot-water plant requests, override the outdoor air damper to the minimum position, and modulate the heating coil to maintain a supply air temperature of at least 6°C (42°F). Disable this function when supply air temperature rises above 7°C (45°F) for 5 minutes.

The first stage of freeze protection locks out the economizer. Most likely this has already occurred by this time, but this logic provides insurance.

5.18.11.2 If the supply air temperature drops below 3°C (38°F) for 5 minutes, fully close both the economizer damper and the minimum outdoor air damper for 1 hour and set a Level 3 alarm noting that minimum ventilation was interrupted. After 1 hour, the unit shall resume minimum outdoor air ventilation and enter the previous stage of freeze protection (see Section 5.18.11.1).

A timer is used (rather than an OAT threshold) to exit the second stage of freeze protection because a bad OAT sensor could lock out ventilation indefinitely; whereas a timer should just work and thus avoid problems with the unit becoming stuck in this mode with no ventilation.

Upon timer expiration, the unit will reenter the previous stage of freeze protection (MinOA ventilation, with heating to maintain SAT of 6°C [42°F]), after which one of three possibilities will occur:

a. *If it is warm enough that the SAT rises above 7°C (45°F) with minimum ventilation, the unit will remain in Stage 1 freeze protection for 5 minutes then resume normal operation.*
b. *If it is cold enough that SAT remains between 3°C (38°F) and 7°C (45°F) with heating and minimum ventilation, the unit will remain in Stage 1 freeze protection indefinitely until outdoor conditions warm up.*
c. *If it is so cold that SAT is less than 3°C (38°F) with minimum ventilation, despite heating, then the unit will revert to Stage 2 freeze protection where it will remain for 1 hour. This process will then repeat.*

5.18.11.3 Upon signal from the freeze-stat (if installed), or if supply air temperature drops below 3°C (38°F) for 15 minutes or below 1°C (34°F) for 5 minutes, shut down supply and return/relief fan(s), close outdoor air damper, make the minimum cooling-coil valve position 100%, and energize the CHW pump system. Send two (or more, as required to ensure that heating plant is active) heating hot-water plant requests, modulate the heating coil to maintain the higher of the supply air temperature or the mixed air temperature at 27°C (80°F), and set a Level 2 alarm indicating the unit is shut down by freeze protection.

a. If a freeze protection shutdown is triggered by a low air temperature sensor reading, 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).

Stage 3 can be triggered by either of two conditions. The second condition is meant to respond to an extreme and sudden cold snap.

Protecting the cooling coil in this situation will require water movement through the coil, which means that the CHW pumps need to be energized.

Heating coil is controlled to an air temperature set point. The sensors will not read accurately with the fan OFF, but they will be influenced by proximity to the heating coil. A temperature of 27°C (80°F) at either of these sensors indicates that the interior of the unit is sufficiently warm. This avoids the situation where a fixed valve position leads to very high (and potentially damaging) temperatures inside the unit.

5.18.12 Standard Alarms

5.18.12.1 Maintenance interval alarm when fan has operated for more than 1500 hours: Level 4. Reset interval counter when alarm is acknowledged.

5.18.12.2 Fan alarm is indicated by the status being different from the command for a period of 15 seconds.

a. Commanded ON, status OFF: Level 2
b. Commanded OFF, status ON: Level 4

Table 5.18.13.2 SZVAV AHU Operating States

Operating State	Heating Valve Position	Cooling Valve Position	Outdoor Air Damper Position
#1: Heating	> 0	= 0	= min
#2: Free cooling, modulating OA	= 0	= 0	min < x < 100%
#3: Mechanical + economizer cooling	= 0	> 0	= 100%
#4: Mechanical cooling, minimum OA	= 0	> 0	= min
#5: Unknown or dehumidification	No other OS applies		

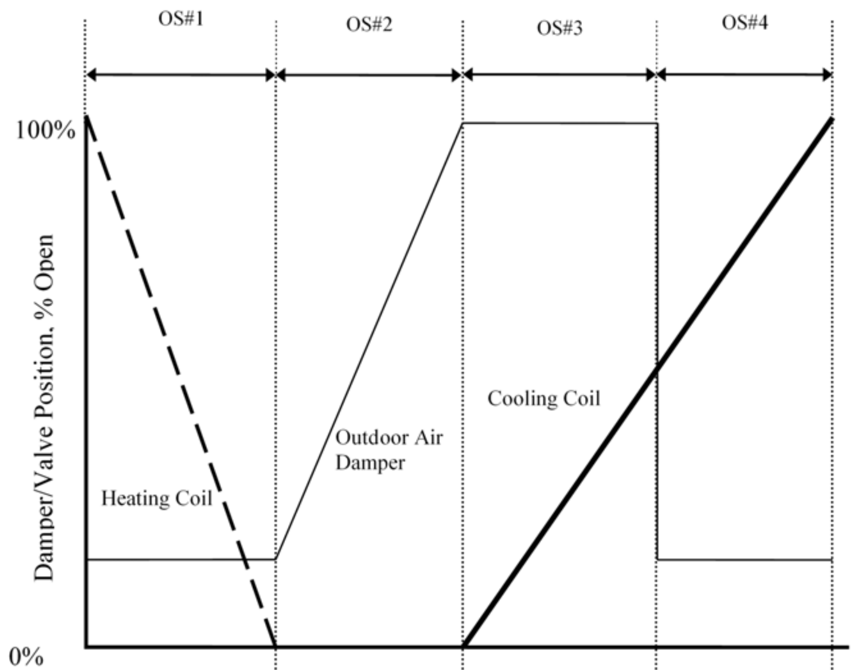

Figure 5.18.13.2 SZVAV AHU operating states.

Automatic Fault Detection and Diagnostics (AFDD) is a sophisticated system for detecting and diagnosing air-handler faults.

To function correctly, AFDD requires specific sensors and data be available, as detailed in the sequences below. If this information is not available, AFDD tests that do not apply should be deleted.

5.18.13 Automatic Fault Detection and Diagnostics

The AFDD routines for AHUs continually assess AHU performance by comparing the values of BAS 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 OS 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 that 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. If an MAT sensor is not installed, omit Fault Conditions #2, #3, #5, #8, #10, and #12.

5.18.13.1 AFDD conditions are evaluated continuously and separately for each operating AHU.

5.18.13.2 The 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 Table 5.18.13.2 and Figure 5.18.13.2.

The OS 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 through OS#4 (see Table 5.18.13.2) represent normal operation during which a fault may nevertheless occur if so determined by the fault condition tests in Section 5.18.13.6. By contrast, OS#5 may represent 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 or during warm-up.

5.18.13.3 The following points must be available to the AFDD routines for each AHU:

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 nonuniform 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.

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a. SAT = supply air temperature
b. MAT = mixed air temperature
c. RAT = return air temperature
d. OAT = outdoor air temperature
e. DSP = duct static pressure
f. SATsp = supply air temperature set point for heating coil and economizer control
g. SATsp-C = supply air temperature set point for cooling coil control
h. HC = heating-coil valve position command; 0% ≤ HC ≤ 100%
i. CC = cooling-coil valve position command; 0% ≤ CC ≤ 100%
j. FS = fan-speed command; 0% ≤ FS ≤ 100%
k. CCET = cooling-coil entering temperature (Depending on the AHU configuration, this could be the MAT or a separate sensor for this specific purpose).
l. CCLT = cooling-coil leaving temperature (Depending on the AHU configuration, this could be the SAT or a separate sensor for this specific purpose.)
m. HCET = heating-coil entering temperature (Depending on the AHU configuration, this could be the MAT or a separate sensor for this specific purpose.)
n. HCLT = heating-coil leaving temperature (Depending on the AHU configuration, this could be the SAT or a separate sensor for this specific purpose.)

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

a. Five-minute rolling averages with 1-minute sampling of the following point values; operator shall have the ability to adjust the averaging window and sampling period for each point independently.
   1. SATavg = rolling average of supply air temperature
   2. MATavg = rolling average of mixed air temperature
   3. RATavg = rolling average of return air temperature
   4. OATavg = rolling average of outdoor air temperature
   5. CCETavg = rolling average of cooling-coil entering temperature
   6. CCLTavg = rolling average of cooling-coil leaving temperature
   7. HCETavg = rolling average of heating-coil entering temperature
   8. HCLTavg = rolling average of heating-coil leaving temperature
   9. ΔOS = number of changes in OS during the previous 60 minutes (moving window)

5.18.13.5 The internal variables shown in Table 5.18.13.5 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 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 toward 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 trend logs. 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.

The purpose of ΔTmin 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.

The purpose of TestModeDelay is to ensure that normal fault reporting occurs after the testing and commissioning process is completed as described in Section 5.18.13.12.

5.18.13.6 Table 5.18.13.6 shows potential fault conditions that can be evaluated by the AFDD routines. (At most, 14 of the 15 fault conditions are actively evaluated, but numbering was carried over from multiple-zone AHUs for consistency.) 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 OS of the AHU.

The equations in Table 5.18.13.6 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 5.18.13.5 SZVAV AHU Internal Variables

Variable Name	Description	Default Value
ΔTSF	Temperature rise across supply fan	0.5°C (1°F)
ΔTmin	Minimum difference between OAT and RAT to evaluate economizer error conditions (FC#6)	6°C (10°F)
εSAT	Temperature error threshold for SAT sensor	1°C (2°F)
εRAT	Temperature error threshold for RAT sensor	1°C (2°F)
εMAT	Temperature error threshold for MAT sensor	3°C (5°F)
εOAT	Temperature error threshold for OAT sensor	1°C (2°F) if local sensor @ unit. 3°C (5°F) if global sensor.
εCCET	Cooling coil entering temperature sensor error. Equal to εMAT or dedicated sensor error	Varies; see description.
εCCLT	Cooling coil leaving temperature sensor error. Equal to εSAT or dedicated sensor error	
εHCET	Heating coil entering temperature sensor error; equal to εMAT or dedicated sensor error	
εHCLT	Heating coil leaving temperature sensor error. Equal to εSAT or dedicated sensor error	
ΔOSmax	Maximum number of changes in Operating State during the previous 60 minutes (moving window)	7
ModeDelay	Time in minutes to suspend Fault Condition evaluation after a change in mode	30
AlarmDelay	Time in minutes that a Fault Condition must persist before triggering an alarm	30
TestModeDelay	Time in minutes that Test Mode is enabled	120

To detect the required economizer faults in California Title 24 section 120.2(i)7, use FC#2, #3, and #5 through #13 at a minimum. Other Title 24 AFDD requirements, including acceptance tests, are not met through these fault conditions.

5.18.13.7 A subset of all potential fault conditions is evaluated by the AFDD routines. The set of applicable fault conditions depends on the OS of the AHU. If an MAT sensor is not installed, omit FCs #2, #3, #5, #8, #10, and #12:

a. In OS#1 (Heating), the following fault conditions shall be evaluated:
   1. FC#2: MAT too low; should be between RAT and OAT
   2. FC#3: MAT too high; should be between RAT and OAT
   3. FC#4: Too many changes in OS
   4. FC#5: SAT too low; should be higher than MAT
   5. FC#6: OA fraction too high; MAT should be closer to RAT than to OAT
   6. FC#7: SAT too low in full heating
   7. FC#14: Temperature drop across inactive cooling coil
b. In OS#2 (modulating economizer), the following fault conditions shall be evaluated:
   1. FC#2: MAT too low; should be between RAT and OAT
   2. FC#3: MAT too high; should be between RAT and OAT
   3. FC#4: Too many changes in OS
   4. FC#8: SAT and MAT should be approximately equal
   5. FC#9: OAT too high for free cooling without mechanical cooling
   6. FC#14: Temperature drop across inactive cooling coil
   7. FC#15: Temperature rise across inactive heating coil
c. In OS#3 (mechanical + 100% economizer cooling), the following fault conditions shall be evaluated:
   1. FC#2: MAT too low; should be between RAT and OAT
   2. FC#3: MAT too high; should be between RAT and OAT
   3. FC#4: Too many changes in OS
   4. FC#10: OAT and MAT should be approximately equal
   5. FC#11: OAT too low for 100% OA
   6. FC#12: SAT too high; should be less than MAT
   7. FC#13: SAT too high in full cooling
   8. FC#15: Temperature rise across inactive heating coil
d. In OS#4 (mechanical cooling, minimum OA), the following fault conditions shall be evaluated:
   1. FC#2: MAT too low; should be between RAT and OAT
   2. FC#3: MAT too high; should be between RAT and OAT
   3. FC#4: Too many changes in OS
   4. FC#6: OA fraction too high; MAT should be closer to RAT than to OAT
   5. FC#12: SAT too high; should be less than MAT
   6. FC#13: SAT too high in full cooling
   7. FC#15: Temperature rise across inactive heating coil
e. In OS#5 (other), the following fault conditions shall be evaluated:
   1. FC#2: MAT too low; should be between RAT and OAT
   2. FC#3: MAT too high; should be between RAT and OAT
   3. FC#4: Too many changes in OS

5.18.13.8 For each air handler, the operator shall be able to suppress the alarm for any fault condition.

Table 5.18.13.6 SZVAV AHU Fault Conditions

FC#1	This fault condition is not used in single zone units, as it requires a static pressure set point.		**Applies to OS#1 through OS#5**
FC#2 (omit if no MAT sensor)	**Equation**	MATavg + εMAT < min[(RATavg – εRAT), (OATavg – εOAT)]	**Applies to OS#1 through OS#5**
	Description	MAT too low; should be between OAT and RAT	
	Possible Diagnosis	RAT sensor error	
		MAT sensor error	
		OAT sensor error	
FC#3 (omit if no MAT sensor)	**Equation**	MATavg – εMAT > min[(RATavg + εRAT), (OATavg + εOAT)]	**Applies to OS#1 through OS#5**
	Description	MAT too high; should be between OAT and RAT	
	Possible Diagnosis	• RAT sensor error • MAT sensor error • OAT sensor error	
FC#4	**Equation**	ΔOS > ΔOSmax	**Applies to OS#1 through OS#5**
	Description	Too many changes in OS	
	Possible Diagnosis	Unstable control due to poorly tuned loop or mechanical problem	
FC#5 (omit if no MAT sensor)	**Equation**	SATavg + εSAT ≤ MATavg – εMAT + ΔTSF	**Applies to OS#1**
	Description	SAT too low; should be higher than MAT	
	Possible Diagnosis	• 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 • HW temperature too low or HW unavailable • Gas or electric heat unavailable	
FC#6	**Equation**	|RATavg – OATavg| ≥ ΔTmin **AND** |RATavg – MATavg| > |OATavg – MATavg|	**Applies to OS#1 and OS#4**
	Description	OA fraction too high; MAT should be closer to RAT than to OAT	
	Possible Diagnosis	• RAT sensor error • MAT sensor error • OAT sensor error • Leaking or stuck economizer damper or actuator	
FC#7	**Equation**	SATavg < SATSP – εSAT **AND** HC ≥ 99%	**Applies to OS#1**
	Description	SAT too low in full heating	
	Possible Diagnosis	• SAT sensor error • Cooling-coil valve leaking or stuck open • Heating-coil valve stuck closed or actuator failure • Fouled or undersized heating coil • HW temperature too low or HW unavailable • Gas or electric heat is unavailable • DX cooling is stuck ON • Leaking or stuck economizer damper or actuator	
FC#8 (omit if no MAT sensor)	**Equation**	|SATavg – ΔTSF – MATavg| > $\sqrt{\varepsilon SAT^2 + \varepsilon MAT^2}$	**Applies to OS#2**
	Description	SAT and MAT should be approximately equal	
	Possible Diagnosis	• SAT sensor error • MAT sensor error • Cooling-coil valve leaking or stuck open • DX cooling stuck on • Heating-coil valve leaking or stuck open • Gas or electric heat stuck ON	

Table 5.18.13.6 SZVAV AHU Fault Conditions *(Continued)*

FC#9	**Equation**	$OATavg + \varepsilon OAT > SATSP - \Delta TSF + \varepsilon SAT$	**Applies to OS#2**
	Description	OAT too high for free cooling without additional mechanical cooling	
	Possible Diagnosis	• SAT sensor error • OAT sensor error • Cooling-coil valve leaking or stuck open • DX cooling stuck ON	
FC#10 (omit if no MAT sensor)	**Equation**	$\lvert MATavg - OATavg \rvert > \sqrt{\varepsilon MAT^2 + \varepsilon OAT^2}$	**Applies to OS#3**
	Description	OAT and MAT should be approximately equal	
	Possible Diagnosis	• MAT sensor error • OAT sensor error • Leaking or stuck economizer damper or actuator	
FC#11	**Equation**	$OATavg + \varepsilon OAT < SATSP - \Delta TSF - \varepsilon SAT$	**Applies to OS#3**
	Description	OAT too low for 100% OA cooling	
	Possible Diagnosis	• SAT sensor error • OAT sensor error • Heating-coil valve leaking or stuck open • Gas or electric heat stuck ON • Leaking or stuck economizer damper or actuator	
FC#12 (omit if no MAT sensor)	**Equation**	$SATavg - \varepsilon SAT - \Delta TSF \geq MATavg + \varepsilon MAT$	**Applies to OS#3 and OS#4**
	Description	SAT too high; should be less than MAT	
	Possible Diagnosis	• 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 • DX cooling unavailable • Gas or electric heat stuck ON • Heating-coil valve leaking or stuck open	
FC#13	**Equation**	$SATavg > SATSP\text{-}C + \varepsilon SAT$ **AND** $CC \geq 99\%$	**Applies to OS#3 and OS#4**
	Description	SAT too high in full cooling	
	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 • DX cooling unavailable • Gas or electric heat stuck ON • Heating-coil valve leaking or stuck open	
FC#14	**Equation**	$CCETavg - CCLTavg \geq \sqrt{\varepsilon CCET^2 + \varepsilon CCLT^2} + \Delta TSF^*$ *Fan heat factor included or not, depending on location of sensors used for CCET and CCLT	**Applies to OS#1 and OS#2**
	Description	Temperature drop across inactive cooling coil	
	Possible Diagnosis	• CCET sensor error • CCLT sensor error • Cooling-coil valve stuck open or leaking • DX cooling stuck ON	
FC#15	**Equation**	$HCLTavg - HCETavg \geq \sqrt{\varepsilon HCET^2 + \varepsilon HCLT^2} + \Delta TSF^*$ *Fan heat factor included or not, depending on location of sensors used for HCET and HCLT	**Applies to OS#2 through OS#4**
	Description	Temperature rise across inactive heating coil	
	Possible Diagnosis	• HCET sensor error • HCLT sensor error • Heating-coil valve stuck open or leaking • Gas or electric heat stuck ON	

5.18.13.9 Evaluation of fault conditions shall be suspended under the following conditions:

a. When AHU is not operating
b. 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

5.18.13.10 Fault conditions that are not applicable to the current OS shall not be evaluated.

5.18.13.11 A fault condition that evaluates as TRUE must do so continuously for AlarmDelay minutes before it is reported to the operator.

5.18.13.12 Test mode shall temporarily set ModeDelay and AlarmDelay to 0 minutes for a period of TestModeDelay minutes to allow instant testing of the AFDD system and ensure normal fault detection occurs after testing is complete.

5.18.13.13 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 Table 5.18.13.6.

5.18.14 Testing/Commissioning Overrides. Provide software switches that interlock to a CHW and hot-water plant level to

a. force HW valve full open if there is a hot-water coil,
b. force HW valve full closed if there is a hot-water coil,
c. force CHW valve full open if there is a CHW coil, and
d. force CHW valve full closed if there is a CHW coil.

Per Section 5.1.10, all hardware points can be overridden through the BAS. Each of the following points is interlocked so that they can be overridden as a group on a plant level.

For example, the CxA can check for valve leakage by simultaneously forcing closed all CHW valves at all AHUs served by the chiller plant and then recording flow at the chiller.

Central plant sequences are not part of the initial scope of Guideline 36, but control logic for plant requests are being included for future use, when central plant sequences are added.

Typically, the chiller or heating hot-water 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.

Chilled-water and hot-water reset requests are used in T&R loops to control supply water temperature and/or pump DP set points based on zone and AHU demands.

5.18.15 Plant Requests

5.18.15.1 Chilled-Water Reset Requests

a. If the supply air temperature exceeds SATsp-C by 3°C (5°F) for 2 minutes, send 3 requests.
b. Else if the supply air temperature exceeds SATsp-C by 2°C (3°F) for 2 minutes, send 2 requests.
c. Else if the CHW valve position is greater than 95%, send 1 request until the CHW valve position is less than 85%.
d. Else if the CHW valve position is less than 95%, send 0 requests.

5.18.15.2 Chiller Plant Requests. Send the chiller plant that serves the system a chiller plant request as follows:

a. If the CHW valve position is greater than 95%, send 1 request until the CHW valve position is less than 10%.
b. Else if the CHW valve position is less than 95%, send 0 requests.

5.18.15.3 If There Is a Hot-Water Coil, Hot-Water Reset Requests

a. If the supply air temperature is 17°C (30°F) less than SATsp for 5 minutes, send 3 requests.
b. Else if the supply air temperature is 8°C (15°F) less than SATsp for 5 minutes, send 2 requests.
c. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
d. Else if the HW valve position is less than 95%, send 0 requests.

5.18.15.4 If There Is a Hot-Water Coil, Heating Hot-Water Plant Requests. Send the heating hot-water plant that serves the AHU a heating hot-water plant request as follows:

a. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.
b. Else if the HW valve position is less than 95%, send 0 requests.

(This appendix is not part of this guideline. It is merely informative and does not contain requirements necessary for conformance to the guideline.)

INFORMATIVE APPENDIX A
CONTROL DIAGRAMS

Appendix A provides control diagrams for a selection of the equipment configurations described in this guideline. These diagrams may be used in drawings where appropriate, but they are not intended to represent all of the possible equipment configurations that are supported by these sequences. The designer should edit these diagrams as required for the project.

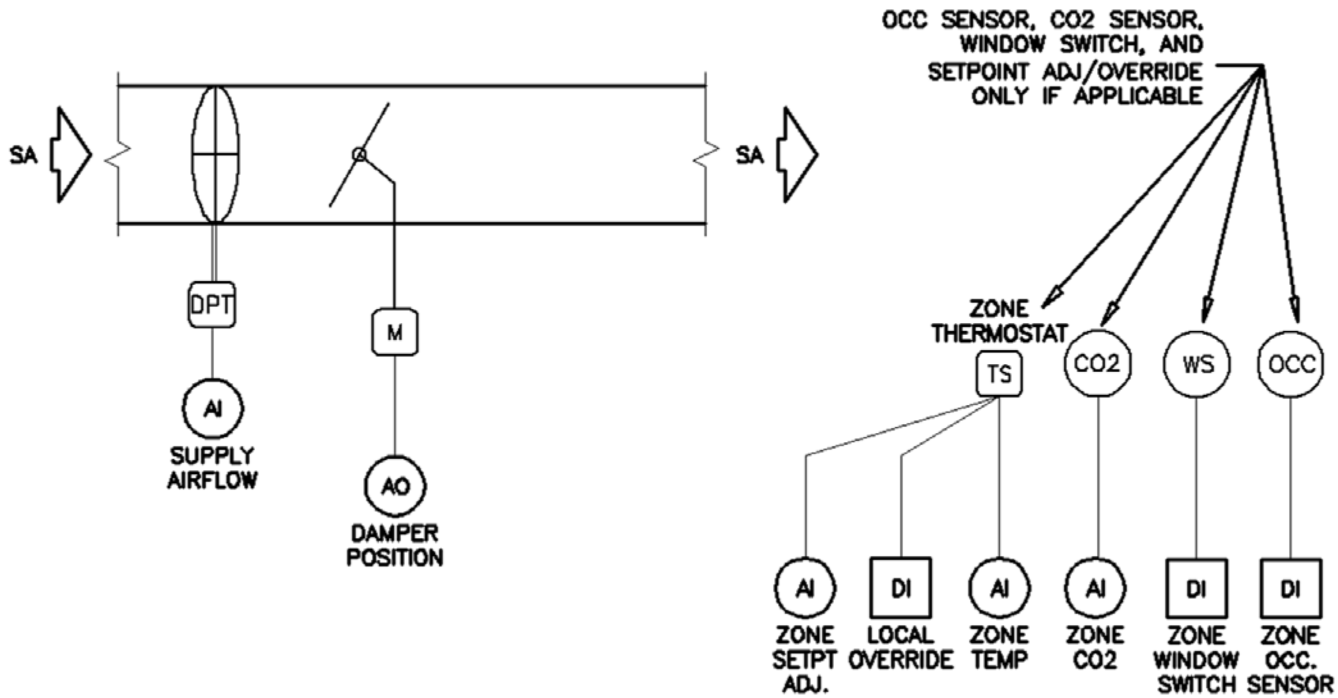

Figure A-1 VAV terminal unit, cooling only.

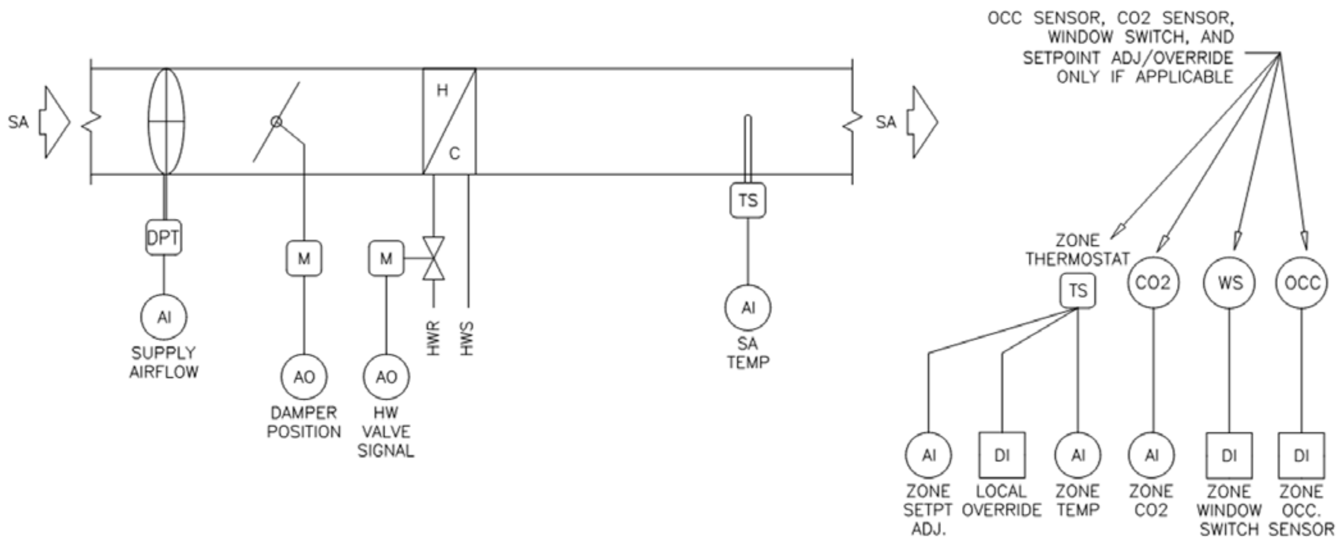

Figure A-2 VAV terminal unit with reheat.

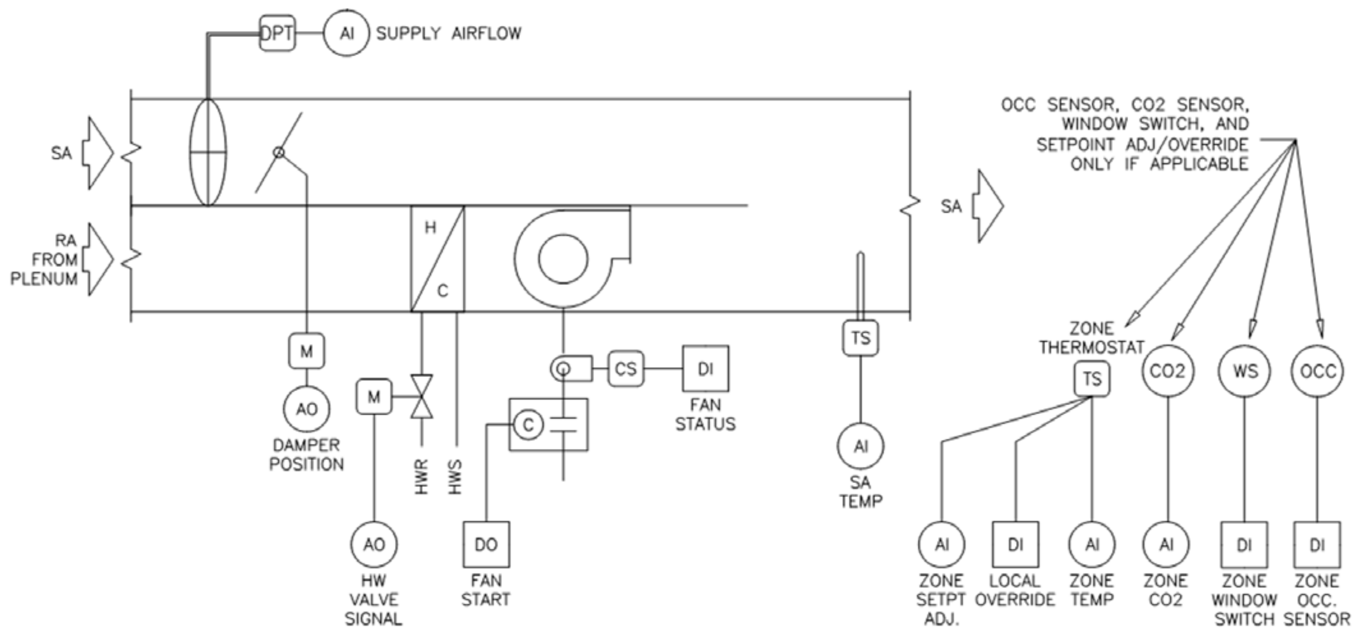

Figure A-3 Parallel fan-powered terminal unit, constant-volume fan.

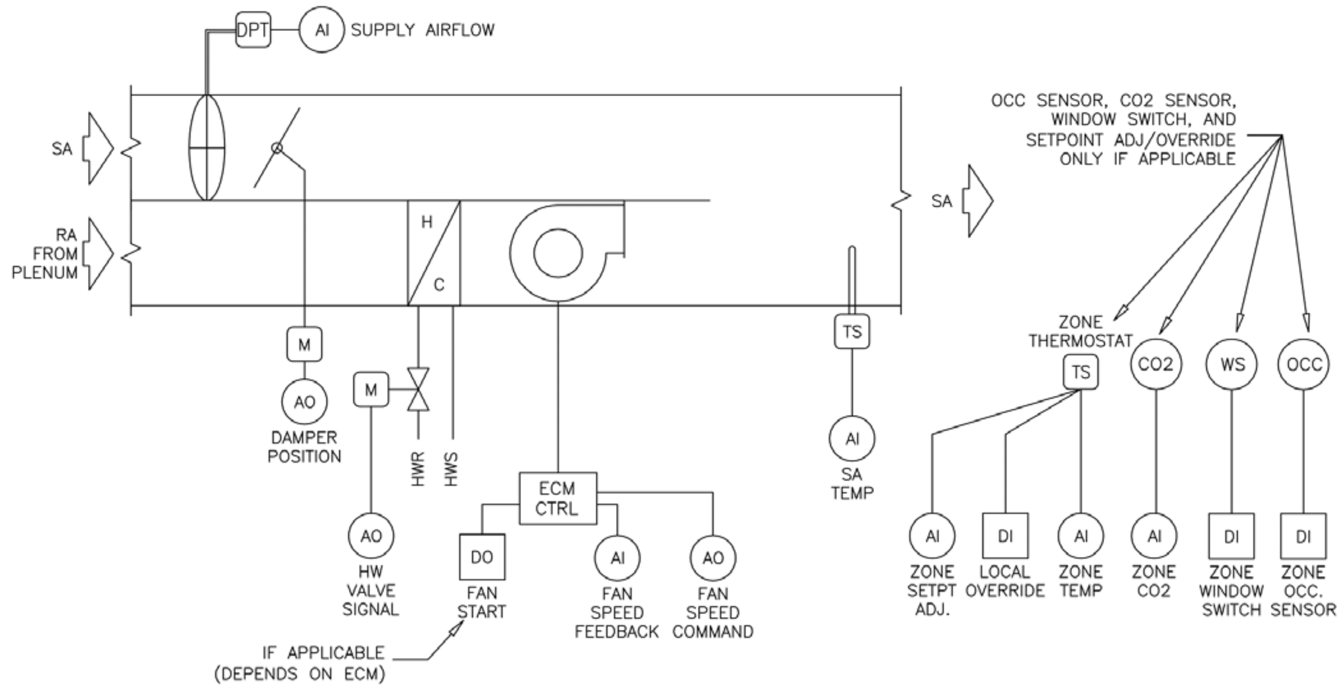

Figure A-4 Parallel fan-powered terminal unit, variable-volume fan.

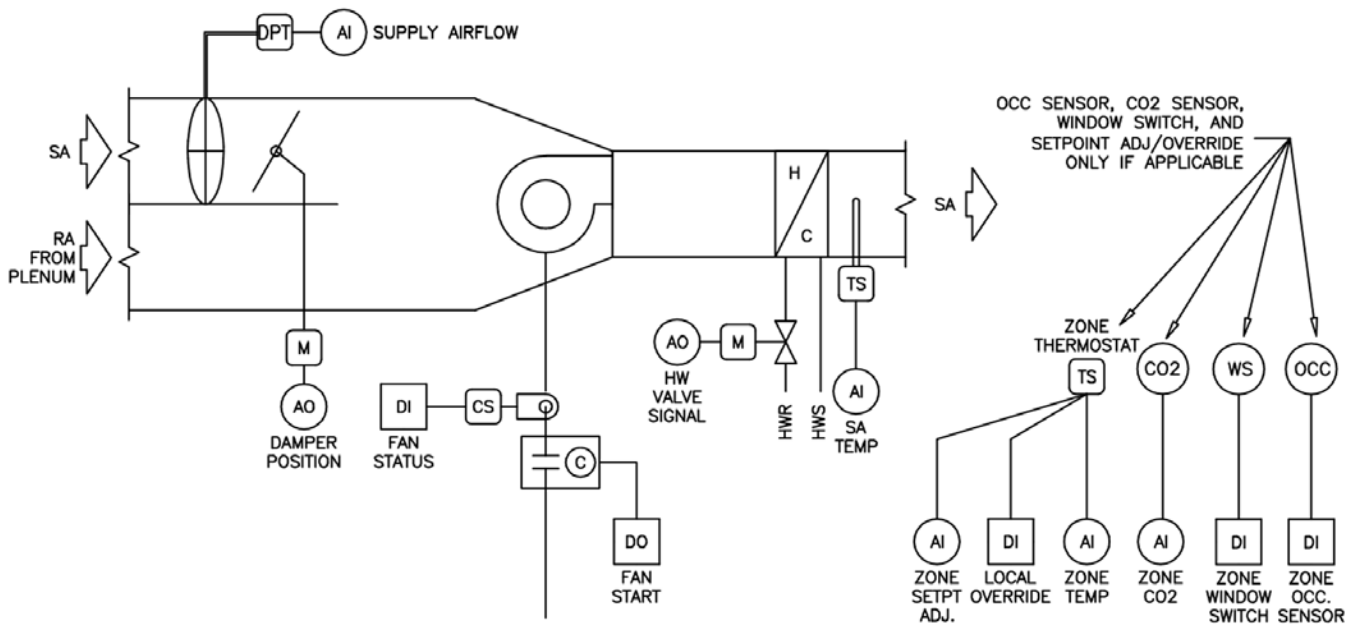

Figure A-5 Series fan-powered terminal unit, constant-volume fan.

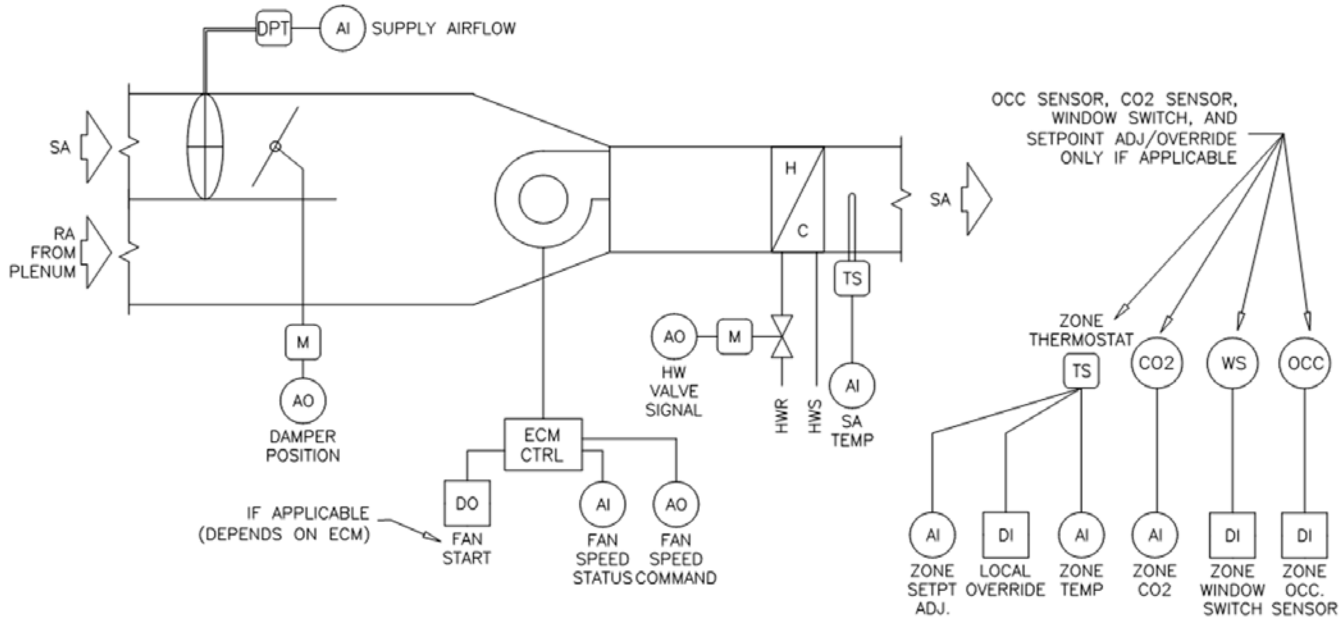

Figure A-6 Series fan-powered terminal unit, variable-volume fan.

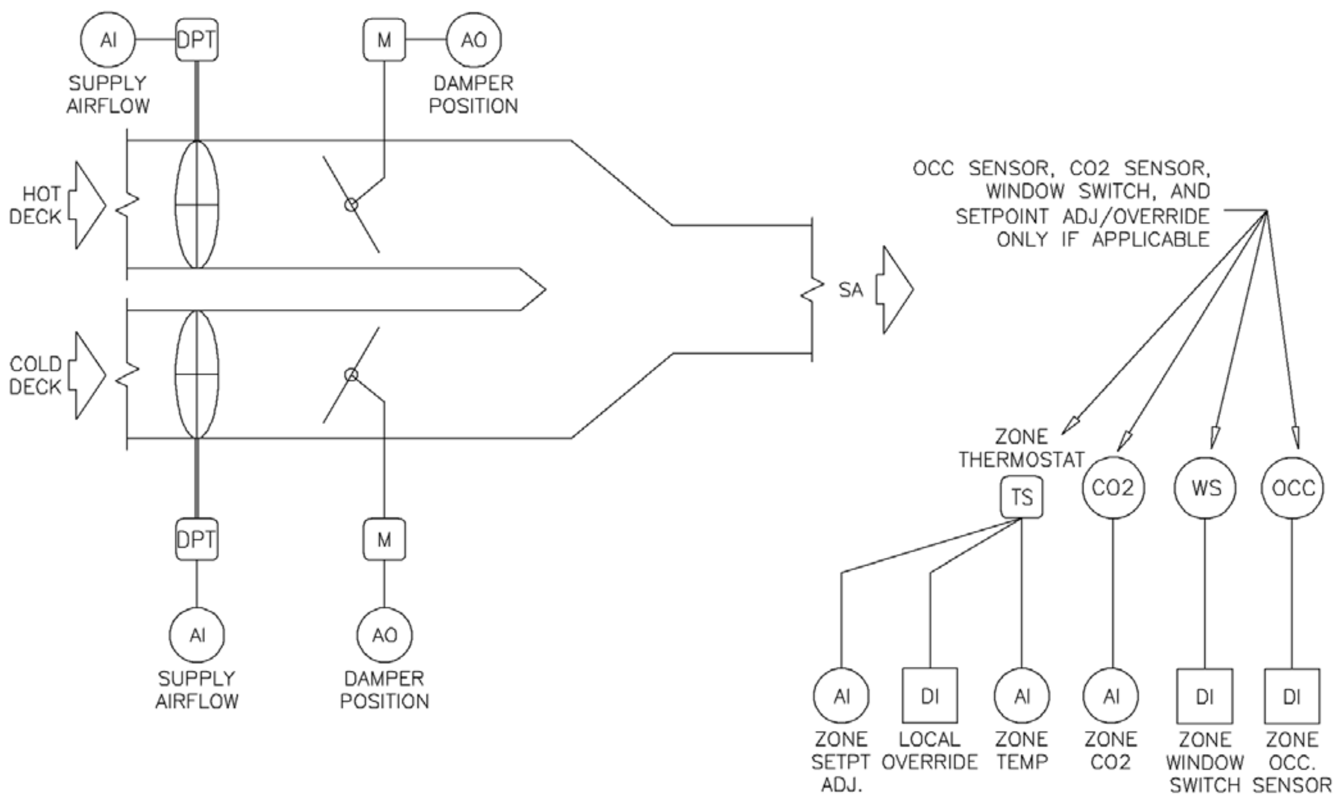

Figure A-7 Dual-duct terminal unit with inlet sensors.

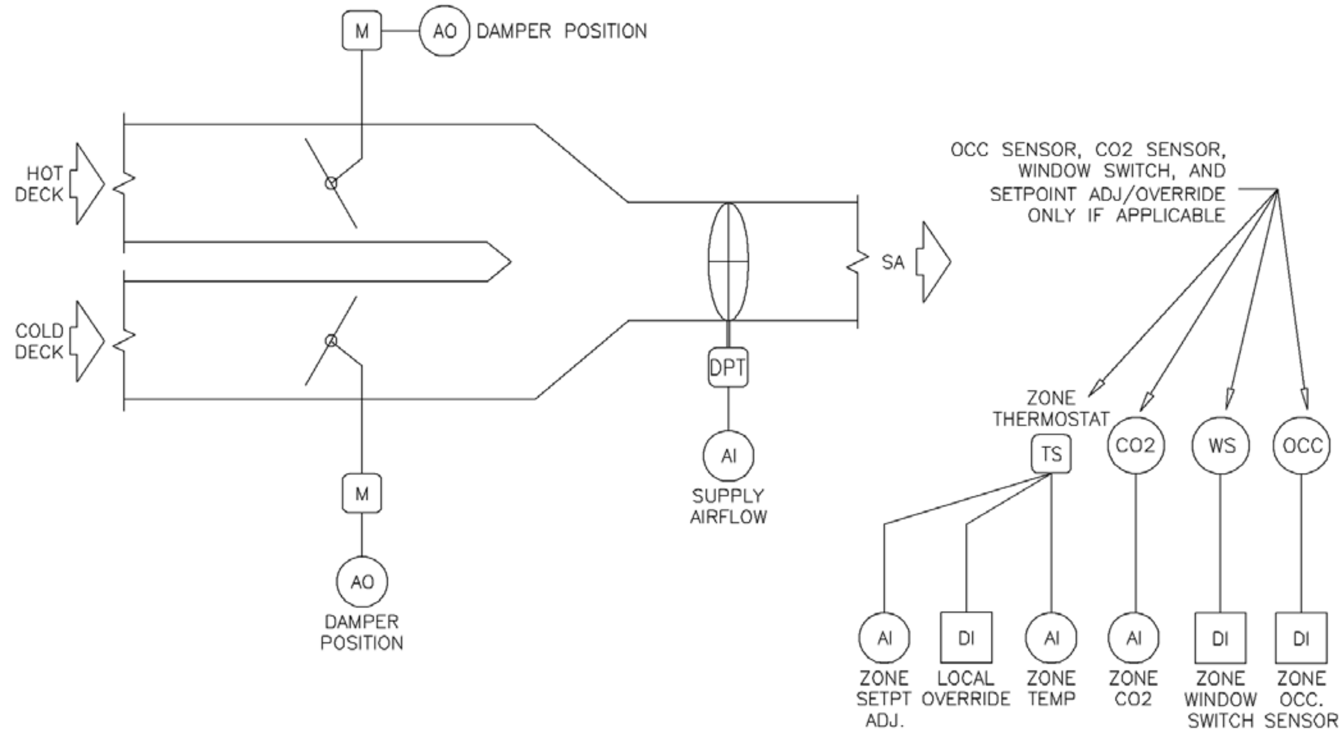

Figure A-8 Dual-Duct terminal unit with discharge sensor.

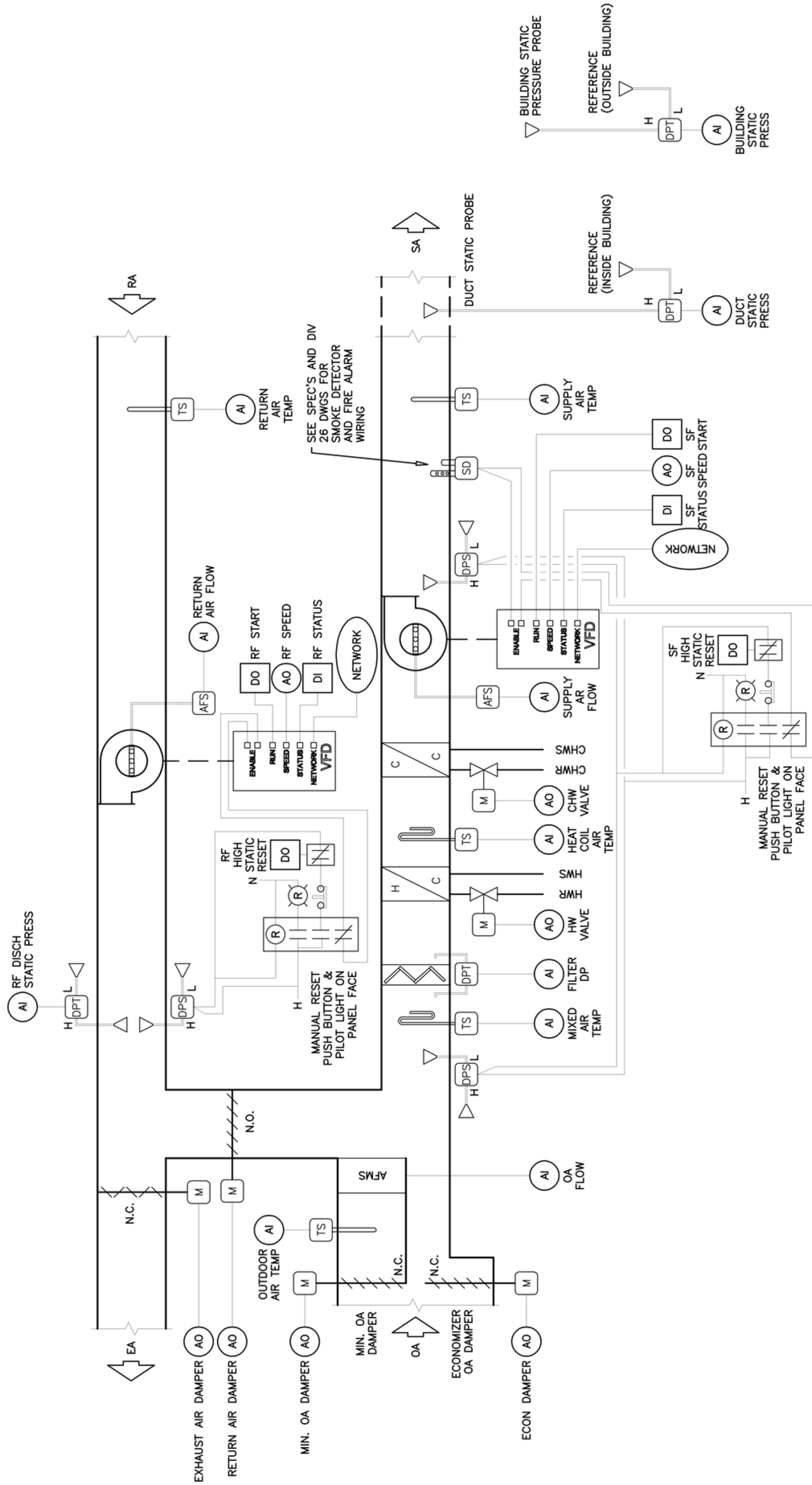

Figure A-9 Multiple-zone VAV air-handling unit with return fan and minimum OA measurement station.

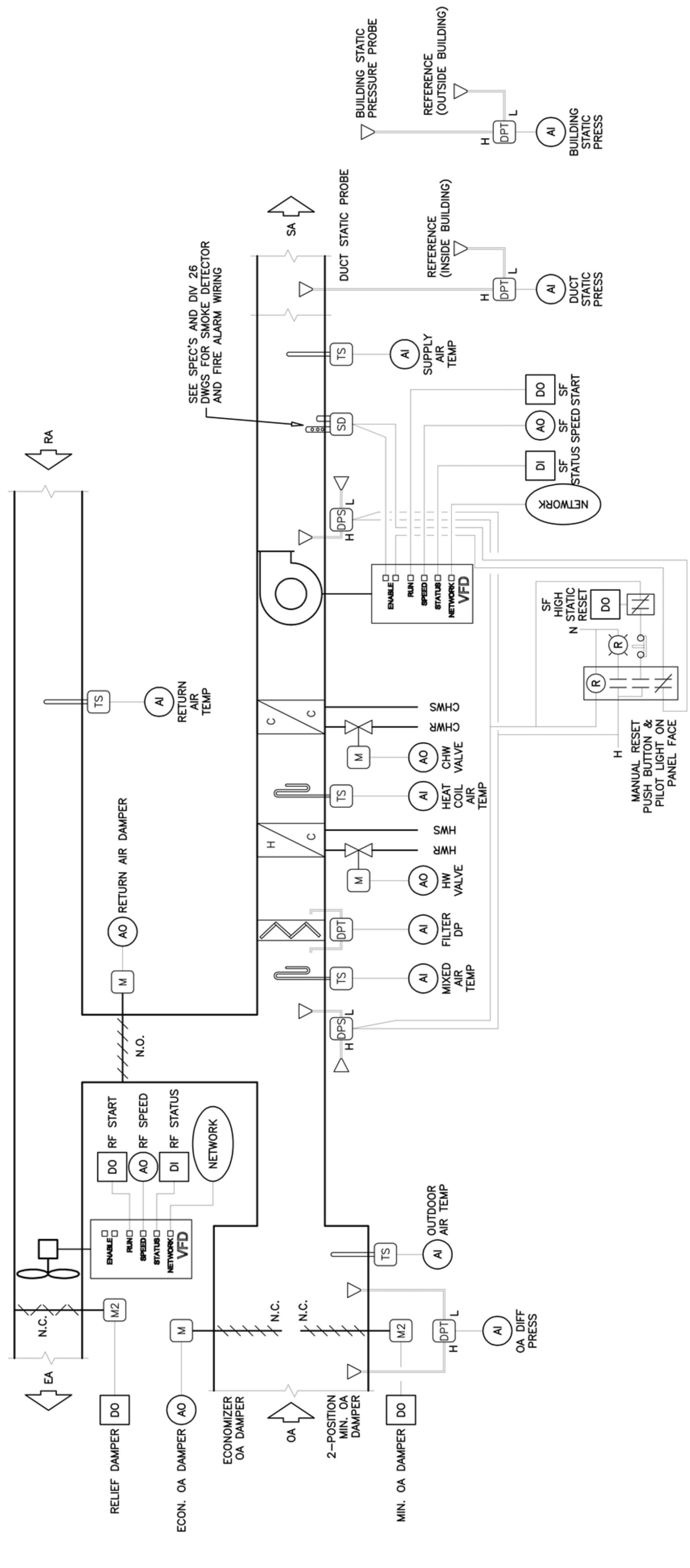

Figure A-10 Multiple-zone VAV air-handling unit with relief fan and differential pressure OA measurement.

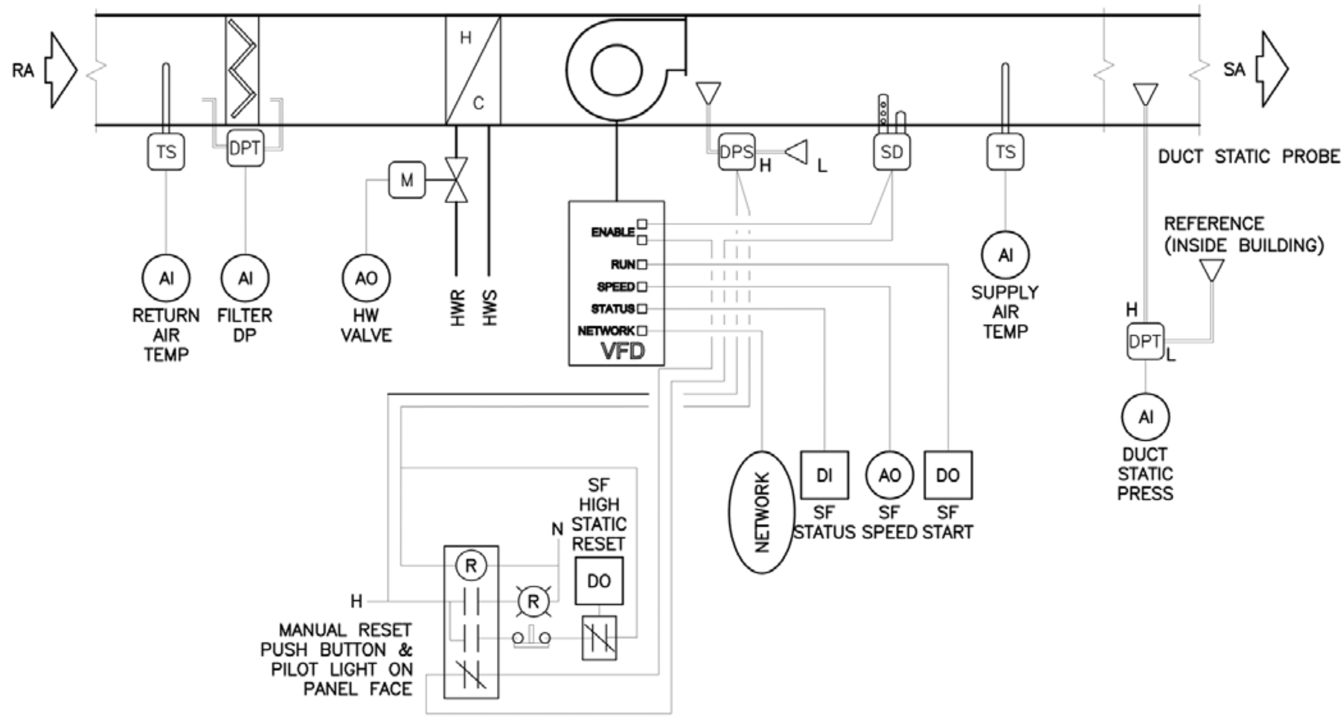

Figure A-11 Dual-fan dual-duct heating VAV air-handling unit.

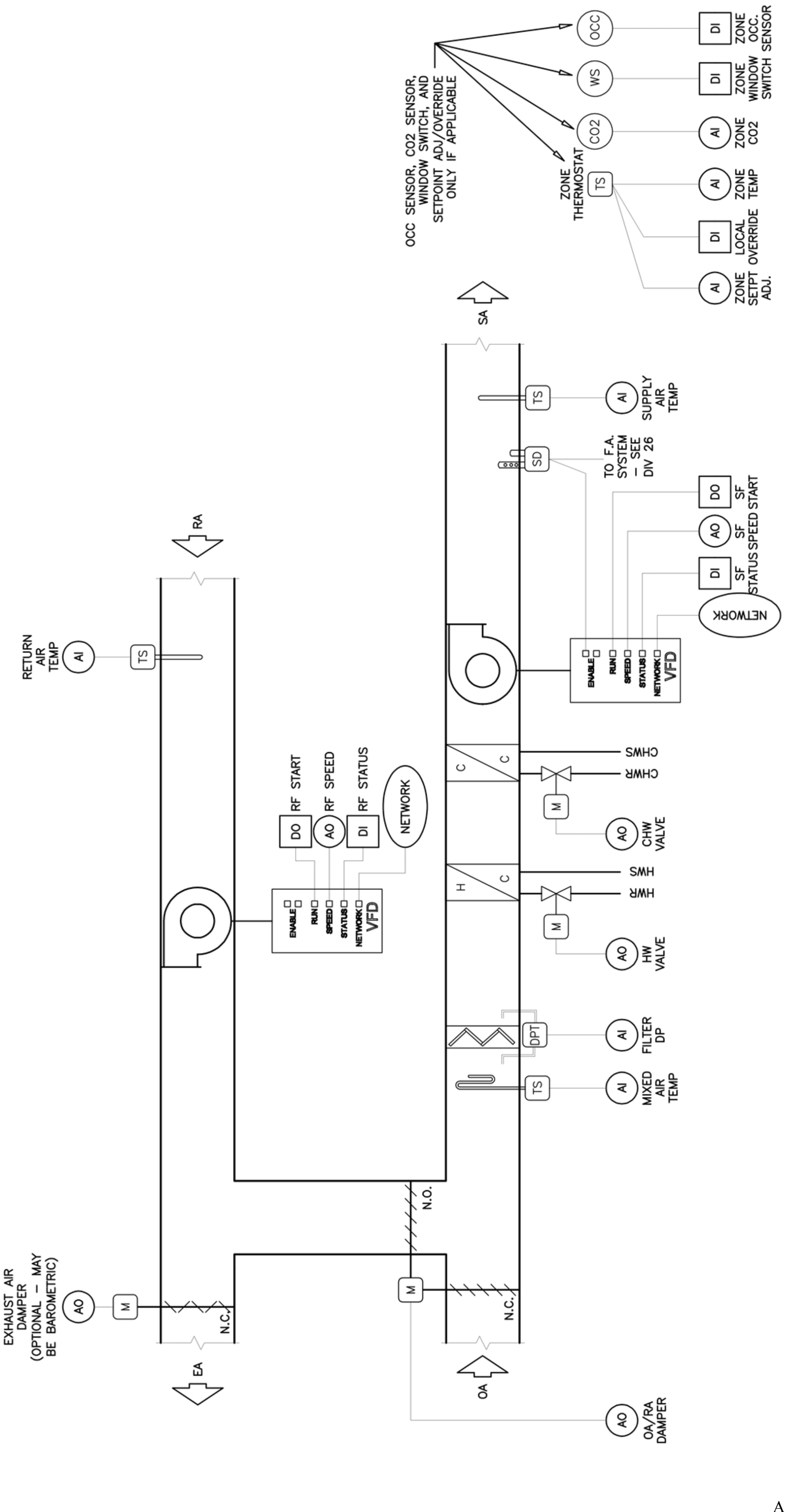

Figure A-12 SZVAV AHU (return-fan option).

(This appendix is not part of this guideline. It is merely informative and does not contain requirements necessary for conformance to the guideline.)

INFORMATIVE APPENDIX B ABBREVIATIONS AND ACRONYMS

AFDD	automatic fault detection and diagnostics
AFMS	airflow measuring station
AHU	air-handling unit
AI	analog input
AO	analog output
BAS	building automation system
BI	binary input
BO	binary output
CC	cooling coil
CCET	cooling-coil entering temperature
CCLT	cooling-coil leaving temperature
CHW	chilled water
CxA	commissioning authority
DAT	discharge air temperature
DCV	demand-controlled ventilation
DD	dual duct
DFDD	dual fan dual duct
DI	digital input
DO	digital output
DP	differential pressure
DSP	duct static pressure
DSPSP	duct static pressure set point
DX	direct expansion
ECM	electronically commutated motor
FC	fault condition
FS	fan speed
FSD	fire/smoke damper
HC	heating coil
HCET	heating-coil entering temperature
HCLT	heating -coil leaving temperature
HOA	hand-OFF-auto
HVAC	heating, ventilating, and air conditioning
HW	hot water
MA	mixed air
MAT	mixed air temperature
OA	outdoor air
OAT	outdoor air temperature
OS	operating state
PID	proportional-integral-derivative
RA	return air
RAT	return air temperature
SA	supply air
SAT	supply air temperature
SATSP	supply air temperature set point
SZ	single-zone
SZVAV	single-zone variable-air-volume
T&R	Trim & Respond
TAB	testing, adjusting, and balancing
VAV	variable-air volume
VFD	variable-frequency drive

NOTICE

INSTRUCTIONS FOR SUBMITTING A PROPOSED CHANGE TO THIS GUIDELINE UNDER CONTINUOUS MAINTENANCE

This guideline is maintained under continuous maintenance procedures by a Standing Guideline Project Committee (SGPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the guideline. SGPC consideration will be given to proposed changes within 13 months of receipt by the Senior Manager of Standards (SMOS).

Proposed changes must be submitted to the SMOS in the latest published format available from the SMOS. However, the SMOS may accept proposed changes in an earlier published format if the SM`OS concludes that the differences are immaterial to the proposed change submittal. If the SMOS concludes that a current form must be utilized, the proposer may be given up to 20 additional days to resubmit the proposed changes in the current format.

ELECTRONIC PREPARATION/SUBMISSION OF FORM FOR PROPOSING CHANGES

An electronic version of each change, which must comply with the instructions in the Notice and the Form, is the preferred form of submittal to ASHRAE Headquarters at the address shown below. The electronic format facilitates both paper-based and computer-based processing. Submittal in paper form is acceptable. The following instructions apply to change proposals submitted in electronic form.

Use the appropriate file format for your word processor and save the file in either a recent version of Microsoft Word (preferred) or another commonly used word-processing program. Please save each change proposal file with a different name (for example, “prop01.doc,” “prop02.doc,” etc.). If supplemental background documents to support changes submitted are included, it is preferred that they also be in electronic form as word-processed or scanned documents.

For files submitted attached to an e-mail, ASHRAE will accept an electronic signature (as a picture; *.tif, or *.wpg) on the change submittal form as equivalent to the signature required on the change submittal form to convey non-exclusive copyright.

Submit an e-mail containing the change proposal files to:
change.proposal@ashrae.org

Alternatively, mail paper versions to:
ASHRAE
Senior Manager of Standards
1791 Tullie Circle, NE
Atlanta, GA 30329-2305

Or fax them to:
Attn: Senior Manager of Standards
404-321-5478

The form and instructions for electronic submittal may be obtained from the Standards section of ASHRAE’s Home Page, www.ashrae.org, or by contacting a Standards Secretary via phone (404-636-8400), fax (404-321-5478), e-mail (standards.section@ashrae.org), or mail (1791 Tullie Circle, NE, Atlanta, GA 30329-2305).

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NOTE: Use a separate form for each comment. Submittals (Microsoft Word preferred) may be attached to e-mail (preferred), or submitted in paper by mail or fax to ASHRAE, Senior Manager of Standards, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. E-mail: change.proposal@ashrae.org. Fax: +1-404-321-5478.

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4. I propose to: [ ] Change to read as follows [ ] Delete and substitute as follows
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Use underscores to show material to be added (added) and strike through material to be deleted (~~deleted~~). Use additional pages if needed.

5. Proposed change:

6. Reason and substantiation:

7. Will the proposed change increase the cost of engineering or construction? If yes, provide a brief explanation as to why the increase is justified.

[ ] Check if additional pages are attached. Number of additional pages: _______

[ ] Check if attachments or referenced materials cited in this proposal accompany this proposed change. Please verify that all attachments and references are relevant, current, and clearly labeled to avoid processing and review delays. *Please list your attachments here:*

Rev. 1-7-2013

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ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted Standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the Standards and Guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive Technical Committee structure, continue to generate up-to-date Standards and Guidelines where appropriate and adopt, recommend, and promote those new and revised Standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date Standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating Standards and Guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

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