**Integrated Systems Package**

**Specifications**

**Version 1.0**

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Description automatically generated**September 21, 2021**

This resource is part of a toolkit sponsored by the U.S. Department of Energy and developed by Lawrence Berkeley National Laboratory and kW Engineering. Additional resources and information on the toolkit are available at: <https://buildings.lbl.gov/cbs/isp>.

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**Integrated Systems Package - Specifications**

This document is a draft version of template specifications for a building renovation that includes an integrated systems package (ISP) of efficiency measures. ISPs are a combination of measures that were designed to lead to substantial energy savings. The specifications document is provided to a contractor or as part of a bid package that specifies requirements of the project from an energy efficiency perspective. This template is purposely broad to accommodate a wide variety of projects. It must be tailored to your specific project. This can be mostly accomplished by deleting irrelevant sections. However, editing is required for the entire document, especially Part 1.

Part 1 Scope is an overview of the project scope. It covers what work is being done.

Part 2 Parts specifies the parts and equipment specifications for new equipment to be installed.

Part 3 Execution specifies how the installation is to occur.

Part 4 Sequences of Operations specifies the controls sequences.

This document is not intended to cover all aspects of a project in meeting code requirements. Please consult and follow all local and applicable code standards. However, the elements of this package are intended to meet or exceed energy codes, namely CA Title 24 and ASHRAE 90.1.

The HVAC sequences in this document draw heavily upon ASHRAE Guideline 36: High-Performance Sequences of Operation for HVAC Systems. Additional tables and context are provided; the Guideline should not need to be referenced.

How to Use this Document:

Colons (:) indicate where text should be added.

*Italic text* indicates text that should be changed for the specific project.

User context boxes are blue text with gray background. They provide background information for the user. They also provide instructions, such as direction to pick one of two choices. These boxes can be deleted once the background information is understood or the instructions complete. These are typically not needed by contractors/bidders.

Contractor context boxes have black text with green background. They provide guidance to the contractors as to why something is important or specified and additional information on how to go about certain tasks. For the most part, these boxes should be left in the document.

[…Delete this Section once read]

Title Page

Fill out this Title Page with appropriate project and preparer information. Or, replace it entirely with one from your organization.

*Project Name*

*Location*

Scope of Work

Version *1*

*Date*

Prepared By:

*Name*

*Company*

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1. Scope

## Related Documents

Any ancillary documents that will be provided to the general contractor should be listed in this section. These documents may include standard terms and conditions, building drawings, standard hardware requirements, environmental and sustainability requirements, etc.

## Project Information

* + 1. Project Identification:
    2. Project Location:
    3. Owner:
    4. Owner’s Representative:
    5. Preferred Vendors:

## General Project Scope

Part 1 – General Project Scope – provides a complete overview of the project. This section requires the most editing. There should be enough detail to understand the scope, but specifics on parts and components will be included in Part 2 (useful when ordering material), and details on how is should be installed are in Part 3 (references when doing the work). Part 4 covers the sequences used during installation.

* + 1. Base Scope
       1. The base scope of this project is…

Define the scope of this project in broad terms, for example:

The base scope of this project includes a full renovation of 10,000 ft² of office space to be used for a small law firm. The renovation includes 4 private offices, an open office area, and a break room.

* + 1. Energy Efficiency Scope

This section covers a broad scope of the energy efficiency components of the ISP. This section needs to be reviewed to delete sections that are not desirable or relevant.

* + - 1. Lighting and lighting controls

Describe the intended changes to the lighting and lighting control systems

* + - * 1. General
        2. Lighting: The interior lighting shall be retrofit or replaced with new dimmable LED light sources.

Pick one

The lighting layout shall be maintained as-is.

The lighting layout shall be revised to be consistent with either the new furniture plan or the reflected ceiling plan.

* + - * 1. Lighting Controls: Interior spaces shall be provisioned with lighting controls, zoned appropriately for the space layout. Individual zone control strategies and hardware shall be furnished, installed, programmed, and tested as discussed below:

General:

Lighting Functions: Lighting zones shall be wired or zoned such that general lighting is separately controlled from decorative, display, wall-washing, and task lighting.

Daylighting Controls: Each discrete area shall be provisioned with daylighting controls only when the primary daylit zone includes more than 120W of general lighting.

We’ve used the lesser of two code requirements for the 120W threshold. ASHRAE 90.1 §9.4.1.1 requires daylighting for systems 150W or greater. Title 24 2019 §130.1(d) Exception 3 exempts spaces < 120W.

The primary daylit zone is defined using the following metrics, based on the daylight source from sidelit (e.g. windows) and skylit (e.g. skylights) sources.

For the primary sidelit daylight zone, the zone extends out 1 window head height from the wall (the distance between the floor and the top of the window). Luminaires in or partially in this zone should be switched based on the daylight availability in the space. The daylit zone extends to either side of the window, up to 2 feet beyond the window. The daylit zone ignores any structural elements that block daylight if they’re less than 2-foot wide. The zone ends (either width or depth) after encountering a permanently installed barrier higher than 6 feet.

The primary skylit daylighting zone extends around a skylight or skylight well out to 70% of the floor to ceiling plane height (thus a 10-foot ceiling with square skylights would have a square skylit zone with sides measuring 7 feet on each side [14 feet total] plus the width of the skylight). The skylit zone should exclude areas shaded by floor-to-ceiling barriers.

When skylit and sidelit daylighting zones overlap, control affects luminaires by the skylit zone only.

Demand Response Controls: The following lighting functions shall be shut-off completely during a demand response event:

This document specifies that the lighting controls system has the ability to curtain lighting from a demand response trigger. Specifically, decorative lighting can be able to be turned off completely and general lighting can dim to a specified percentage. However, this does not mandate that the building participate in a Demand Response event or program.

The ability for demand Response (or demand limiting) is also built into the HVAC sequences to globally increase the zone setpoints.

Decorative lighting

Wall-washing lighting that does not interfere with path of egress minimum illuminance levels.

Display lighting

Single-occupant Offices

Manual Controls with Dimming: Each zone shall have a manual on-off/dimming switch capable of turning off, turning on, and adjusting the light output. Manual dimming controls shall be provided for each functional control group in each discrete area.

Occupancy and/or Vacancy-Sensing Controls: Each discrete area shall be provisioned with controls capable of sensing the occupancy status of the room and turning off the lighting after a programmed time interval has elapsed.

Demand Response Controls: Each discrete area shall be included in the demand responsive control sequence, shedding load as directed by the demand response interface.

Multi-occupant Offices

Manual Controls with Dimming: The zone lighting controls in each discrete zone shall have dimming controls as follows:

Pick one

Manual dimming controls laid out in a manner such that an operator of the switch can see the entire zone it controls from the switch location.

A dimming controller that allows the control start-up technician to task-tune the light output. The zone shall be provisioned only with manual-on/off light switches for occupant use.

Occupancy and/or Vacancy-Sensing Controls: Each discrete area shall be provisioned with controls capable of sensing the occupancy status of the area (or zone) and either turning off the lighting or dimming the lighting after a programmed time interval has elapsed.

Selecting your occupancy sensor behavior in multi-occupant offices depends on user preferences. Using the concept of ‘differential scheduling’, open offices could have a different “business hours” versus “after-hours” behavior.

In open offices, due the desire to keep the space uniform and appear “open of business”, a user may decide that open-office areas will operate the lighting system at the design light-levels where a space is occupied and dim unoccupied areas by 50%.After-hours, when no-one is present, the user may decide to allow unoccupied areas to shut-off completely. Or they may allow the zones immediately surrounding any occupied area to dim to 50%, while zones further away shut off completely.

Demand Response Controls: Each discrete area shall be included in the demand responsive control sequence, shedding load as directed by the DR interface.

Break Rooms

Manual Controls with Dimming: Each zone shall have a manual on-off/dimming switch capable of turning off, turning on, and adjusting the light output. Manual dimming controls shall be provided for each functional control group in each discrete area.

Occupancy and/or Vacancy-Sensing Controls: Each discrete area shall be provisioned with controls capable of sensing the occupancy status of the room and turning off the lighting after a programmed time interval has elapsed. The vacancy sensing controls shall be configured to shut off undercabinet lighting.

Demand Response Controls: Each discrete area shall be included in the demand responsive control sequence, shedding load as directed by the DR interface.

Conference Rooms

Manual Controls with Dimming: Each zone shall have a manual on-off/dimming switch capable of turning off, turning on, and adjusting the light output. Manual dimming controls shall be provided for each functional control group in each discrete area.

Pick one

Dimmers shall be permanently labeled describing the function of each switch in the zone.

A scene selector shall be provided with a labeled display indicating discrete operating modes (presentation, video, general, etc.).

Occupancy and/or Vacancy-Sensing Controls: Each discrete area shall be provisioned with controls capable of sensing the occupancy status of the room and turning off the lighting after a programmed time interval has elapsed.

Demand Response Controls: Each discrete area shall be included in the demand responsive control sequence, shedding load as directed by the DR interface.

Lobbies

Manual Controls with Dimming: Manual dimming controls shall be provided for each lobby area, as discussed below:

Building lobbies shall have dimming controls located in a secure location where they cannot be accessed by the general public.

Suite lobbies shall have the dimming controls located near the entrance to the suite.

Automatic Shut-Off Controls:

Building lobbies shall have a lighting control that allows the building operator to schedule the on and off time based on the time of day and day of week.

Suite lobbies shall be provisioned with controls capable of sensing the occupancy status of the room and turning off the lighting after a programmed time interval has elapsed.

Demand Response Controls: Each discrete area shall be included in the demand responsive control sequence, shedding load as directed by the DR interface.

Restrooms

Manual Controls are shall be installed only in single-occupant restrooms.

Occupancy Sensing Controls: Each area shall be provisioned with controls capable of sensing the occupancy status of the room and turning off the lighting after a programmed time interval has elapsed.

Demand Response Controls: None

* + - 1. Plug loads and plug load controls

Describe the intended changes to the plug loads and plug load control system

* + - * 1. Plug load controls shall be provided in private offices, conference rooms, rooms primarily used for printing and/or copying functions, break rooms, classrooms, and individual workstations (e.g. cubicles). The plug load controls shall control 50% of the receptacles in the space and no uncontrolled receptacle shall be more than 6 feet from a controlled receptacle. Controlled plugs shall be clearly and permanently marked or labeled. (See Section 3.6 A. 1)

For the next two topic areas, please review whether single-zone systems or multi-zone systems are used in this project. If one system type is not present, remove. If both system types are present, leave them in.

* + - 1. Single-Zone HVAC controls

Describe the intended changes to the HVAC control system

* + - * 1. Demolish the existing thermostat controller. Furnish and install a new networked thermostat. The networked thermostats shall provide remote setpoint and scheduling management.
        2. For buildings with a BMS, provide best-in-class airside sequences of operations, including the following:

Variable speed fan control

Economizer control

Supply air temperature control

Fault detection

* + - * 1. For buildings that do not have a BMS (typically this applies to single zone units):

Demolish the existing economizer controller, if feasible; otherwise abandon-in-place. Furnish and install an advanced diagnostic economizer controller (ADEC).

* + - 1. Multi-zone VAV Terminal Unit HVAC Controls

Review and select the appropriate options below, based on your multi-zone scope of work

* + - * 1. Demolish each existing pneumatic terminal unit controller. Furnish and install a new direct digital control (DDC) terminal unit controller.

Each pneumatic valve and damper actuators shall be replaced with a proportional electric actuator.

The existing flow measurement equipment (e.g. flow crosses or hot-wire anemometers) shall be retained unless shown to be beyond repair.

The existing hot water reheat valve bodies shall be retained, unless shown to be leaky or beyond repair.

* + - * 1. Demolish each existing pneumatic thermostat. Furnish and install a new DDC thermostat for each terminal unit controller.

Thermostats in conference rooms, auditoria, meeting rooms, classrooms, training rooms, and other assembly-type spaces shall include CO2 controls either integral to the thermostat or as a discrete sensor tied to the VAV box.

* + - * 1. The contractor shall be responsible for determining and programming the airflow setpoints for each zone.

Section 4.5 lists the known VAV box design variables to be used in this task. These values are listed below:

Terminal unit number

Zone name or number (often this the area name or room number)

Area served (size of zone area is s.f.)

Space type (e.g. private office, open office, break room, etc.)

Expected zone population (From mechanical code, fire code, or other sources. More detail provided in Section 4.5)

Maximum terminal unit cooling airflow (specification from terminal box)

Minimum terminal unit controllable airflow (specification from terminal box and controller)

Maximum terminal unit heating airflow (specification from terminal box and reheat coil specifications), if applicable.

Airflow setpoints shall be determined using applicable code. Setpoints and sequences are detailed in Sections 4.5 and 4.8 of this document.

For projects complying with ASHRAE 62.1 ventilation requirements, see Section 4.5 A. 2. a. and Section 4.8 A. 3.

For compliance with California Title 24 ventilation requirements, see Section 4.5 A. 2. b and Section 4.8 A. 4

If the minimum controllable airflow is greater than 30% of the maximum cooling for 5 or more terminal units, then the contractor shall be responsible for field testing the minimum controllable airflow setpoints.

Greater than 30% was selected as an arbitrary threshold that represents terminal unit setpoints designed with an older rule of thumb. Terminal unit boxes with higher minimums are likely either old boxes and controllers or have been specified with conservative design parameters. Research has shown that most controllers has handle lower airflows than those stated by manufacturers, so these boxes can probably handle lower minimum airflows.

With higher than 30% minimums, occupants may notice the on/off cycling of the airflow more than with lower percentages, so reducing these may improve comfort.

For terminal units with lower than 30% minimums, the time-averaged ventilation (TAV) sequence of operations in this document, specified in Section 4.8B, reduces the need for lower controllable minimums because the terminal unit damper will alternate between closed and open positions to achieve a low flow setpoint. So, lower minimums are not explicitly needed (but could still reduce the airflow changes that occupants could notice).

Thus, we recommend re-tuning the controllable minimum when is it above 30%, but the owner could choose to alter this threshold and/or scope.

A procedure for field testing the VAV box controllable minimum is provided in Section 4.7O.5.c.i of this document.

* + - * 1. The contractor shall be responsible for programming trim and respond sequences that leverage the DDC data and shall revise the associated air handler sequences to reset the supply air temperature and the duct static pressure. Full sequences of operation are detailed in Part 4 of this document. These sequences include the following:

Optimum Start Sequences

Trim & Respond Resets

Duct Static Pressure Reset

Supply Air Temperature Reset

Economizer control, including:

Dynamic minimum outside air damper position for DCV control

Building pressurization control

* + - 1. HVAC systems and equipment

Describe the intended changes to the HVAC systems and equipment scope here.

* + - * 1. New RTUs.

This specification provides minimum equipment efficiency specs.

* + - * 1. New Heat Pumps (likely only for data closets)

New Air-Source or Water-Source Heat Pumps

Air-source heat pumps could be used for cooling data closets. Water-source heat pump may be used if there is already a 24/7 cooling source provided (this is rare but could be present in large facilities). This package does not cover heat pumps as means of space comfort conditioning (i.e. HVAC system with heat pumps).

* + - * 1. High Capacity Air Filters

Air handlers use air filter to remove particulates from the air stream. This reduces the amount of dirt left on heat transfer surfaces inside the air handler (e.g. the chilled water or DX coil) and reduces the amount of dirt brought into the building. Air filters have an energy cost associated with their use, as they create a pressure differential that the fan must work against. High capacity filters can save energy due to their greater surface area, resulting in less pressure drop, provided they’re replaced at the same interval as the existing filters.

* + - 1. Energy meters
         1. Building-Level Meters

The energy dashboard for this building shall incorporate build-level energy consumption data using one of the following approaches:

Existing Meter Integration: The information from the existing utility or campus electricity, natural gas, steam, hot water, and chilled water meters serving this building shall be integrated into the energy dashboard.

Redundant Meter: Where the existing meter cannot be integrated or no meter exists, a redundant meter shall be installed to measure the incoming electricity, natural gas, steam, hot water, and chilled water services serving the building.

Describe the intended changes to the energy meters. One of the core requirements of ISPs is that each energy type to a building/space is metered. For example, electricity and natural gas to the building. If heating hot water (or steam) or chilled water are provided to a building from a district plant, these should be metered with a Btu meter.

* + - * 1. New sub-meters

Submetering can be very useful for monitoring more granular loads (i.e. floor or equipment) or loads from a different use type (i.e. restaurant or data closet).

Data closets/server loads larger than 70 kW are recommended to have electrical submetering on the IT load and the cooling system. These are large enough to require a design consultant so they should be independently metered.

Restaurants, gas and electric sub-meters. These loads are drastically different than for offices, so they should be sub-metered.

It is best to have sub-metering at a reasonable granular level. We recommend sub-metering major equipment and tenant or floor if possible. Examples: each air handler, floor lighting and plug load, central plant, etc.

* + - 1. Envelope Modifications
         1. Window Film

Window film shall be installed on the following window aspects:

Criteria for window film is provided in Section 2.4 and Section 3.7.

* + - * 1. Cool Roofs

Cool roof coating shall be installed on the entire roof surface.

Describe size and details on roof surface. Note any HVAC work that will be done on the roof. Is roof flat or sloped?

Criteria for cool roof is provided in Section Cool Roofs2.5 and Section 3.8.

* + - * 1. Windows or Window Inserts

The following changes should be made to windows:

New windows can offer both improved insulating properties against extreme outdoor air temperatures and reduce radiative heat gains and losses, especially when compared against single-pane, aluminum-frame windows. New windows can also reduce some types of glare (leading to visual discomfort), reduce comfort complaints from window-adjacent zones.

This document does not provide window specifications, as the needs and specific concerns of building owners and operators often will dictate what window options are viable in any given building. We recommend working with an architect or building envelope specialist to determine the best replacement and/or retrofit options. Local energy code will provide the minimum requirements; although we recommend using Energy Star rated products.

There are three options for window replacements in buildings:

Option 1 - Replacement Windows: Installing new windows in existing buildings can dramatically alter the look of a building and offers exceptional energy performance. The drawback with replacement windows is the cost and extent of envelope modifications required to accommodate the new windows.

Option 2 – Refabricated Windows: Some structures have windows that have a compelling appearance or characteristic that makes them difficult to replace. In this case, refabricating the windows may be an option. A specialty manufacturer/contractor will remove the window frames and/or other useful components from the existing windows and improve the window properties with new window subassemblies, seals, and other components. Refabricated windows do not necessarily have a substantial cost advantage over new windows; however, each case is unique.

Option 3 – Retrofit Window Inserts: Also marketed as secondary glazing systems or fixed window panels, these products install directly into the inside of the existing frame. The advantage is that most of the thermal and comfort advantages of new windows are realized but at a fraction of the cost and down-time. However, window inserts create a potential problem of moisture control in the insulated air space between the old window glass and the new insert glass.

Since the air gap spaces are neither hermetically sealed nor desiccated, they are considered unsealed and moisture can travel from either the room or the exterior. This moisture will condense when the surface temperature of a window component drops below the dew point or frost point of the air adjacent to the surface. Excessive condensation can contribute to the growth of mold in frames or wall cavities. Thus, for window insert products, it is especially important to follow all manufacturer recommendations.

* + - * 1. Other

Describe the intended changes to the envelope. Envelope modifications, aside from window films and cool roofs, are not addressed as part of the ISP, but you may have them anyway as part of your project. Put in any relevant envelope measures.

* + - 1. Ceiling Fans
         1. Install ceiling fans in the following areas:

Describe scope of ceiling fans

* + - * 1. Ceiling fans controls specify a setpoint adjustment when operational. See Section 4.9 B. 9.
      1. Automated Interior Shades
         1. Install automated interior shades on the following window areas:

Scope of interior shade retrofits.

* + - * 1. Criteria for automated interior shades is provided in Section 2.7Cool Roofs, Section 3.10, and Section 4.4.
      1. HVAC Controls
         1. The current building management system (BMS) is the following:

Provide specification on existing (or new) BMS for integration and compatibility.

* + - * 1. HVAC controls sequences are specified in Part 4 of this document. The sequences are heavily based on ASHRAE Guideline 36 which utilizes trim and respond programming.
        2. All multi-zone VAV terminal boxes that are DDC shall be re-programmed to the provided sequences.

1. Parts

## General

Add general parts and material requirements, add them here. E.g. sustainable purchasing, specific vendors, etc.

## Lighting and Lighting Controls

* + 1. LED Luminaires
       1. General

These general requirements apply to all LED luminaires. These requirements should be met by many vendors.

* + - * 1. The products shall comply with the requirements of the following safety standards:

NFPA 70, National Electric Code.

UL 8750, Standard for Light Emitting Diode (LED) Equipment for Use in Lighting Products.

UL 1598, Standard for Luminaires in non-hazardous locations less than <600V

* + - * 1. The fixtures shall be fully dimmable.

The luminaire dimming protocol shall be coordinated with the lighting control system.

The fixtures shall be tested in accordance with IES LM-79 and IES LM-80.

Correlated color temperature describes the apparent color of light emitted by the light source. Color temperature is often a sensitive issue for occupants. Standard LED color temperature are as follows: 3,000K; 3,500K; 4,000K; and 5,000K. Most lighting designers will default to 3,500K given no stated preference. If matching existing lighting, this should be the same CCT.

* + - * 1. The fixtures shall have a correlated color temperature (CCT) of 3,000K.
        2. The fixtures shall have a correlated color temperature (CCT) of 3,500K.
        3. The fixtures shall have a correlated color temperature (CCT) of 4,000K.
        4. The fixtures shall have a correlated color temperature (CCT) of 5,000K.
        5. The fixtures shall have a minimum color rendering index (CRI) of 80.

Color rendering index reflects the ability of a light source to provide light of sufficient quality that colors appear normal to the human eye. Light sources with a minimum CRI of 80 are widely available for interior applications. LED light sources with a CRI above 90 are not as widely available and tend to use somewhat more energy to deliver the same quantity of light.

* + - * 1. The driver for each LED luminaire shall have:

A power factor of ≥ 0.90.

A total harmonic distortion of ≤ 20%.

* + - * 1. Luminaires life shall be rated in accordance with IES TM-21 based on the test data collected during LM-80 testing. The luminaires shall have extrapolated lumen maintenance as follows:

Lumen life (or maintenance) describes the gradual reduction in light output by the LED engine inside a luminaire. The requirements listed in the specification are achievable using current high-quality LED lighting technologies.

At 36,000 hours of operation, total luminous flux shall be ≥80% of initial lumens

At 50,000 hours of operation, total luminous flux shall be ≥70% of initial lumens

If your facility has very long operating hours or some of the luminaires will be particularly difficult to replace, delete the language above in favor of the better lumen maintenance requirements below.

At 36,000 hours of operation, the total luminous flux shall be ≥90% of initial lumens

At 50,000 hours of operation, the total luminous flux shall be ≥80% of initial lumens

* + - 1. Luminaire Efficiency

For the following individual luminaire types, we’ve only specified the minimum luminaire efficiency; the general requirements listed above still apply. Depending on site specific details, you may wish to add additional details (e.g. air return troffers; luminaire appearance, distribution patterns, cut-off angles, etc.). You may also wish to provide an example manufacturer and model number that gives your contractor an idea of what you’re looking for.

Minimum efficacy specifications from DLC premium technical requirement v4.4

* + - * 1. Type A – Troffers (Including 2x2, 1x4, and 2x4 interior ambient lighting luminaires)

The fixtures shall have a minimum efficacy (lumens/watt) of 125.

* + - * 1. Type B – Downlights

The fixtures shall have a minimum efficacy (lumens/watt) of 90.

* + - * 1. Type C – Pendant

The fixtures shall have a minimum efficacy (lumens/watt) of 130.

* + 1. Lighting Control System
       1. Network Requirements
          1. The lighting control system shall network occupancy sensors, manual controls and daylighting control devices on a single network platform.

Individually addressable luminaire control is optional.

Individually addressable luminaire control is required.

* + - * 1. The lighting control system shall support a standards-based data exchange protocol that allows the system to relay occupancy status to other building control systems (e.g. BACnet).
        2. Hosting requirements

When selecting hosting details, you need to consider which approach best suits your building, staffing, and risk tolerance. There are two main hosting options widely available:

On-site hosting solutions involve installing a local server. This server is either a physical, stand-alone piece of equipment or, increasingly, these servers are installed on a “virtual machine” hosted on a server already on-site. The server ultimately becomes the responsibility of the customer’s IT department, meaning administering patches to the operating system and support software (MySQL, Java, etc.) will be reliant on-site staff or contractors and may increase overhead costs. The benefit of a locally hosted control system is that all the software is hosted locally, behind your firewall and is not subject to the manufacturer’s on-going operation of their servers.

Cloud hosting solutions relay the system status of individual devices to the Internet. In order for the system status to be viewed, the Internet connection must be active on the host site. The systems offer lower IT administration requirements, since the software is all maintained on a remote server; however, should the control company suffer an outage (or worst-case scenario, go out of business), access to the facility software may be lost. Depending on your internal security requirements, cloud hosting may not be secure enough for every building and/or application.

The lighting control system server shall be hosted on a local server.

The server shall be a stand-alone physical sever.

The server shall be a virtualized and hosted on a shared server.

The lighting control system server shall be hosted in the cloud. The server shall support https encryption using AES 128-bit or equal.

* + - 1. System Capabilities
         1. Interface

The lighting control system shall have a graphic front end that can display room (or zone) occupancy and lighting system status (on/off) for each room (or zone).

The lighting control system shall support a tabular view of the lighting control system, listing lighting zone details, including: occupancy status, lighting system status, task tuning percentage, daylighting status, manual dimming status, and zone power.

* + - * 1. Scheduling

The lighting control system shall be capable of scheduling system on and off using a standard clock and an astronomic clock function.

Standard scheduling uses the time of day and day of week to schedule the system on and/or off.

Astronomic scheduling factors in the facility’s location (i.e. latitude) to set on/off times relative to sunrise and sunset. Thus, a system could be told to turn the lights off at dawn + 30 minutes and turn the lights on at dusk – 30 minutes

The system shall support advanced scheduling of standard United States Federal holidays and user-defined holidays no less than 12 months into the future.

Holiday scheduling capabilities are required by modern energy codes and are included in these requirements. There are two types of holidays one might wish to program in.

The first sets of holidays are routine events that reoccur (like the 4th of July or Thanksgiving). These holidays are ones that you might tick-off once and want to repopulate every year.

The other holidays are days that occur sporadically. Perhaps a tenant has a seasonal shutdown every year starting sometime in December and ending sometime in January. Each year, you’ll need to define that shutdown period.

Each scheduled event shall be capable of adjusting the following: on/off behavior, dimming behavior, and occupancy sensor dwell (i.e. time-out).

Conventional scheduling controls define on/off states for equipment. Newer control systems provide the opportunity to adjust how control equipment operates based on the time of day.

For example, at night, when the janitorial staff is emptying waste-paper baskets and vacuuming carpets, there is no need for a 30-minute occupancy sensor dwell. Similarly, cleaning tasks may not require high illuminance levels, thus, afterhours you could adjust the default-lighting system brightness to be 50% the brightness used during the day.

* + - * 1. Task Tuning

Task tuning is a control strategy whereby the system maximum output is limited using software and thus saves energy. This strategy is useful on two levels:

Most lighting systems are designed to produce extra light output initially, planning for the system output to depreciate over time, using light loss factors. Task tuning allows the system to be dimmed initially and can then be raised over time as depreciation occurs.

Task tuning also allows a facility to standardize on one or two standard luminaire model numbers and adjust the light output in areas where the nominal luminaire output is not required.

The lighting control system shall have the ability to reduce the maximum output of the lighting system that cannot be overridden by zone-level control devices. The system shall support limiting the output at the zone level and/or individual luminaire level.

* + - * 1. Demand Responsive Controls

The lighting control system shall support receiving a standards-based signal from either a demand response server (e.g. Open ADR 2.0) or from another building system capable of receiving a demand response server signal.

If the host customer is enrolled in a demand response program that receives signals from some other control signal (land-line, cell-phone), the system shall additionally be capable of receiving this signal.

* + 1. Lighting Control Devices
       1. Occupancy and Vacancy Sensors

Occupancy and vacancy sensors, regardless of where they’re applied in this document must meet the requirements in this section.

Most modern sensors can be configured for either vacancy or occupancy detection. Vacancy detection requires fixtures to be turned on manually and the sensor will automatically turn them off. Occupancy sensors turn fixtures on and off.

* + - * 1. General Requirements

The sensors shall have an adjustable sensitivity setting

The area coverage for each sensor shall be appropriate for the installation location and the installation application (based on documented product literature).

Each sensor shall have an indicator LED that blinks when occupancy is detected.

Each sensor shall be interchangeably configurable for occupancy-detection or vacancy detection. Sensors installed on the lighting control system network shall be configurable in this manner via the network software interface.

The sensor shall be capable of being programed with a minimum dwell time of 5 mins and a maximum dwell time of 30 mins.

* + - * 1. Sensor Detection Technologies

Ultrasonic Occupancy Sensors

Ceiling mount ultrasonic sensors shall be capable of detecting occupancy when installed at a height of 8 to 12 feet.

Typical application for this type of occupancy sensors include – Small offices with obstructions, restrooms, open office spaces, enclosed hallways and stairwells.

Passive Infrared (PIR) Occupancy Sensors

For low bay ceilings, the occupancy sensors shall be capable of detecting occupancy when installed at a height of 8 to 12 feet.

For high bay ceilings, the occupancy sensors shall be capable of detecting occupancy when installed at a height of 12 to 35 feet.

PIR occupancy sensors are not acceptable in locations where its line of sight will be obstructed.

Typical applications for this type of occupancy sensors include – Gyms, high-bay storage spaces, maintenance areas, library aisles.

Dual-Technology (DT) Occupancy Sensors

DT sensors shall have a combination ultrasonic and PIR detection technologies to detect motion. No other occupant detection technologies are acceptable (e.g. acoustic) for DT sensors. Occupancy sensors integrating hold-off photocell or other daylighting controls are not acceptable DT sensors unless they provide both ultrasonic and passive infrared detection.

Each sensing technology (US and PIR) shall have an independently adjustable sensitivity.

The sensors shall be capable of bypassing either US or PIR motion detection.

This type of occupancy sensor should be installed in small offices, classrooms, conference rooms, and cafeterias.

* + - 1. Daylighting Sensors
         1. Open Loop

The sensor shall be capable of operating in the daylight range of at least 1 to 6,000 footcandles (fc).

The sensor shall automatically establish application-specific setpoint following manual calibration.

For switching operation, an adequate deadband between the ON and OFF setpoints for each zone shall prevent the lights from cycling; for dimming operation, a proportional control algorithm shall maintain the design lighting level in each zone.

* + - * 1. Closed Loop

An internal photodiode shall measure light in a 60 to 90-degree angle, cutting off the unwanted light from bright sources outside of this cone.

Automatically establishes application-specific setpoints following self-calibration. For switching operation, an adequate deadband between the ON and OFF setpoints shall prevent the lights from cycling; for dimming operation a sliding setpoint control algorithm with separate Day and Night setpoints shall prevent abrupt ramping of loads.

* + - * 1. Hybrid Sensors

Generally, these are only applicable for retail areas with skylights. Included here for general reference. This section likely to be deleted.

The sensor shall be capable of operating in the daylight range of 1 to 10,000 footcandles (fc).

The sensor shall automatically establish application-specific setpoint following manual calibration.

For switching operation, an adequate deadband between the ON and OFF setpoints for each zone shall prevent the lights from cycling; for dimming operation, a proportional control algorithm shall maintain the design lighting level in each zone.

* + - 1. Manual Control Devices
         1. General

Must use low voltage power.

* + - * 1. On/Off Switch

Buttons shall be permanently labelled, and labels shall resist mild detergent and wear.

* + - * 1. Dimmer Switch

Dimmer switches shall allow occupants to manipulate the light output between the task tuned light output and the minimum provided by the LED driver.

Dimmer switches shall be capable of turning off the controlled lighting load completely, whether using a slider, a switch, or soft-programmed buttons.

* + - * 1. Overrides Switches

Override switches shall have a programmable override duration no greater than 2 hours.

## Plug Loads and Plug Load Controls

* + 1. The plug load control system shall use one of the following approaches to turn off the plug loads.
       1. Schedule-based controls shall use a time-of-day scheduling device to turn receptacles off at specific programmed times. The scheduling device shall be accompanied by an override switch; override switches shall have a programmable override duration no greater than 2 hours.
       2. An occupancy-based control device shall use a signal from the lighting control occupancy sensor in the space to determine when the space is unoccupied and turn off the receptacles. The delay-to-off should be no more than 20 minutes.

Plug-load control systems that rely on independent occupancy sensors require additional maintenance, configuration, and functional testing. If possible, sharing the lighting occupancy sensor reduces the number of devices in the space and provides cleaner, neater appearance.

* + - * 1. Alternatively, if the plug-load system has its own occupancy sensor, this occupancy sensor may be used.

A hardwired power strip controlled by an occupant sensing control may alternately be used. We do not recommend plug-in strips or other plug-in devices since these can be easily unplugged (These plug-in devices are not allowed for code compliance, per CA Title 24).

* + - 1. Another control system shall send an automated signal that shall turn-off receptacles within 20 minutes after determining all occupants have left the space.

We recommend a 20-minute maximum delay. Title 24 (for CA) does not set a limit, while ASHRAE 90.1 limits the delay to 20 minutes.

* + 1. Controlled Receptacles
       1. Split-wired receptacles (with one half of the outlets powered all the time and one half switched by schedule or sensors) are acceptable, provided they meet the other requirements in this section.

## Window Film

Window films can improve comfort and save energy. In the summer they block some radiant heat into the building. During winter they improve conductive insulation.

Solar heat gain coefficient (SHGC) is the fraction of solar heat transmitted through a window via radiative heat transfer. A lower SHGC allows less heat-carrying radiation to pass through the glazing. A low SHGC may also result in lower visible transmittance (VT). VT is the ratio of visible light that can pass through the window.

A window film with low VT might alter the appearance of the building from outside. If a window film has a high SHGC, it might not act as an effective barrier against outside heat during summer realizing lower energy benefit. The window film specification below is the middle of the road option that balances exterior appearance of the building while realizing good energy benefits.

Installing window films on the south facing windows is most beneficial.

Installing window film might reduce summer cooling load on the HVAC equipment. We recommend adjusting the VAV cooling minimums to avoid over-cooling during summer. In addition, please refer to the time-average ventilation section to modify sequences for VAV boxes post-implementation.

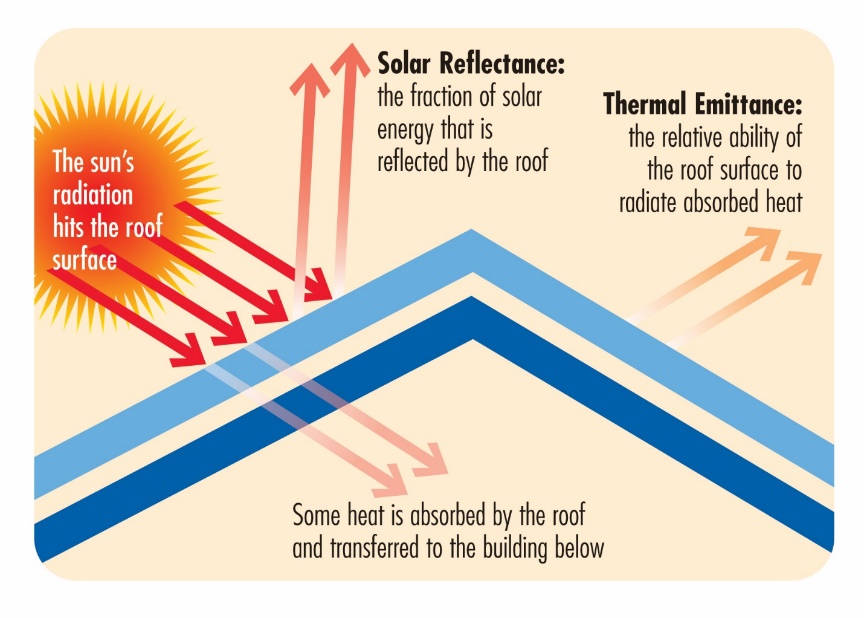
* + 1. Performance Requirements (Typical for applying to single pane, ¼” clear glass)
       1. Solar control films with UV absorbing materials that limit weighted UV transmission to one percent or less when measured according to ASTM E903.
       2. Solar control films shall not have masking sheet.
       3. Solar control films shall have a neutral color.
       4. Solar control films shall have a light-to-solar heat gain ratio of at least 1.0.
       5. Solar film shall have a visible light transmittance of 28% or more.
       6. Solar film shall have ultraviolet ray protection greater that 99%.
       7. The film shall have a solar heat gain coefficient (SHGC) of 0.28 or less.
       8. The film shall have a winter U-value of 0.72 or less.
       9. The solar film adhesive shall be water activated, dry adhesive system that forms a molecular bond between the film and the glass.

## Cool Roofs

Cool roofs are designed to reduce heat absorption by reflecting sunlight and emitting the sun’s thermal energy from the roof surface. This is achieved by using roofing materials that are white or very light in color and/or contain reflective materials. Roofs are the main source of heat entry into a building, so there is large opportunity for energy savings by installing a cool roof, especially in warmer climates.

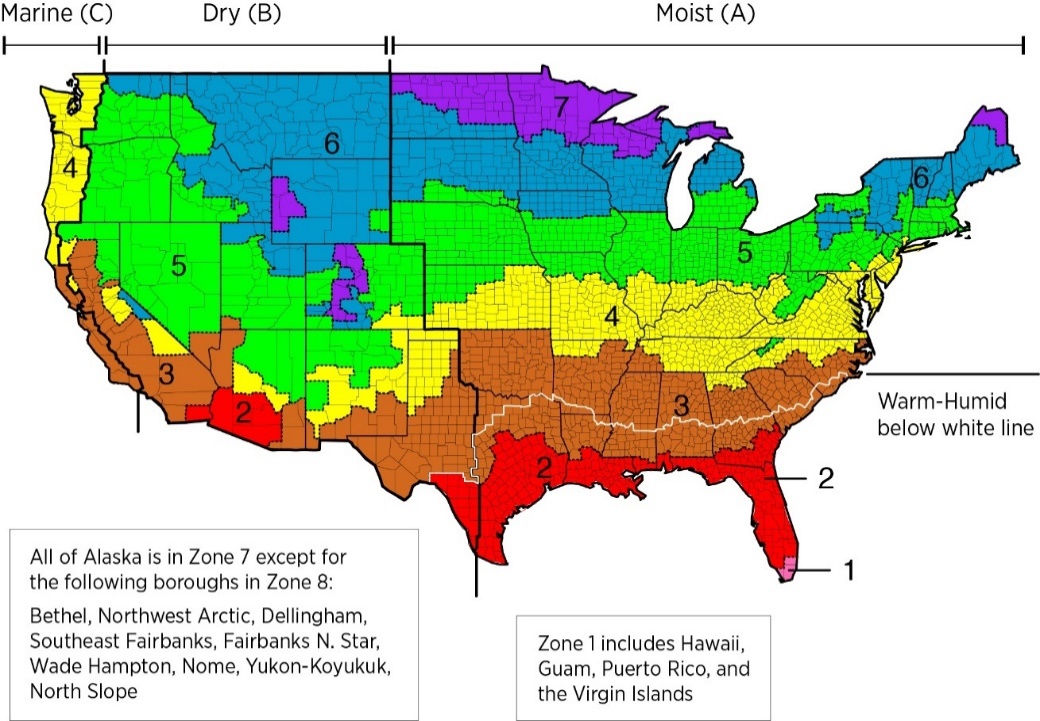
The primary advantage of cool roofs is to reduce the building’s heat gains during warm days, which decreases cooling energy requirements. This improved occupant comfort, reduced load on cooling equipment, and reduces urban heat island effect.

A cool roof’s performance is measured by its solar reflectance and thermal emittance. Solar reflectance is the fraction of sunlight and heat that is reflected by the roof surface. Thermal emittance is the fraction of thermal energy that is released from the roof surface. These two properties work in tandem in a cool roof to reduce the heat absorbed from the sun, and then expel the heat that is absorbed rather than holding it in the roof surface.

Source: coolroof.org

Solar Reflectance Index (SRI) incorporates solar reflectance and thermal emittance into one value to assess the effectiveness of a cool roof. It is measured on scale of 0-100, 100 being the most effective cool roof.

Cool roofs are recommended for ASHRAE Climate zones 1-3 and all of California (required).



For ASHRAE climate zones 3-7, we recommend using the Cool Roof Calculator, developed by the U.S. Department of Energy’s Oak Ridge National Laboratory, to estimate cooling and heating savings (or penalty) for different roof types.

<https://web.ornl.gov/sci/buildings/tools/cool-roof/>

The energy savings realized from cool roofs range from 7-15% of total cooling costs (as high as 50 cents per square foot). Payback periods can be as low as six years. However, retrofitting a conventional roof that is in good condition with a cool roof product can be expensive in the upfront installation costs.

Cool roofs are generally very affordable and don’t always cost more than a conventional roof, with cost premiums ranging from zero to 10 cents per square foot for most products, or 10 to 20 cents per square foot for some built-up products. Costs vary on the size, climate, and roof accessibility. The

Cool roof coatings can be applied to new or existing roofs. New roofs can be pre-coated at the factory and installed no differently than non-cool roofs. Existing roofs can have the coating painted or sprayed over the current roof surface. Coatings may cost $0.75-$1.50 per square foot.

Cool roof membranes are typically used for new roofs or roof replacements and installed the same way as non-cool roof membranes are installed. Existing non-cool membranes to be retrofitted usually have a cool roof coating applied over them. Membranes may cost $1.50-$3.00 per square foot.

* + 1. Minimum Radiative Properties

These minimum radiative requirements are based on CA Title 24. (Energy Standards Table 140.3-B, 2019)

These exceed ASHRAE requirements; ASHRAE 90.1 requires Climate Zones 1-3 roofs to have an aged reflectance 0.55 and emittance of 0.75. (Or 3-year aged SRI of 64).

LEED requires products with an initial SRI of 82. (higher than the minimums here).

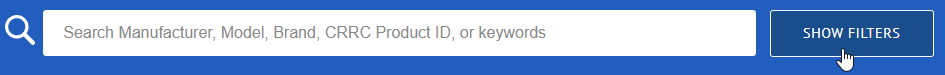
* + - 1. Low sloped roofs (pitch of less than 9.5°)
         1. Three-year aged reflectance of 0.63 or greater.

Aged reflectance represents the solar reflectance of a roofing product after three years of weathering due to climate conditions.

* + - * 1. Emittance of 0.75 or greater.
        2. Solar reflectance index (SRI) of 75 or greater.
      1. Steep-sloped roofs (pitch greater than 9.5°)
         1. Three-year aged reflectance of 0.2 or greater.
         2. Emittance of 0.75 or greater.
         3. Solar reflectance index (SRI) of 16 or greater.
    1. General
       1. Cool Roof product must be certified by the Cool Roof Rating Council (CRRC).

The Cool Roof Rating Council (CRRC) is the governing body on evaluating and certifying cool roof products. A certified cool product directory can be found on their website:

<https://coolroofs.org/directory/results>



Hint: Be sure to click the ‘Show filters’ button to enter the minimum radiative properties.

## Ceiling Fans

Ceiling fans do not cool air; rather, they help cool human skin by enhancing evaporation and convective heat transfer through increase air movement in the space. Ceiling fans can increase thermal comfort during cooling periods as a result. Energy savings occurs when HVAC space setpoints are raised at the same time that ceiling fans are operational; the additional energy use of the fans is significantly less than the savings realized by the reduced mechanical cooling load, and occupants will feel a similar level of comfort. We recommend that ceiling fans only be installed with cooling setpoint adjustments of at least 4 °F (e.g. from 74 °F to 78 °F).

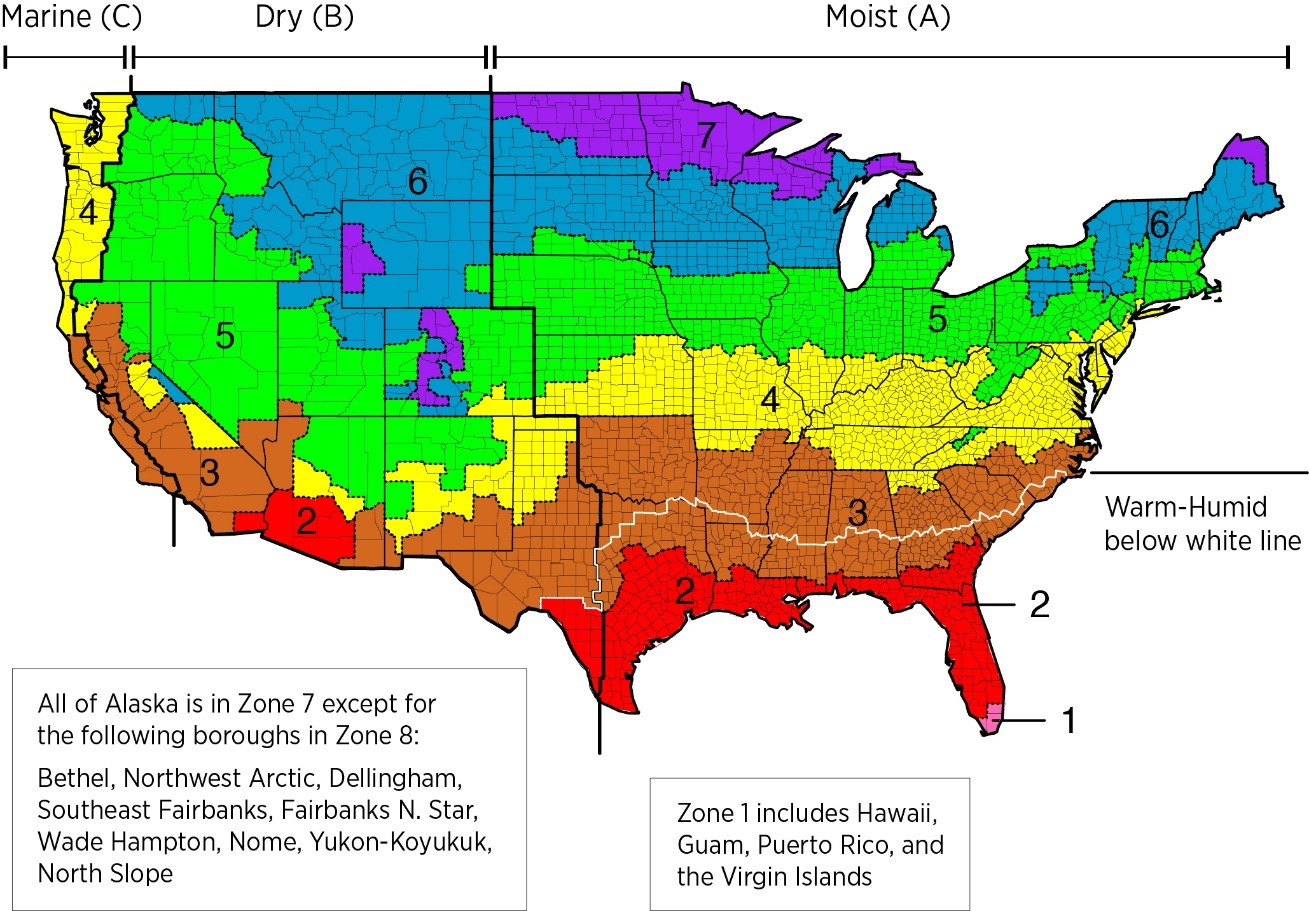
When heating, ceiling fans may provide benefits primarily by mixing stratified air.

Energy simulation studies have shown building energy savings of 4% to 11% for raising the cooling setpoint 4 °F. Projects typically have a 10 year or less payback when installation costs are $1.50/ft2 or less. See below for rough cost/savings estimates.



Data from: Kiatreungwattana, K, et. Al., GSA Green Proving Ground Smart Ceiling Fan – White Paper, GSA, NREL, 2016

Climate Zones



* + 1. Prerequisites for Installation
       1. Ceilings at least 9 ft high.
       2. Open office partition height of 54 inches or less.
       3. Lighting layout does not interfere with ceiling fan locations.
       4. Occupancy sensors must be mounted so they detect motion below the ceiling fan. (And are not triggered by the motion of the fan.)
    2. General - Energy Star Qualified
       1. Fan airflow efficiency

|  |  |  |
| --- | --- | --- |
| Fan Speed | Minimum Airflow | Minimum Efficiency |
| Low | 1,250 CFM | 155 CFM/watt |
| Medium | 3,000 CFM | 100 CFM/watt |
| High | 5,000 CFM | 75 CFM/watt |

* + - 1. Motor Warranty – Minimum of 30 years (if warrantied separate from fan.)

Motors with sealed bearings require little to no maintenance. Motors with oil bath bearings need occasional service, such as adding oil.

* + - 1. Component Warranty – Minimum of one year
      2. Integral or Attached Lighting – Must meet ENERGY STAR luminaire specifications
      3. Must permit convenient consumer adjustment of fan speed such as by means of one or more wall-mounted switches, remote control, or accessible pull chain.

Product information: <https://www.energystar.gov/most-efficient/me-certified-ceiling-fans>

* + 1. Controls Functionality

The controls functionality and corresponding sequence of operations (Part 4) for ceiling fans are designed around manually turning on the fans and having the BMS increase the cooling setpoints when the fans are operational. This is the simplest control sequence, but it is also less effective from an energy savings perspective because it relies on manual operation.

Other controls sequence approaches could have automated control of the ceiling fans. This approach was not pursued due to concerns over occupant comfort if fans are not controllable and/or control complexities from having occupant overrides.

* + - 1. Fan Speed
         1. Can be multi-speed or variable speed. Maximum speed setting shall correspond to 4 degrees above nominal cooling setpoint.
      2. Fan Direction
         1. Fan direction shall be reversible for seasonal operation changes.

For summer cooling operation, fans draw airflow upwards. In winter, fans force airflow down to take the warm air near the ceiling and mix it into the space.

* + - 1. Activation
         1. Fans shall be activated by manual controls. (This could be a switch or remote control).
      2. Shut-off
         1. Fans must be able to shut off in one of these ways:

Unit must be able to turn off automatically (local sensors) when spaces are unoccupied

Or be integrated into BMS control system for scheduling control.

Or, if manual control is the only way to turn them off, then the BMS shall send an alarm when fans are operating outside the scheduled occupancy period.

* + - 1. Status
         1. The HVAC BMS shall receive the start/stop status for each fan or group of fans controlled together. (This will likely require a relay switch on each fan.)

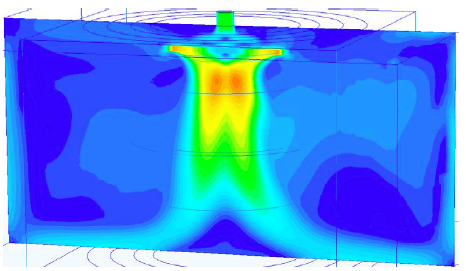
The ceiling fan control sequence receives a simple on/off fan status to the BMS even through multi-speed fans are required. A more advanced signal/sequence would report an analog signal from each fan and be able to adjust the setpoint proportionally, but this approach would be more expensive to implement.

Sequences are provided and discusses in Part 4.

* + 1. Design

Fan layout and design is typically done with assistance from manufacturer representatives. Often, they use computational fluid dynamic software to model the geometry and obstructions of the space, combined with fan performance data, to calculate the air speed that occupants will experience.

Occupant comfort criteria is defined by ASHRAE Standard 55, which defines conditions for human thermal comfort, and this Standard is used by manufacturer design software. Additionally, the Standard parameters have been programmed into an interactive tool by the Center for the Built Environment: Air flow on occupants should be around 60-80 fpm to represent a 4° F cooling effect. Air flow is limited by Standard 55 to no more than 160 fpm. However, note that it may be difficult to obtain accurate field measurement for occupant air flow.



ASHRAE Standard 216P, *Methods of Test for Determining Application Data of Overhead Circulator Fans,* is still in draft phase, but may be subsequently available and could help with fan layout parameters.

<https://cbe.berkeley.edu/research/advanced-ceiling-fan-design-tool/>

* + - 1. Fan size, spacing and speed shall be designed with assistance from manufacturer representatives to meet ASHARE Standard 55 comfort criteria based on user activity and clothing levels.
         1. Air speeds shall not exceed 160 fpm when speed settings cannot be set by occupants. (This is the upper limit from Standard 55; actual values will typically be much lower.)

## Automated Interior Shades

Automated interior shades are often referred to as roller shades, solar shades, or screen shades.

The shades control solar gain through perimeter windows so that envelope-related thermal loads are minimized while meeting daylighting requirements. Glare is also minimized.

Shade openness is a percentage that refers to the amount you are able to see through the shades. The larger the percentage, the more transparent the screen is.

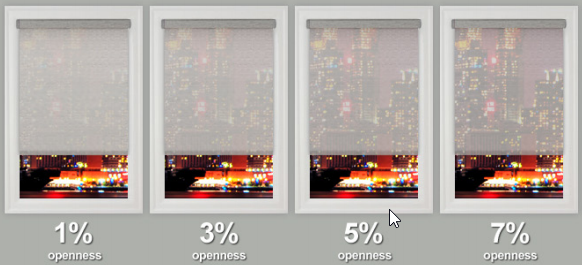


Image from: stevesblindsandwallpaper.com

* + 1. Elements: An automated interior shading and shade control system should be comprised of the following elements:

Note: System elements may vary by manufacturer.

* + - 1. Shading element – roller shades (various fabric options).
      2. Motor for shades/blinds operation, and housing for blinds when retracted.
      3. Sensors for primary control inputs.
      4. Controls system support hardware: Routers, controllers, processors and servers.
      5. Programming software.
      6. User interface method to enable user control and override of automatic operation.
         1. Examples include: keypads, remote controls, wall switches, etc.
      7. Control system that utilizes an automated, computer server-based control system with the ability to receive inputs from multiple occupancy sensors and/or photo sensors.
    1. Additional requirements:
       1. Interior roller shades shall have an openness factor between 1-3%.
       2. Exterior reflectance shall be greater than 60%.
       3. Interior reflectance shall be lower than exterior reflectance.
       4. The control system should allow for at least 3 shade height settings, including fully raised and fully lowered.
       5. The types, locations and number of sensors shall be determined by the shade controls system supplier.
    2. Optional requirements:

This section provides some optional ideas for automated interior shades integration. These items should be carefully thought about before inclusion as requires specifications. The section heading should be reworded if they are deemed to be required for the project.

* + - 1. The control system should have the capability to interface with the HVAC control system or Building Management System (BMS).
      2. The shade control database should maintain archived log files of key parameters such as position of shades, glare photo sensor data, profile angles, radiometer readings and system control mode.

## Energy Meters

* + 1. Electricity Meter
       1. The electricity meter shall have system components capable of withstanding the following environmental conditions without mechanical or electrical damage or degradation of operating capability: Indoor installation in non-air-conditioned non temperature-controlled spaces that have environmental controls to maintain ambient conditions of 0 to 122°F dry bulb and 20 to 90 percent relative humidity, noncondensing.

Power meters aligned with this specification are revenue grade, which provides sufficient reliability and accuracy to bill individual tenants for their specific energy use.

* + - 1. The electricity meter shall record the following RMS real-time measurements
         1. Current: Each phase, neutral, average of three phases, percent unbalance.
         2. Voltage: Line-to-line each phase, line-to-line average of three phases, line-to-neutral each phase, line-to-neutral average of three phases, line-to-neutral percent unbalance.
         3. Power: Per phase and three-phase total.
         4. Reactive Power: Per phase and three-phase total.
         5. Power Factor: Per phase and three-phase total.

High accuracy meters are specified. In whole building cases, there will likely only be one meter. For multi-tenant buildings, these meters are high enough accuracy to allow for billing tenants for their electric use.

* + - 1. Accuracy
         1. Comply with ANSI C12.20, Class 0.5; and IEC 60687, Class 0.5 for revenue meters.
         2. Accuracy from Light to Full Rating:

Power: Accurate to 0.25% of reading, +0.025% of full scale.

Voltage and Current: Accurate to 0.075% of reading, +0.025% of full scale.

Power Factor: ±0.002, from 0.5 leading to 0.5 lagging.

Frequency: ±0.01 Hz at 45 to 67 Hz.

* + - 1. Onboard Data Logging:
         1. The electricity meter shall store logged data, alarms, events, and waveforms in onboard nonvolatile memory.
         2. Stored Data:

Billing Log: User configurable; data shall be recorded every 15 minutes, identified by month, day, and 15-minute interval. Accumulate 24 months of monthly data, 32 days of daily data, and between 2 to 52 days of 15-minute interval data, depending on number of quantities selected.

Custom Data Logs: Three user-defined log(s) holding up to 96 parameters. Date and time stamp each entry to second and include the following user definitions:

Schedule interval.

Event definition.

Configured as "fill-and-hold" or "circular, first-in first-out."

Default values for logs to be initially set at factory, with logging to begin on device power up.

* + - 1. Communications:

This section should define the approach for integrating the electricity meters into the building control system, typical integration methods include BACnet, Modbus RTU, and LonTalk. Select the appropriate integration protocol based on your communication network protocols.

* + 1. Natural Gas Meter

Units and conversion for natural gas meters:

SCFM - standard cubic feet per minute (SCFM); 1 SCFM ≈ 1,000 Btu = 1 kBtu

MCF – one thousand cubic feet; 10.37 therms/mcf

1 therm = 100,000 Btu = 100 kBtu

* + - 1. General Requirements
         1. Maximum meter capacity shall be at least [*update value here, see context below*] SCFM.

Update the meter capacity based on the total aggregate heating input of the systems to be metered. Thus, if you have 10 rooftop units with 120,000 Btu of input capacity, your system meter should handle at least 1,200 SCFM.

Small meters’ minimum readings are approximately 0.023 SCFM. Gas use from a pilot light may be lower than can be detected, so meter readings may not align exactly with utility billing.

* + - * 1. The gas meter shall be suitable for ambient temperatures of -40° to 150°F
        2. The gas meter shall accommodate a delivery pressure of 5 psig.
        3. The gas meter shall have a maximum pressure drop as follows:

Pipe size > 1.5-inch diameter, 0.5 inches of water column.

Pipe size ≤ 1.5-inch diameter, 0.9 inches of water column.

* + - * 1. The gas meter shall either include an integral signal transducer or be provided with a remote signal transducer. This transducer shall provide sufficient pulse resolution to detect the entire range of flows, between the minimum and maximum pulse per second.
        2. The gas meter electronics, including pulse-out connections and signal transducer shall be housed in a NEMA 4X enclosure. (These enclosures are rain and dust proof.)
        3. Communications:

This section should define the approach for integrating the gas meter into the building control system, typical integration methods include BACnet, Modbus RTU, and LonTalk. Select the appropriate integration protocol based on your communication network protocols.

* + - 1. Diaphragm Meters

Diaphragm meters are suitable for applications where there is enough space to accommodate the diaphragm body. They’re generally accurate at a wide range of flows. A diaphragm meter is a positive displacement meter, meaning they fill up a known volume with gas and then discharge the gas to the system, turning a dial in the process. For this meter to be reliable, pressure and temperature must be relatively consistent. Good applications for this meter include applications where the meter is installed in a temperature controlled/consistent space (e.g. a parking garage or mechanical room).

* + - * 1. Minimum Flow: 0.2 SCFM
        2. Minimum Gas Accuracy: ± 1.0% at full
      1. Rotary Meters

Rotary meters are generally smaller than diaphragm meters. They generally have very good accuracy between full flow and 10% flow. Rotary meters are positive displacement meters.

* + - * 1. Minimum Flow: 0.2 SCFM
        2. Minimum Gas Accuracy: ± 1.0%
      1. Thermal Mass Flow Meter

Thermal mass flow meters detect flow using a heated temperature sensor that loses heat to the moving gas. The more gas flow is present, the more the heated sensor loses heat. We compare the heated sensor against an unheated sensor to account for any inconsistencies between. With no moving parts these meters are easy to install and maintain long-term.

* + - * 1. Minimum Flow: 0 SCFM
        2. Minimum Gas Accuracy: ± 0.50%
      1. Coriolis Flow Meter

Coriolis flow meters are mass-flow meters that infer flow rate using the Coriolis effect. These flow meters are ideal when the temperature or pressure of the incoming gas is inconsistent (e.g. gas meters installed on the roof of a building, exposed to the elements).

* + - * 1. Minimum Flow: 0 SCFM
        2. Minimum Gas Accuracy: ± 0.75%
    1. BTU Meter
       1. Accuracy shall be ±0.5% of actual reading from 3 to 30 feet per second flow velocities, and ±0.015 fps from 0.04 fps to 3 fps.
       2. Calibration: The sensor must be factory calibrated on an internationally accredited water flow rig with accuracy better than 0.1%.
       3. Temperature: The temperature sensors shall meet the following requirements:
          1. Accuracy:

The temperature sensor accuracy shall be evaluated based on the temperature differential between the incoming and outgoing sensors.

The temperature reading used in the energy calculation shall be within 0.15°F.

* + - * 1. Calibration: The temperature sensors shall be bath-calibrated using NIST-traceable equipment.
    1. Water Flow Meter
       1. Accuracy shall be ±0.5% of actual reading from 3 to 30 feet per second flow velocities, and ±0.015 fps from 0.04 fps to 3 fps.
       2. Calibration: The sensor must be factory calibrated on an internationally accredited water flow rig with accuracy better than 0.1%.
          1. Certificate of calibration must accompany every water meter.

## HVAC Controls

* + 1. Terminal Unit Controller
       1. Terminal unit controllers shall be fully programmable, native BACnet.

Configurable controllers are not allowed.

Fully programmable controllers can be re-programmed to accommodate future changes in code and best practices. Configurable controllers mean that the sequences are fixed to sequences that the manufacturer has (sometimes incorrectly) pre-programmed.

* + - 1. Terminal unit controllers shall have an integrated proportional damper actuator and air flow sensor.

Floating point type damper actuators are not allowed.

* + - 1. Each terminal unit controller shall support airflow measurement using the existing terminal unit flow cross(es).
      2. Controllers shall have available IO for all points included in the control schematics including the add/alternates. Each controller shall include an occupancy-sensor input terminal (BI).
      3. Each controller shall be capable of holding 48 hours of trend activity for all supported points at 5-minute intervals.
      4. Controllers shall have pressure-independent flow sensing.
    1. VAV Box Actuator (for dual duct terminal box)
       1. Proportional, Not floating point
    2. Water Control Valves (VAV box reheat valves, fan-coil valves)

Water control valves specifications are provided primarily for VAV terminal box reheat valves (heating hot water). However, the specifications also apply to fan coil valves that may be present in server rooms, air handlers, or roof-top units; this is why chilled water thresholds are specified.

* + - 1. Control valves shall be characterized ball valves.
      2. Select valves to provide tight shut-off against maximum system temperatures and pressure encountered.
         1. Heating hot water: 210°F
         2. Chilled water: 40°F, 65 psi
      3. Control valves shall have electric actuator. Actuator shall be compatible with and from same manufacturer as control valve.
      4. Characteristics:
         1. Turn down ratio: 40:1
         2. Flow Characteristics: Modified. Equal percentage
         3. Control Action: Fail in place (hot water and chilled water)
         4. Body Type: threaded ends 2 inch and smaller, flanged 2½ inch and larger
         5. Body Material: Bronze, or Stainless Steel as required by service
         6. Body Trim: Bronze, or Stainless Steel as required by service.
         7. Stem: Stainless Steel
    1. Water Control Valve Actuator
       1. 0-10 VDC, proportional (modulating) only.
       2. Actuators shall be brushless DC motor technology with stall protection.
       3. 3-way valves shall close off against double the maximum pressure differential to which they are subjected.
    2. Thermostats

Note, single-zone and multi-zone thermostats have the same requirements, but they may require different thermostat hardware to implement the scope.

* + - 1. Room thermostats shall be of the gradual acting type and include the following:
         1. User-adjustable setpoint controls.
         2. Setpoint or temperature display.

Depending on the owner or property manager preference, this requirement can be removed. There are some property management firms who prefer to avoid providing occupants a direct indication of the temperature or temperature setpoint in their space, since this can generate spurious hot/cold calls.

* + - * 1. Push-button override. When the system is in unoccupied mode and a thermostat button press occurs, the system shall send a signal to the associated air handler controller.

Push buttons allow for “override requests” to the air handler. For example, an override request can trigger the air handler to be enabled when an occupant stays later than occupied hours or comes in on the weekend. Programming the air handler response to these requests is addressed later in this document.

* + - * 1. Temperature accuracy at Calibration point: ±0.5°F
    1. Thermostat with CO2 Monitoring
       1. Room thermostats shall be of the gradual acting type and include the following:
          1. Two-button, adjustable setpoint controls. Setpoint adjustment shall not indicate temperature setpoint.
          2. Push-button override. When the system is in unoccupied mode and a thermostat button press occurs, the system shall record the activity at the associated air handler controller.

Push buttons allow for “override requests” to the air handler. For example, an override request can trigger the air handler to be enabled when an occupant stays later than occupied hours or comes in on the weekend. Programming the air handler response to these requests is addressed later in this document.

* + - * 1. Temperature accuracy at Calibration point: ±0.5°F
      1. The CO2 sensor shall either be integrated into the thermostat body or be a discrete device. The thermostat shall have a CO2 sensor range between 0 – 2,000 ppm, with an accuracy of ±50 ppm. The CO2 sensor shall be capable of periodic recalibration.
    1. Outdoor Air CO2 Monitoring

California Title 24 allows the use of differential CO2 control sequences using an ambient CO2 reading. The HVAC control sequences will use this ambient reading to determine an appropriate indoor CO2 concentration.

The Outdoor Air CO2 Monitoring may be omitted, and a static 400 ppm ambient CO2 reading assumed. This may not properly ventilate spaces where ambient CO2 concentrations deviate from the 400-ppm assumption (e.g. buildings adjacent to combustion sources).

* + - 1. The outdoor air CO2 sensor shall be installed inside a rain-proof enclosure.
         1. The sensor shall be rated for the extreme outdoor air temperatures expected at the site. If the sensor will be installed in areas with temperatures below 0°F, the case shall include a heating element to keep the sensor above 0°F.
         2. The sensor shall have a minimum sensor range of 0 -2,000 ppm, with an accuracy of 50 ppm and ±3% of reading.
    1. Discharge Air Temperature Sensor (required for all new reheat terminal boxes)

Discharge air temperature sensors are required for all reheat terminal boxes. They are an extremely useful diagnostic tool for operators and Cx agents. Required for all new reheat boxes. They should also be considered for existing boxes if the VAV controller is being replaced; though this may involve a high installation cost.

* + - 1. Accuracy at calibration point ± 1.0°F.
      2. Temperature monitoring range: 20°F to 120°F.
      3. Resolution no worse than 0.3°F.
      4. Output signal: variable resistance.
      5. Include junction box for wiring and gasket to prevent air leakage and vibration noise.

## Variable Air Volume Terminal Box

For any new VAV Terminal unit box. Terminal unit controller is specified in HVAC controls section.

* + 1. General
       1. Construction
          1. All VAV Boxes shall be AHRI 880 certified and labeled.
          2. The VAV box and the valves shall be 22-gauge galvanized steel casing.
          3. The box shall have ½” thick fiberglass insulation.
       2. Primary Air Valve
          1. The VAV box shall have embossed rigidity rings.
          2. The end of the damper shaft shall have a position indicator.
          3. The open and closed positions shall have mechanical stops.
          4. The sensor tubing shall be plenum rated.
    2. Single Duct VAV Box with Reheat

Pick One of the following, as appropriate for your building

* + - 1. Hot Water Coils
         1. The coils shall be aluminum fin construction with die formed spacer collars for uniform spacing.
         2. Mechanically expanded copper tubes shall be leak tested to 400 PSIG air pressure and rated at 230 PSIG working pressure.
         3. The heating hot water coils shall have one or two row configurations.

Electric reheat coils are used in buildings without heating hot water loops or where penetrations are difficult. These are not particularly efficient, but may be necessary in fully-electrified buildings. Consult local building codes before allowing the use of Electric Reheat in a building with existing hot water reheat coils.

* + - 1. Electric Reheat
         1. The electric reheat shall have single point power connection.
         2. The reheat coil shall have primary manual reset high limit.

## Rooftop Units (RTUs) and Heat Pumps

* + 1. Performance
       1. Units shall meet or exceed the efficiency levels of CEE Tier 2 performance specifications.

CEE Commercial Unitary AC and HP Specification, <http://library.cee1.org/content/cee-commercial-unitary-ac-and-hp-specification-0>

* + - * 1. When CEE Tier 2 is not specified, units shall meet or exceed the efficiency levels of CEE Tier 1 performance specifications. (This may apply to unitary heat pumps.)
      1. Test Method
         1. For units less than 65,000 Btu/h (5.4 tons):

EER or SEER tested in accordance with ANSI/AHRI 210/240

* + - * 1. For units greater or equal to 65,000 Btu/h (5.4 tons):

EER or IEER tested in accordance with ANSI/AHRI 340/360

SEER and IEER performance metrics are recommended because they represent the part load performance, which is a better indicator for annual performance.

* + 1. Fan Performance
       1. Supply fan efficiency shall be 60% or greater.
       2. Fan motor shall be direct drive and meet NEMA premium efficiency for over 1 hp, or fan motor shall be electrically commutative motor (ECM) for 1 hp and under.
    2. Fan Operation
       1. Supply air fan shall either be:
          1. Continuously variable volume or
          2. Variable speed with discrete stages and, at minimum, three speed setpoints corresponding to the following operational modes:

ventilation or fan-only;

cooling at 50 percent of rated capacity;

cooling at 100 percent of rated capacity.

* + - 1. Fan speed(s) for heating mode(s) can match that for 100 percent cooling mode; alternatively, fan speed(s) for heating mode(s) can be specified as additional, independent speed(s). For ventilation or fan-only mode, the supply fan controls shall be able to reduce the airflow to no greater than the larger of: (1) 50% of the maximum fan speed; or (2) the volume of outdoor air required to meet the minimum ventilation requirement.
    1. Control
       1. Unit shall have a stand-alone Direct Digital Control (DDC) based control system and be compatible with the building management system (BMS).
       2. DDC unit control system shall include all required input/output boards, main microprocessor, software and operator interface for stand-alone operation and for communication with an external third-party device, network or BMS.
       3. DDC controller shall be compatible with external BACnet third party devices or networks.
          1. All required BACnet objects and properties shall be open protocol, non-proprietary type.
       4. Unit shall be controlled via one of the following approaches:
          1. A building management system (BMS). The BMS shall provide day-of-week, time-of-day, and holiday scheduling controls of the temperature setpoints and fan operation.
          2. A networked programmable indoor thermostat system. The networked thermostats shall provide day-of-week, time-of-day, and holiday scheduling controls of the temperature setpoints and fan operation.
    2. Economizer
       1. Dry bulb temperature sensor required.

Although differential enthalpy sensors can result in improved economizer performance in some climate zones, the additional maintenance required, calibration issues, and compounded errors from two sensors (temp and humidity) makes the marginal performance improvements not worth it in the long run.

* + - 1. Return air temperature sensor required.
      2. The economizing function shall be capable of actuating outdoor air intake up to 100% of AHRI rated flow.
      3. Integrated economizer operation is required; the unit shall be able to economize while also providing mechanical cooling if economizer can’t fully satisfy the zone cooling load.
      4. If economizer is available, and the zone is in cooling mode, and no compressors are running, the OA damper shall modulate to achieve discharge air temperature control.
      5. Outdoor air damper shall be able to fully close. (Closed when unit is off)
    1. Outdoor Air Dampers
       1. Outdoor air dampers shall be able to fully close (switching to 100% recirculation mode) and maintain leakage rates per ANSI/ASHRAE/IESNA Standard 90.1-2010.
       2. Outdoor air dampers must be able to respond to schedule-based occupancy signals (from the BMS or programmable thermostat) to facilitate demand control ventilation.
       3. Outdoor air dampers must be able to respond to fan speed signals (from the BMS or unit itself) to ensure that ventilation requirements are met in reduced fan speed modes.
    2. Heating
       1. Gas Furnace
          1. Thermal efficiency shall be greater than 80%.
          2. Gas heater units shall have electronic ignition.
       2. Electric
          1. All electric heat specified above 15-kW nominal heat shall have 2 stages.
    3. General
       1. Units shall include a transformer-powered 115V GFCI convenience outlet
       2. Unit coils shall be easy-access (no formed coils or coils that require being split to be cleaned.)
       3. Units shall use variable frequency drives (VFDs) or electronically commutated (EC) motors for fan speed control.
       4. Variable speed or scroll compressors.
       5. Units shall be shipped completely factory assembled, pre-charged, piped and wired internally ready for field connections.
       6. Information plates:
          1. Outside Nameplate

Material shall be durable and weather resistant.

Located on outside of unit

Information on the nameplate shall contain:

Name of manufacturer

Model and serial number

* + - * 1. Unit shall have tags/decals showing lifting/rigging points, caution areas and refrigerant type.
        2. Information in control compartment:

Unit(s) shall have Installation and Maintenance manuals supplied with each unit in the control access section.

* + 1. Remote or Advanced Diagnostics
       1. For buildings that do not have a BMS (typically this is for single zone units), units shall include an advanced economizer diagnostic controller (AEDC).
    2. Air Filtration
       1. 2-inch Minimum MERV 7, Factory-Installed for use during construction.
       2. 2-inch pleated Replacement Set: Minimum MERV 8.
    3. Warranty
       1. Warranty Period begins date of start-up
       2. Warranty Period
          1. Entire unit: Manufacturer shall warrant units against defective materials, labor and workmanship for a period of one year from date of start-up.
          2. Compressor Failure and any leaks in the condenser or evaporator coils: 5 years after date of start-up.
          3. Gas Heat Exchanger: Parts 10 years or 20 years (for stainless) after date of startup.
          4. Unit Control Module: Parts 3 years after date of start-up
       3. Renewal: Warranty must be renewable, at the owner’s option and expense, each year until the equipment is ten (10) years old.
    4. Energy Recovery Ventilators
       1. See Enthalpy Recovery Wheel Section 2.12, below.

## Enthalpy Recovery Wheel

Enthalpy recovery wheel consists of a circular honeycomb matrix of heat-absorbing material, which slowly rotates within the supply and exhaust air stream. Enthalpy wheel exchanges heat and humidity from one air stream to another. Rather than discard used building air, an enthalpy wheel salvages useful energy and transfers it to incoming fresh air. This saves energy by reducing the need for cooling in the summer and heating in winter.

ASHRAE 90.1-2016 Section 6.5.6.1 requires fan systems to recover energy from exhaust air stream if it meets the criteria included in the narrative below.

* + 1. General
       1. The fan system shall have an energy recovery system when the design supply fan airflow rates exceed the value listed in the tables below based on the ASHRAE climate zones and the percentage of outdoor air at design flow conditions:
          1. Units Operating Less than 8,000 hours per Year in ASHRAE Climate Zones 3B, 3C,4B,4C, or 5B

Not Required

* + - * 1. Units Operating Less than 8,000 hours per Year in ASHRAE Climate Zones 1B, 2B, 5C

|  |  |
| --- | --- |
| % Outside Air at Design Conditions | Design Air Flow (CFM) |
| ≥ 10% and < 20% | Not Required |
| ≥ 20% and < 30% | Not Required |
| ≥ 30% and < 40% | Not Required |
| ≥ 40% and < 50% | Not Required |
| ≥ 50% and < 60% | ≥ 26,000 |
| ≥ 60% and < 70% | ≥ 12,000 |
| ≥ 70% and < 80% | ≥ 5,000 |
| ≥ 80% | ≥ 4,000 |

* + - * 1. Units Operating Less than 8,000 hours per Year in ASHRAE Climate Zones 6B

|  |  |
| --- | --- |
| % Outside Air at Design Conditions | Design Air Flow (CFM) |
| ≥ 10% and < 20% | ≥ 28,000 |
| ≥ 20% and < 30% | ≥ 26,500 |
| ≥ 30% and < 40% | ≥ 11,000 |
| ≥ 40% and < 50% | ≥ 5,500 |
| ≥ 50% and < 60% | ≥ 4,500 |
| ≥ 60% and < 70% | ≥ 3,500 |
| ≥ 70% and < 80% | ≥ 2,500 |
| ≥ 80% | ≥ 1,500 |

* + - * 1. Units Operating Less than 8,000 hours per Year in ASHRAE Climate Zones 1A, 2A, 3A, 4A, 5A, 6A

|  |  |
| --- | --- |
| % Outside Air at Design Conditions | Design Air Flow (CFM) |
| ≥ 10% and < 20% | ≥ 26,000 |
| ≥ 20% and < 30% | ≥ 16,000 |
| ≥ 30% and < 40% | ≥ 5,500 |
| ≥ 40% and < 50% | ≥ 4,500 |
| ≥ 50% and < 60% | ≥ 3,500 |
| ≥ 60% and < 70% | ≥ 2,000 |
| ≥ 70% and < 80% | ≥ 1,000 |
| ≥ 80% | ≥ 120 |

* + - * 1. Units Operating Less than 8,000 hours per Year in ASHRAE Climate Zones 7,8

|  |  |
| --- | --- |
| % Outside Air at Design Conditions | Design Air Flow (CFM) |
| ≥ 10% and < 20% | ≥ 26,000 |
| ≥ 20% and < 30% | ≥ 16,000 |
| ≥ 30% and < 40% | ≥ 5,500 |
| ≥ 40% and < 50% | ≥ 4,500 |
| ≥ 50% and < 60% | ≥ 3,500 |
| ≥ 60% and < 70% | ≥ 2,000 |
| ≥ 70% and < 80% | ≥ 1,000 |
| ≥ 80% | ≥ 120 |

* + - * 1. Units Operating More than 8,000 hours per Year in ASHRAE Climate Zones 3C

Not Required

* + - * 1. Units Operating More than 8,000 hours per Year in ASHRAE Climate Zones 1B, 2B, 3B, 4C, 5C

|  |  |
| --- | --- |
| % Outside Air at Design Conditions | Design Air Flow (CFM) |
| ≥ 10% and < 20% | Not Required |
| ≥ 20% and < 30% | ≥ 19,500 |
| ≥ 30% and < 40% | ≥ 9,000 |
| ≥ 40% and < 50% | ≥ 5,000 |
| ≥ 50% and < 60% | ≥ 4,000 |
| ≥ 60% and < 70% | ≥ 3,000 |
| ≥ 70% and < 80% | ≥ 1,500 |
| ≥ 80% | ≥ 120 |

* + - * 1. Units Operating More than 8,000 hours per Year in ASHRAE Climate Zones 1A, 2A, 3A, 4B, 5B

|  |  |
| --- | --- |
| % Outside Air at Design Conditions | Design Air Flow (CFM) |
| ≥ 10% and < 20% | ≥ 2,500 |
| ≥ 20% and < 30% | ≥ 2,000 |
| ≥ 30% and < 40% | ≥ 1,000 |
| ≥ 40% and < 50% | ≥ 500 |
| ≥ 50% and < 60% | ≥ 140 |
| ≥ 60% and < 70% | ≥ 120 |
| ≥ 70% and < 80% | ≥ 100 |
| ≥ 80% | ≥ 80 |

* + - * 1. Units Operating More than 8,000 hours per Year in ASHRAE Climate Zones 4A, 5A, 6A, 6B, 7, 8

|  |  |
| --- | --- |
| % Outside Air at Design Conditions | Design Air Flow (CFM) |
| ≥ 10% and < 20% | ≥ 200 |
| ≥ 20% and < 30% | ≥ 130 |
| ≥ 30% and < 40% | ≥ 100 |
| ≥ 40% and < 50% | ≥ 80 |
| ≥ 50% and < 60% | ≥ 70 |
| ≥ 60% and < 70% | ≥ 60 |
| ≥ 70% and < 80% | ≥ 50 |
| ≥ 80% | ≥ 40 |

* + 1. Recovery Wheel Unit
       1. The rotor media shall be made of corrosion resistant material like aluminum.
       2. The media surfaces shall be coated with a solid migrant non-absorbent layer.
       3. The media shall have a flame spread of less than 25 and a smoke developed of less than 50 when rated in accordance with ASTM E84.
       4. The enthalpy recovery system shall have an enthalpy recovery ratio of at least 65% when the system is tested, and the results are presented in accordance with ARI 1060 standards.
    2. Media Cleaning
       1. The media shall be largely self-cleaning.
       2. Dry particles up to 800 microns shall pass freely through the media.
       3. To remove oil-based aerosol films that have collected on the desiccant surfaces, the media shall be cleanable using low pressure steam, hot water, or light detergent.
    3. Purge Section
       1. Purge sector shall be designed to limit cross contamination to less than .04% of that of the exhaust stream concentration.
    4. Rotor Seals
       1. Rotors shall be supplied with labyrinth seals only.
    5. Rotor Housing
       1. Rotor housing shall be made of corrosion resistant material like galvanized steel.

## Data Closet and Server Rooms

* + 1. General
       1. System Tie-Ins
          1. Server rooms must be conditioned 24/7. HVAC system serving the server room shall not require any central systems to run 24/7 unless there is already a central system operating 24/7 to serve permanent loads. If the future schedule of the central system (such as a chilled water or cooling tower plant) is in question, do not connect server room HVAC to that system.
       2. Redundancy
          1. Redundancy of cooling equipment shall be coordinated with the IT department. Depending on the criticality of the IT equipment being served, it is possible that a level of redundancy is required. If that is the case, the HVAC systems shall be designed such that any one component (or potentially more) can fail and the remaining equipment can still provide adequate cooling.
    2. Computer Rooms with Design IT Loads less than 20 kW (~6 tons)
       1. HVAC System Type
          1. Fan Coil Units

Fan Coils are the only reasonable cooling solution for small IT loads. The coil could have dedicated heat rejection or tie into a larger system.

All server rooms in this category shall be served by wall, ceiling or floor-mounted fan coil units.

* + - * 1. Heat Rejection Options

For this small size category of server rooms (<20 kW), all three options below can provide similar efficiency. The appropriate system should be decided based on installation cost and feasibility.

Heating is only relevant for server rooms where the introduction of outside air or heat losses through the envelope in a cold climate could cause the temperature in the space to drop. Typically, HVAC systems do not need to have the ability to provide heat because the servers themselves heat the space.

Air-Source Heat Pump

These systems utilize exterior-mounted condensing units that reject heat into the atmosphere. Refrigerant supply and return lines must be routed from the condensing units to fan coil units in the server room.

Equipment shall meet CEE Tier 2 performance specifications.

CEE Commercial Unitary AC and HP Specification, <http://library.cee1.org/content/cee-commercial-unitary-ac-and-hp-specification-0>

Heating capacity shall be specified, if necessary, for the space. Electric resistance heating shall not be used.

Water-Source Heat Pump

A water-source heat pump rejects or absorbs heat from a central condenser water loop.

This option shall only be used if the building has a central condenser water loop that operates 24/7 to serve another permanent load.

Equipment shall meet CEE Tier 1 performance specifications.

CEE Commercial Unitary AC and HP Specification, <http://library.cee1.org/content/cee-commercial-unitary-ac-and-hp-specification-0>

Two-way condenser water valves shall be specified.

This assumes that the chilled water system is variable flow, which is a modern best practice.

Heating capacity shall be specified, if necessary for the space. Electric resistance heating shall not be used.

Chilled Water

These systems use fan coils with chilled water coils to reject heat to a central chilled water system.

This option shall only be used if the building already has a central chilled water plant that operates 24/7.

Two-way chilled water valves shall be specified.

This assumes that the chilled water system is variable flow, which is a modern best practice.

This system shall not be specified if heating is necessary for the space.

* + 1. Computer Rooms with Design IT Loads between 20 to 70 kW (~6 to ~20 tons)

For these mid-sized systems, a design engineer or efficiency consultant *could* be consulted to maximize system efficiency.

* + - 1. The total fan power at design conditions of each fan system shall not exceed 27 W/kBtuh of net sensible cooling capacity. (Title 24 requirement)
      2. HVAC System Options:
         1. Air-cooled computer room air conditioning (CRAC) unit or in-row cooler

Variable speed fan controls shall be specified, programmed to vary as a function of load.

Equipment shall meet ASHRAE 90.1 Minimum Efficiency Requirements for Computer Rooms.

Consider units with refrigerant economizing capability where available.

* + - * 1. Water-cooled computer room air conditioning (CRAC) unit or in-row cooler

Variable speed fan controls shall be specified, programmed to vary as a function of load.

This option shall only be used if the building has a central condenser water loop that operates 24/7.

Two-way condenser water valves shall be specified.

Equipment shall meet ASHRAE 90.1 Minimum Efficiency Requirements for Computer Rooms.

* + - * 1. Chilled water computer room air handling (CRAH) unit or in-row cooler

Variable speed fan controls shall be specified, programmed to vary as a function of load.

This option shall only be used if the building has a central chilled water plant that operates 24/7).

Two-way chilled water valves shall be specified.

* + 1. Computer Rooms with Design IT Loads over 70 kW (~20 tons)
       1. For these larger systems, a design engineer or efficiency consultant shall be consulted.
       2. Follow requirements listed in California Building Energy Efficiency Standards (Title 24), Section 140.9.
          1. Economizer requirements do not apply to ASHRAE Climate Zones 0 (equatorial regions outside the U.S.) and 1 (Southern Florida).

Although defined by Title 24, these requirements for large IT loads are not just relevant for California. There are economizing requirements for new server rooms in existing buildings. If outside air is used in the final design, the designer may consider humidity sensors and/or control.

## Miscellaneous

* + 1. Hot Water Distribution
       1. Eliminate Victaulic-type piping connections if hot water piping work is part of project scope.

Victaulic-type connections (“valves”) are cheaper than other connections, but they reduce the effectiveness of hot water scheduling. Hot water temperatures can be scheduled to be lowered when spaces are not occupied, but this can cause leaking where Victaulic-type connections are used. They should be replaced whenever they are accessible as part of the project scope.

* + - 1. Use welder or soldered connections instead of Victaulic-type connections.
    1. Exhaust fans (typically for kitchens or bathrooms)
       1. Must be capable of being scheduled
          1. Scheduling can occur via BAS, occupancy sensor, or timeclock
       2. Exhaust Fan shall be sized such that the exhaust fan plume is clear of any outside air intakes.

Exhaust odors could cause economizers to be overridden to closed.

* + - 1. The NEMA Nominal Motors Efficiency shall be super premium efficiency (IE4) based on the motor size.
    1. Appliances
       1. Appliances shall be EnergyStar rated.

If new appliances are included in project scope, like say for a new break room, this will ensure a minimum level of energy efficiency. For more information visit: <https://www.energystar.gov/products/appliances>

* + 1. Ducting

If any re-zoning is occurring, there may be new duct runs installed.

* + - 1. For Single zone
         1. Rigid duct required from roof to floor.
         2. Flex duct permitted after first zone.
      2. Roof Duct Runs
         1. Ducts in exterior locations (anything exposed to the elements) shall be insulated to the following levels:

For climate zones 5-8, R-12 or higher required.

For climate Zones 1-4, R-8 or higher required.

* + 1. High Capacity Air Filters
       1. Pleated panel filters
          1. Provide low pressure drop UL 900 class 1 or 2 approved air filters.
          2. The filters shall have a minimum MERV rating of 13 as per ANSI/ASHRAE Standard 52.2.
          3. Filters shall be of standard sizes and readily available.
          4. Filter media shall be made of synthetic fibers and coated with nonflammable adhesive.
          5. Filter media shall be coated with anti-microbial agent.
          6. Filter media shall be bonded to frame to prevent air bypass.
          7. Filter media frame shall be made of cardboard
          8. Filter performance:

|  |  |  |  |
| --- | --- | --- | --- |
| Filter Efficiency | Filter Thickness/ Depth (in.) | Desired Maximum Face Velocity (fpm) | Maximum Initial Pressure Drop (in. w.g.) |
| MERV 13 | 1 | 400 | .19 |
| 2 | 400 | .15 |

* + - * 1. Filter Pressure Drop (required for air handlers larger than 10,000 cfm)

Each filter bank will have a magnehelic filter gauge installed outdoors. The gauges shall have UV, weather protective cover.

An independent transmitter shall measure pressure differential across the filter and display it on the energy management system.

1. Execution

The Execution section covers how the work is to be completed and includes details on various components that should be referenced when planning for and during execution of the project by the contractor and implementation team.

## General

In this section add details specific to your facility. Some of the details below may be covered under existing standard terms and conditions. Feel free to eliminate these sections here or use them to refer to other associated documents.

This section could cover where material is to be stored, assumptions around work hours, and other general work guidance for implementation.

## Commissioning, Testing, and Acceptance

* + 1. General
       1. Functional performance testing (FPT) procedures will be provided by the owner’s representative. Procedures shall be reviewed by the Contractor for issues pertaining to safety, equipment protection and warranty, and appropriateness of the procedure. The owner’s designated representative has the option to witness all tests.

Note that FPT tests are available as part of this ISP package.

* + - 1. The contractor shall submit the results of functional and diagnostic tests in a three-ring binder for final system acceptance. System will not be considered complete until all tests are successfully completed and documented. Provide documentation of all On-Site Testing to the owner as part of the O&M package.
      2. The contractor shall incorporate all Commissioning and testing activities into the construction schedule.
      3. Prior to functional testing, the Contractor shall provide the following to the Owner’s designated representative:
         1. Remote read/write access to the building control systems; including HVAC, lighting, plug loads, and energy metering.
         2. A copy of the programming logic
         3. The following completed pre-functional tests:

Point-to-Point Installation Verification of all DDC I/O

Controller Startup and Verification

Calibration of Analog Inputs

* + 1. Functional Testing and Sequence of Operation Verification for Commissioning Procedures
       1. Point-to-Point Installation Verification Procedure to consist of the following (at a minimum) for all hard-wired points:
          1. Documentation: an Excel spreadsheet listing all I/O in the system including point name, address, analog range or digital normal state, engineering units. Provide one signature block per page for Contractor’s representative and Owner’s representative to accept the test results.
          2. Digital inputs: jumper or open the wires at the device and verify change of state at controller. Record results on spreadsheet.
          3. Analog Inputs: lift wire at device to see change of state and record default value on spreadsheet.
          4. Digital/Analog Outputs: command the field device from the controller and verify corresponding change of state at the field device. Record results on spreadsheet.
       2. Controller Startup Procedures to consist of the following (as a minimum):
          1. Documentation - An Excel spreadsheet listing all controllers in the system including System Name, Controller Address, Application Type, Application #, Flow Ranges, etc. Provide one signature block per page for Contractor’s representative and Owner’s representative to accept test results.
       3. Calibration of analog inputs:
          1. Confirm and document proper calibration of all installed thermostats. Temperature sensors must match Contractor’s temperature readings within ±1 °F.
          2. Confirm and document proper calibration of all installed supply air temperature sensors. Sensors must match Contractor’s temperature readings within ±0.5 °F.
          3. Use calibration tool with twice the accuracy of instrument being tested. Record calibration offset on spreadsheet.
          4. Provide documentation to show that calibration tool has been calibrated in the last year.
          5. It is not acceptable to use an infrared non-contact thermometer to calibrate air temperature sensors.
    2. Functional Performance Testing
       1. Provide a qualified technician to complete the functional testing per the functional performance test (FPT) procedures provided by the owner’s representative.

FPTs are provided as additional resources documents with this ISP.

The functional performance test form is to include areas to check and record each facet of the sequence of operations including but not limited to the following:

* + - * 1. Start/Stop
        2. Interlocks
        3. Safeties
        4. Valve stroke
        5. PID loops
        6. Modes of operation
        7. Power failure/recovery
      1. The owner’s representative may decide to verify functional performance using trend review in place of functional performance tests. The contractor shall provide requested trend data in CSV format.
      2. Performance testing will be done on site and remotely from the wireless management system.
      3. Any unit malfunctions or temperature readings that are out of calibration will be presented to the Contractor in the form of a Project Deficiencies and Resolutions Log (PDR Log).
      4. The Contractor shall repair promptly any deficiencies found during functional testing.
      5. The Contractor shall be back charged for any additional testing time required by the owner’s representative as a result of equipment not passing the functional test the first time.
      6. The Contractor shall repeat the functional performance testing until all functional tests are passed.
      7. Six months after project turn-over, the owner’s representative will conduct a trend review to confirm that the new control system accurately responds to seasonal weather changes. The contractor shall have a technician familiar with the building available for control adjustments.

## Training

* + 1. The Contractor shall provide training to designated personnel in the operation and maintenance of the system installed. An agenda must be submitted prior to training. Instructors shall be thoroughly familiar with all aspects of the subject matter they are to teach. All training shall be held during normal working hours.
       1. Training for Owner's designated operating personnel shall include the following on-site training:
          1. Explanation of drawings, operations and maintenance manuals.
          2. Walk-through of the job to locate control components.
          3. Controller operation/function.
          4. Operator control functions including graphic generation and field panel programming.
          5. Explanation of adjustment, calibration and replacement procedures for all equipment provided on this project.
          6. Explanation of procedures to restore any network controller or zone controller. Training manual shall include screen captures, including instructional annotation, of each step required to accomplish the task.
          7. Training binder with training modules.
       2. Training for the Owner’s designated operating personal shall include the following off-site training (which need not be offered directly by the contractor):
          1. Introductory course describing programming fundamentals for the control interface.
    2. The Owner may require personnel to have more comprehensive understanding of the hardware and software; additional training must be available from the Contractor. If such training is required by Owner, it will be contracted later.

## Warranty

* + 1. General Requirements: Provide all labor, materials and equipment necessary to warrant the entire system for a period of one year after project acceptance by the Owner.
    2. Personnel: Provide qualified personnel to accomplish all work promptly and satisfactorily. The Owner shall be advised in writing of the name of the designated service representative, and of any changes in personnel.
    3. Service: The Owner will initiate service calls when the system is not functioning properly. Qualified personnel shall be available to provide service to the complete system. Furnish Owner with a telephone number and e-mail address where the service representative can always be reached.
    4. Systems Modifications: Provide any recommendations for system modification in writing to the Owner. Do not make any system modifications, including operating parameters and control settings, without prior written approval of the Owner. Any modifications made to the system shall be incorporated into the operations and maintenance manuals, and other documentation affected.

## Lighting and Lighting Controls

* + 1. Luminaire Installation: Cleaning
       1. After installation, luminaires shall be wiped down with a lint free cloth to remove any smudges, fingerprints, dirt, dust, and/or construction debris.
    2. Lighting Control Devices
       1. Occupancy and Vacancy Sensors
          1. Occupancy sensor detection sensitivity shall be adjusted for good occupant detection, minimal false-occupancy, and minimal false-vacancy. Specifically:

The sensors shall not respond to transient occupancy of spaces outside the area for which they are intended to control. E.g. The sensor shall not trigger when an occupant passes outside the door or outside a window.

The sensor sensitivity shall be adjusted such that an occupant, when standing still in the room, is able to wave their arm at chest-level and trigger the sensor.

The sensor delay-to-off (dwell) shall be adjusted per the following dwell schedule:

Storage rooms, closets: 10 minutes

Restrooms: 15 minutes

ASHRAE 90.1 requires 20-minute shut off in all areas requiring automatic full-off controls. §9.4.1.1(h)

Title 24-2019 does not regulate occupancy sensor dwells, deferring to California Title 20-2019.

Title 20-2019 §1605.3 (j) 2 (G) states that 30 minutes is the maximum allowable dwell.

All other space types: 20 minutes

* + - 1. Photocells & Daylighting Controls
         1. All daylighting control devices shall be field-adjusted to maintain the horizontal illuminance levels required by the Owner.

Where no illuminance criteria are provided by the Owner, the Contractor shall adjust the daylighting controls to maintain the horizontal illuminance levels on at the designated workplane height for the dominant task type appropriate for each space per the latest edition of the Illuminating Engineering Society’s Lighting Handbook.

* + - 1. Schedules
         1. Schedules shall be programmed per the Owner’s specified schedules, as described in the Sequence of Operations (Section 4).

## Plug Loads and Plug Load Controls

* + 1. Installation
       1. All controlled receptacles shall be permanently marked to visually differentiate them from uncontrolled receptacles.
       2. At least one controlled receptacle must be installed within six feet from each uncontrolled receptacle or install a split wired receptacle with at least one controlled and one uncontrolled receptacle.
       3. Where receptacles are in modular furniture in open office area, at least one controlled receptacle shall be installed at each workstation.
       4. All controlled receptacles shall be oriented consistently on a project site.

Split wired receptacles are easier to install and offer a less cluttered appearance. They are also harder to tell apart from a distance, given that the control receptacle indicators tend to be small (e.g. 0.25” square). Indicators typically show a power symbol or “Controlled”, see images below.

Redundant receptacles can allow the use of different colored plastics (e.g. blue receptacles are controlled); however, they require more installation labor and offer a more cluttered appearance on the wall.

 Split Wired  Redundant

Images Source: Levitron

* + - * 1. Split wired receptacles: Duplex receptacles in which one receptacle is automatically switched while the other is always on, shall be installed such that the entire project site has all the controlled receptacles either on the top or the bottom of any receptacle pair.
      1. Redundant receptacles: Redundant receptacles, in which two duplex receptacle pairs are provided on the same wall, and one receptacle pair is controlled, shall be installed such that the controlled receptacle pair is always to the left or right of the viewer when looking at the receptacle installation.

## Window Film

* + 1. Install the solar film with no gaps or overlaps.
    2. If seamed, make seams non-overlapping.
    3. Do not remove release liner from film until just before each piece of film is cut and ready for installation.
    4. Remove air bubbles, blisters, and other defects. Be careful to remove “fingers” to eliminate any contamination or excess water pockets.
    5. Protect window frames and surrounding surfaces to prevent damage during installation.

## Cool Roof

* + 1. Installation
       1. Roof coatings shall not be applied to roofs with less than 5 years of remaining useful life.

## Ceiling Fans

* + 1. Mounting
       1. Fans shall be installed so that blades are:
          1. 8 inches or more from ceiling
          2. 18 inches or more from walls
          3. At least 7 feet above finished floor
       2. Fans shall be installed in a way that will not interfere with occupants, safety equipment, or other building systems.

## Automated Interior Shades

* + 1. Installation
       1. Install shades such that the shade band is not closer than 2 inches to the interior face of the glass. Allow sufficient clearances for window operation hardware.
       2. The shades shall block direct sun so that the depth of direct sun penetration is no greater than a specified horizontal depth from the face of the window wall at floor level. The specified maximum penetration distance may vary for different perimeter areas based on user requirements.
       3. The deployment of shades should consider obstruction of direct sunlight by external objects such as surrounding buildings.
       4. Automatic response to light level changes should be limited so as to avoid shade movement hysteresis. Response to variable sky conditions should be immediate when going from cloudy to sunny but delayed when going from sunny to cloudy.
       5. The shades shall control glare so that the average window luminance viewed from any angle within the workspace is no greater than a specified level (e.g. 2000 cd/m2) during the day. This includes all periods throughout the day whether there is or is not direct sun in the plane of the window.

## Energy Meters

* + 1. Data Collection
       1. Energy meters shall be configured to collect data at 15-minute intervals. All energy meters installed as part of this project shall be time-synchronized, such that all measurements are conterminous.
       2. The energy meters shall be configured to collect the following units:
          1. Electricity Meters: kW
          2. Natural Gas: therms/hour
          3. BTU Meter: kBtu/hr
    2. Data Visualization: The metering interface shall be configured to show the following energy charts
       1. General
          1. Each data visual shall have the following options

User-selected display units, including:

Native Units: Each metric shown in default units against as many secondary axes as needed.

Normalized “Site” Units: Each metric converted into kBtu/hr without considering the energy loss associated with energy delivery:

1 therm/hr = 100 kBtu/hr

1 kW = 3.412 kBtu/hr

Data Export

The interface shall be set-up to export raw interval data in an .xls or .csv format over a user-defined period.

* + - * 1. Discrete Visuals

Rate of energy use (kW, therm/hr, kBtu/hr)

This chart shall be configured to show the rate of energy use with a user-defined start date and end date.

The chart shall have a default view for a single day and for a single week.

Total energy consumed (kWh, therms, kBtu)

This chart shall be configured to show the total energy use with a user-defined start date and end date.

Addition graphics requirements and sample charts will be provided in future versions of this document.

## Enthalpy Recovery Wheel

* + 1. Service Clearance
       1. Typical minimum clearance required is equal to the module width plus 12 inches to allow for the removal of energy wheel cassette.

## Data Closet and Server Rooms

* + 1. General
       1. System Tie-Ins
          1. Server rooms must be conditioned 24/7. HVAC system serving the server room shall not require any central systems to run 24/7 unless there is already a central system operating 24/7 to serve other such continuous loads. If the future schedule of the central system (such as a chilled water or cooling tower plant) is in question, do not connect server room HVAC to that system.
       2. Thermostat Placement
          1. Install thermostat in a location that reflects the temperature of the air entering the IT equipment.
       3. Rack Arrangement
          1. IT equipment and racks to be mounted in hot/cold aisle configuration.

Hot/cold aisle arrangement is the practice of aligning cold supply air with the inlets of the servers. The diagram below shows a larger server room with hot/cold aisle configuration. Note that the cold air is only supplied to the front of the racks, and never to the backs of racks, where hot air is exhausted from the servers.

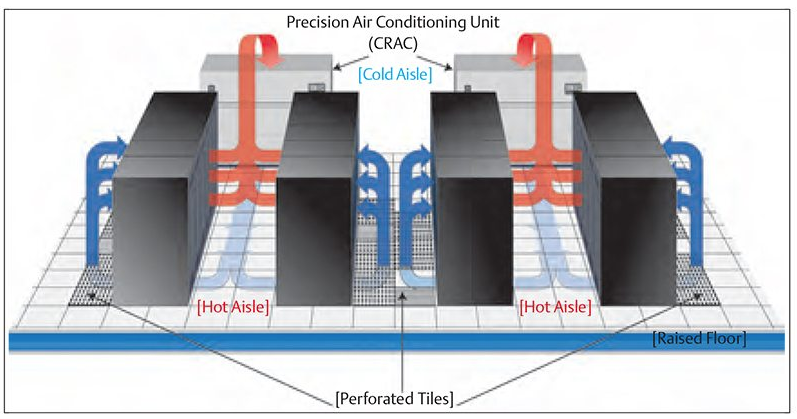


Image source: www.joepowell.com

This arrangement is intended to assist with effective airflow distribution in the space, even if there is only one rack. This will enable the HVAC system to provide cold air directly to the front of all servers, where temperature matters most. Unorganized server orientation can result in some servers receiving warmer-than-recommended air. To counteract this effect, it could also require HVAC equipment to provide colder air or more air than otherwise necessary. This increases energy consumption.

All equipment in each rack shall be mounted the same direction so that air moves from front to back.

If there are multiple racks in a row, then racks shall be in the same orientation.

Racks shall be arranged so that supply air from the HVAC systems is supplied to the cold aisle (inlet side) of the racks.

* + - * 1. Fan Coil Unit Mounting

Fan coil should be mounted or ducted such that the supply air is directed into the cold aisle (front of the servers). Air shall not be provided in the hot aisles.

## High Capacity Air Filters

* + - 1. General
         1. Temporary disposable filters shall be used during the construction process. Just prior to building turn-over, new low-pressure drop filters shall be provided. At no time shall the air handling systems be allowed to run without air filters installed.
         2. Install final filters only after completion of construction.
         3. Install filter gauge, static pressure taps upstream and downstream from the filters. Adjust and level inclined gauges.
         4. Coordinate filter installations with duct and air handling unit installations.

1. Sequences of Operation

## General

Any general sequences or notes on BMS platform and software.

## Lighting

* + - 1. Scheduling
         1. Mechanical Timeclocks/Astronomical Timeclocks

Timeclocks shall automatically shut off all lighting in a space when the space is typically unoccupied.

The timeclocks shall incorporate an automatic holiday “shut-off” feature that turns off all loads for at least 24 hours and then resumes normally scheduled operation.

* + - 1. Task Tuning
         1. The LED luminaires shall be dimmed to a maximum output of 80% with the capability to increase output over the course of the lighting systems rated life, for consistent illuminance levels.
         2. Fine tuning of acceptable illuminance levels for task tuning shall be done after furniture and finishes are completely installed.
      2. Occupancy & Vacancy Sensing

Sensors should be installed in *vacancy* configuration in spaces where the manual light switch is easy to locate and is accessible. In addition, vacancy sensors when installed in spaces with access to daylight potentially reduces energy consumption. Vacancy sensors are a good fit for spaces like copy rooms or private offices with windows that bring in daylight.

Sensors should be installed in *occupancy* configuration in spaces where the manual switch is difficult to locate and is in an inaccessible location. Also, spaces with no access to daylight shall have occupancy sensors to control lighting in the area. Occupancy sensors are a good fit for places like storage rooms, warehouses, etc.

* + - * 1. Occupancy sensors

Occupancy sensors shall be installed in the following spaces:

Restrooms

Small storage rooms

Occupancy sensors upon detecting occupants shall activate all lighting to full brightness level (maximum tuned lighting power).

* + - * 1. Vacancy sensors

Vacancy sensors shall be installed in the following spaces:

Offices (250 ft² or smaller),

Multipurpose Rooms (1,000 ft² or smaller)

Classrooms

Conference Rooms

Break Rooms

Lighting in the room shall be activated by manual “On” input, only.

This occupancy sensor should only be used when manual-on controls are prohibited by the owner.

* + - * 1. Partial ‘On’ occupancy sensor

Partial ‘On’ sensors shall be installed in the following spaces:

Offices (250 ft² or smaller),

Multipurpose Rooms (1,000 ft² or smaller)

Classrooms

Conference Rooms

Break Rooms

Lighting in the room shall be activated by manual “On” input, only.

Partial ‘On’ occupancy sensors shall be capable of automatically activating light fixtures to 50%-70% of lighting power.

* + - * 1. Partial ‘Off’ occupancy sensors

Shall be installed in the following applications:

Warehouses and Storage Areas with Aisles

Occupancy sensors controlling light fixtures in aisle ways, open areas in warehouses shall reduce lighting power by at least 50% when the areas are unoccupied. The occupancy sensors shall independently control lighting in each aisle way and shall not control lighting beyond the aisle-way.

Hallways and Stairwells

Occupancy sensors shall separately reduce lighting in each space by at least 50% when the area is unoccupied.

The occupancy sensors shall automatically fully turn ON the lights in each separately controlled space.

In addition to the above behavior, after normal business hours (defined in Table 4.2.1), the partial-off occupancy sensors shall behave as occupancy sensors.

* + - 1. Daylighting Controls
         1. Photocell sensors shall be located and calibrated according to the manufacturer’s recommended procedures. Photocells shall generally be located away from excessive shading. Photocells shall not be placed above luminaires that directly light the ceiling (e.g. indirect lighting).
         2. Photocell sensors shall automatically adjust the power of installed lighting up and down in the skylit daylit zones and primary sidelit daylit zones to keep the total light levels stable and in accordance with IESNA recommendation for a given space.
         3. The photocell sensors shall continuously dim the controlled lighting installed.
      2. Manual Control Devices
         1. On/Off Switches

Each area enclosed by ceiling height partitions shall provide manual wall switches to turn lights on/off.

The light switches shall be in the same enclosed area with the lighting it controls.

* + - * 1. Dimming Switches

General lighting in any enclosed area 100 sq. ft. or larger with a connected lighting load of 0.5 watts/sq. ft. or more shall provide dimming wall switch with the capability to continuously dim light fixtures from 10% to 100%.

* + - * 1. Lighting Override Switches

The lighting system shall provide the occupant some means of overriding any schedule based-controls (either on/off scheduling or device-level differential scheduling) when the building is occupied during non-routine events.

Where provided these override switches shall control no-more than a single tenant suite or a single-floor of a building, whichever is smaller.

The table below is an example of the information that may need to be specified for a lighting control system. These values are typical for most office buildings.

Table 4.2.1. Lighting Zone Configuration Summary

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Room # | Room Use | Horizontal Illuminance | | | Automatic Shut-OFF Controls | | | | | |
| Light Target (fc) | target  location | Control Type | | Delay (minutes) | Vacant Behavior | | Schedule |
| Business-day | After-hours |
| 0100 | Lobby | 20 fc | 0 ft AFF | Scheduled | | N/A | N/A | N/A | M-F, 6:30 am to 7:30 pm |
| 0101 | Private Office | 50 fc | 2.5 ft AFF | Vacancy | | 20 | OFF | OFF | M-F, 7:30 am to 6:30 pm |
| 0102 | Open Office | 30 fc | 2.5 ft AFF | Occupancy | | 20 | Dim to 50% | OFF | M-F, 7:30 am to 6:30 pm |
| 0103 | Break Room | 30 fc | 2.5 ft AFF | Vacancy | | 10 | OFF | OFF | M-F, 7:30 am to 6:30 pm |
| 0104 | Conference | 50 fc | 2.5 ft AFF | Vacancy | | 20 | OFF | OFF | M-F, 7:30 am to 6:30 pm |
| 0105 | Restroom | 15 fc | @ fixture | Occupancy | | 20 | OFF | OFF | M-F, 7:30 am to 6:30 pm |
| 0106 | Corridor | 10 fc | 0 ft AFF | Occupancy | | 20 | Dim to 50% | OFF | M-F, 7:30 am to 6:30 pm |
|  |  |  |  |  | |  |  |  |  |

## Plug Loads

* + - 1. Central Controls
         1. The plug load control device shall automatically shut off the controlled receptacles using one of the following approaches:

Occupancy based plug load controls are preferable given the responsiveness of the sensor.

Timeclock based plug load controls require an override switch to allow occupants to temporarily override the time clock for after-hours work.

Occupancy-based: Using the occupancy data from the lighting control system, the controlled receptacles shall shut off when the zone has been vacant for 20 minutes.

365-day Timeclock: Using the time of day and the calendar date, the system shall shut off the controlled plugs when the space is expected to be unoccupied. This system shall be capable of shutting off the plug loads on user-defined holidays.

Each tenant area shall be provisioned with an override switch that will override the shut-off command for no more than 2 hours.

## Automated Interior Shades

* + - 1. Sequences
         1. The primary control objective is to control glare while maximizing daylight availability.
         2. Setpoints for glare control and maximizing daylight should be set based on use characteristics and user preferences.
         3. Primary control shall be in response to solar conditions, based on real-time solar radiation sensor input. A combination of one or more of the following inputs may be used:

Sun position

Direct solar radiation

Diffuse solar radiation

Façade azimuth

Interior and/or exterior surface luminance

Interior and/or exterior illuminance

* + - * 1. Occupants shall always have manual override capability.
        2. Additional secondary control may include a combination of vacancy-detection and HVAC mode, as follows:

When the zone is vacant and HVAC is in cooling mode, shades are fully deployed (i.e. down).

When the zone is vacant and HVAC is in heating mode, shades are fully retracted (i.e. up) during daytime hours and fully deployed (i.e. down) during night time hours.

* + - * 1. All control inputs shall be configured to reflect each site’s specific characteristics and requirements.

## HVAC Design Variables

The design set points listed in this section must be scheduled in design documents for each zone and air handler by the design engineer. The setpoints herein serve merely as a starting place.

* + 1. General Zone Information
       1. Zone Temperature Set Points: Default set points shall be based on zone type as shown below

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.

* + - * 1. Default set points shall be based on zone type as shown below.

Table 4.5.1: Zone Temperature Setpoint Defaults

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Zone Type | Occupied | | Unoccupied | |
| Heating | Cooling | Heating | Cooling |
| Office Areas | 70°F | 74°F | 60°F | 90°F |
| Mechanical/Electrical Rooms | 65°F | 85°F | 65°F | 85°F |
| Networking/Computer Rooms | 65°F | 75°F | 65°F | 75°F |

* + - * 1. Networking, Data-Closets, Small Server Rooms

As listed in the table above, the occupied & unoccupied setpoints are:

Heating Setpoint: 65°F

Cooling Setpoint: 75°F

Industry standard practice for server inlet temperature thermal control is the following:

Maximum: 80.6 °F dry bulb, 59 °F dew point, and 60% relativity

Minimum: 64.4 °F dry bulb and 15.8 °F dew point.

We recommend a lower cooling setpoint of 75 °F to account for imperfect airflow management. The simplified relative humidity range provided in this report is relevant for measured dry bulb temperatures between 65 °F and 75 °F.

Based on the maximum and minimum recommendations above, humidity should be between 15% and 60%. However, since outside air is rarely used in small systems, humidity is rarely a concern, and we do not recommend using any humidity sensors or controls. If outside air is being used (this could apply to systems with IT loads above 70 kW), then consider using a designer or consultant and specifying humidity controls.

Source: *Thermal Guidelines for Data Center Environments,* ASHRAE Technical Committee (TC) 9.9, 2015

* + - 1. Zone Outdoor 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 Section 4.5 A. 2. a and delete Section 4.5 A. 2. b.

• If the project is to comply with California Title 24 ventilation requirements, keep subsection 4.5 A. 2. b and delete subsection 4.5 A. 2. a.

* + - * 1. For project complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1-2016

The area component of the breathing zone outdoor air-flow 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.

The population component of the breathing zone out-door 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.

Zone air distribution effectiveness EzH in heating

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.

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 4.10 F zone-group operating modes.

* + - * 1. For projects complying with California Title 24 ventilation standards:

Vocc-min. Zone minimum outdoor airflow for occupants, per California Title 24 prescribed airflow-per-occupant requirements.

Varea-min. Zone minimum outdoor airflow for building area, per California Title 24 prescribed airflow-per-area requirements.

Indicate where occupied standby mode is allowed based on the zone occupancy category per Title-24-2019, Table 120.1-A.

* + - 1. Zone CO2 Set Points

Space CO2 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 CO2 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.

* + - * 1. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1-2016

**Standard 62.1 CO2 Set Point Guidance** (Source: Lawrence, T. 2008. Selecting CO2 criteria for outdoor air monitoring. ASHRAE Journal 50(12).)

Recommended maximum CO2 is 90% of the steady state concentration:

where COA is the outdoor air CO2 concentration in ppm, Ez is the zone ventilation effectiveness, m is the metabolic rate of occupants, Rp is the people-based component of the ventilation rate, Ra is the area-based component of the ventilation rate, Az is the zone floor area, and Pz is the number of occupants.

These sequences are based on not having an ambient sensor. This will be conservative in areas with high ambient CO2 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 CO2-Based Demand Controlled Ventilation for Multiple Zone HVAC Systems in Direct Digital Control Systems.”

The maximum CO2 setpoint shall be calculated at 90% of the steady-state concentration.

* + - * 1. For projects complying with the California Title 24 ventilation standards:

**California Title 24 CO2 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 CO2 set point for all occupancy types is 1000 ppm.

The maximum CO2 setpoint shall be calculated either by adding 600 ppm to the ambient CO2 level

The ambient CO2 level may be measured directly or assumed to be 400 ppm.

* + 1. Zone 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.

* + - 1. VAV Cooling-Only Terminal Unit
         1. Zone maximum cooling airflow set point (Vcool-max)
         2. Zone minimum airflow set point (Vmin). This is an optional entry. If no value is scheduled, or a value of AUTO is scheduled, Vmin will be calculated automatically and dynamically to meet ventilation requirements.

In most cases, Vmin should be allowed to be automatically calculated. This ensures compliance with Standard 62.1 and Standard 90.1 prescriptive requirements and with California’s Title 24 Energy Standards requirements, and it results in the lowest energy costs.

* + - 1. VAV Reheat Terminal Unit
         1. Zone maximum cooling airflow set point (Vcool-max)
         2. Zone minimum airflow set point (Vmin). This is an optional entry. If no value is scheduled, or a value of AUTO is scheduled, Vmin will be calculated automatically and dynamically to meet ventilation requirements.

In most cases, Vmin should be allowed to be automatically calculated. This ensures compliance with Standard 62.1 and Standard 90.1 prescriptive requirements and with California’s Title 24 Energy Standards requirements, and it results in the lowest energy costs.

* + - * 1. Zone maximum heating airflow set point (Vheat-max)

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

* + - * 1. Zone maximum DAT above heating set point (MaxΔT)
        2. Zone 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.

* + - 1. Parallel Fan-Powered Terminal Unit, Constant-Volume Fan
         1. Zone maximum cooling (primary) airflow set point (Vcool-max)
         2. Zone minimum primary airflow set point (Vmin). This is an optional entry. If no value is scheduled, or a value of AUTO is scheduled, Vmin will be calculated automatically and dynamically to meet ventilation requirements.

In most cases, Vmin should be allowed to be automatically calculated. This ensures compliance with Standard 62.1 and Standard 90.1 prescriptive requirements and with California’s Title 24 Energy Standards requirements, and it results in the lowest energy costs.

* + - * 1. Zone maximum DAT above heating set point (MaxΔT)
      1. 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.

* + - * 1. Zone maximum cooling (primary) airflow set point (Vcool-max)
        2. Zone minimum primary airflow set point (Vmin). This is an optional entry. If no value is scheduled, or a value of AUTO is scheduled, Vmin will be calculated automatically and dynamically to meet ventilation requirements.

In most cases, Vmin should be allowed to be automatically calculated. This ensures compliance with Standard 62.1 and Standard 90.1 prescriptive requirements and with California’s Title 24 Energy Standards requirements, and it results in the lowest energy costs.

* + - * 1. 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 20°F above space temperature set point per ASHRAE/IES Standard 90.1-2016 (e.g., DAT no more than 90°F at 70°F space temperature set point) for systems supplying air greater than 6 ft above floor, e.g., ceiling supply systems. Zone air distribution effectiveness EzH can be improved if MaxΔT is less than 15°F, provided that the 0.8 m/s (150 fpm) supply air jet reaches to within 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.

* + - * 1. Zone maximum DAT above heating set point (MaxΔT)
      1. Series Fan-Powered Terminal Unit, Constant-Volume Fan
         1. Zone maximum cooling airflow set point (Vcool-max)
         2. Zone minimum airflow set point (Vmin). This is an optional entry. If no value is scheduled, or a value of AUTO is scheduled, Vmin will be calculated automatically and dynamically to meet ventilation requirements.

In most cases, Vmin should be allowed to be automatically calculated. This ensures compliance with Standard 62.1 and Standard 90.1 prescriptive requirements and with California’s Title 24 Energy Standards requirements, and it results in the lowest energy costs.

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 20°F above space temperature set point per ASHRAE/IES Standard 90.1-2016 (e.g., DAT no more than 90°F at 70°F space temperature set point) for systems supplying air greater than 6 ft above floor, e.g., ceiling supply systems. Zone air distribution effectiveness EzH can be improved if MaxΔT is less than 15°F, provided that the 0.8 m/s (150 fpm) supply air jet reaches to within 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.

* + - * 1. Zone maximum DAT above heating set point (MaxΔT)
      1. 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.

* + - * 1. Zone maximum cooling airflow set point (Vcool-max)
        2. Zone minimum airflow set point (Vmin). This is an optional entry. If no value is scheduled, or a value of AUTO is scheduled, Vmin will be calculated automatically and dynamically to meet ventilation requirements.

In most cases, Vmin should be allowed to be automatically calculated. This ensures compliance with Standard 62.1 and Standard 90.1 prescriptive requirements and with California’s Title 24 Energy Standards requirements, and it results in the lowest energy costs.

* + - * 1. Series fan maximum heating airflow set point (Sfan-htgmax)

The design engineer should set the Sfan-htgmax 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 20°F above space temperature set point per ASHRAE/IES Standard 90.1-2016 (e.g., DAT no more than 90°F at 70°F space temperature set point) for systems supplying air greater than 6 ft above floor, e.g., ceiling supply systems. Zone air distribution effectiveness EzH can be improved if MaxΔT is less than 15°F, provided that the 0.8 m/s (150 fpm) supply air jet reaches to within 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 Sfan-htgmax to ensure these conditions are maintained.

* + - * 1. Zone maximum DAT above heating set point (MaxΔT)
      1. Dual-Duct VAV Terminal Unit
         1. Zone maximum cooling airflow set point (Vcool-max)
         2. Zone minimum cooling airflow set point (Vcool-min). This is an optional entry. If no value is scheduled, or a value of AUTO is scheduled, Vmin will be calculated automatically and dynamically to meet ventilation requirements.
         3. Zone maximum heating airflow set point (Vheat-max)
         4. Zone minimum heating airflow set point (Vheat-min)

In most cases, Vmin should be allowed to be automatically calculated. This ensures compliance with Standard 62.1 and Standard 90.1 prescriptive requirements and with California’s Title 24 Energy Standards requirements, and it results in the lowest energy costs.

The tables below should be populated for each terminal unit. The Area and Population variables are a function of the spaces served, while Effectiveness in heating and cooling modes are a function of the air distribution system. The minimum volume (Vmin) is calculated per the ventilation standard applied. Generally, owners and operators might have records for the existing distribution system in the VAV Schedule included in older as-built documents; however, it will be up to the responsible designer (either the contractor or the design engineer) to verify the values are correct and program the values.

The population variable (Pop.) should use the best available data. Since this document is unlikely to be applied to fixed seating areas (like lecture halls, theaters, fast-casual restaurants, etc.), the responsible designer will need to select a number of occupants for each terminal unit. There are three possible sources:

• Mechanical Code: ASHRAE 62.1 is included in mechanical codes for most jurisdictions – including California. This standard provides guidance for typical occupant densities, generally in terms of number of people per 1,000 ft².

• Fire Code: NFPA 1 or other local fire code lists the occupant load. Occupant load reflects how many people could be expected to populate an area. In this document, a maximum floor area per person is provided. The total number of people can then be calculated by dividing the zone area by the area allowed per person.

• Other Known Criteria: If for whatever reason, people more densely populate a space that would otherwise be assumed by either Fire or Mechanical code, the responsible designer can provide a higher occupancy rate.

Whatever method is used to determine the population of a zone, pay careful attention to zones with mixed space uses – unique space use types will likely have different occupant densities that need to be considered.

Table 4.5.2: VAV Box Design Information – VAV Terminal Unit Cooling Only – ASHRAE 62.1

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| VAV # | Group | Cooling Airflow  Max (cfm) | Zone Ventilation Details | | | | | | | | | CO2 Set point (ppm) |
| Area | | | Population | | | Effectiveness | | Vmin |
| Area (ft²) | Rate (cfm/ft²) | Airflow (cfm) | Pop. (prs) | Rate (cfm/prs) | Airflow (cfm) | Htg (EzH) | Clg (EzC) |
| Example | Suite 101 | 400 | 1500 | 0.05 | 75 | 5 | 5 | 25 | 0.8 | 1.0 | 100 | 894 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |

Table 4.5.3: VAV Box Design Information – VAV Terminal Unit Cooling Only – Title 24

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| VAV # | Group | Cooling Airflow  Max (cfm) | Zone Ventilation Details | | | | | | | CO2 Set point (ppm) |
| Area | | | Population | | | Vmin |
| Area (ft²) | Rate (cfm/ft²) | Airflow (cfm) | Pop. (prs) | Rate (cfm/prs) | Airflow (cfm) |
| Example | Suite 101 | 400 | 1500 | 0.15 | 225 | 5 | 15 | 75 | 225 | 894 |
|  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |

Table 4.5.4: VAV Box Design Information – VAV Terminal Unit with Reheat – ASHRAE 62.1

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| VAV # | Group | Cooling Airflow | | Heating Airflow | | Max Heating  DAT ΔT  (°F) | Zone Ventilation Details | | | | | | | | | CO2 Set point (ppm) |
| Max (cfm) | Min (cfm) | Max (cfm) | Min (cfm) | Area | | | Population | | | Effectiveness | | Vmin |
| Area (ft²) | Rate (cfm/ft²) | Airflow (cfm) | Pop. (prs) | Rate (cfm/prs) | Airflow (cfm) | Htg (EzH) | Clg (EzC) |
| Example | Suite 101 | 400 | 100 | 180 | 100 |  | 1500 | 0.05 | 75 | 5 | 5 | 25 | 0.8 | 1.0 | 100 | 894 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table 4.5.5: VAV Box Design Information – VAV Terminal Unit with Reheat – Title 24

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| VAV # | Group | Cooling Airflow | | Heating Airflow | | Max Heating  DAT ΔT  (°F) | Zone Ventilation Details | | | | | | | CO2 Set point (ppm) |
| Max (cfm) | Min (cfm) | Max (cfm) | Min (cfm) | Area | | | Population | | | Vmin |
| Area (ft²) | Rate (cfm/ft²) | Airflow (cfm) | Pop. (prs) | Rate (cfm/prs) | Airflow (cfm) |
| Example | Suite 101 | 400 | 100 | 180 | 100 |  | 1500 | 0.15 | 225 | 5 | 15 | 75 | 225 | 894 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table 4.5.6: VAV Box Design Information – Parallel Fan-Powered Terminal Unit – Constant Speed – ASHRAE 62.1

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| VAV # | Group | Cooling Airflow  Max (cfm) | Max Heating  DAT  ΔT  (°F) | Zone Ventilation Details | | | | | | | | | CO2 Set point (ppm) |
| Area | | | Population | | | Effectiveness | | Vmin |
| Area (ft²) | Rate (cfm/ft²) | Airflow (cfm) | Pop. (prs) | Rate (cfm/prs) | Airflow (cfm) | Htg (EzH) | Clg (EzC) |
| Example | Suite 101 | 400 | 20 | 1500 | 0.05 | 75 | 5 | 5 | 25 | 0.8 | 1.0 | 100 | 894 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table 4.5.7: VAV Box Design Information – Parallel Fan-Powered Terminal Unit – Constant Speed - Title 24

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| VAV # | Group | Cooling Airflow  Max (cfm) | Max Heating  DAT  ΔT  (°F) | Zone Ventilation Details | | | | | | | CO2 Set point (ppm) |
| Area | | | Population | | | Vmin |
| Area (ft²) | Rate (cfm/ft²) | Airflow (cfm) | Pop. (prs) | Rate (cfm/prs) | Airflow (cfm) |
| Example | Suite 101 | 400 | 20 | 1500 | 0.15 | 225 | 5 | 15 | 75 | 225 | 894 |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |

Table 4.5.8: VAV Box Design Information – Parallel Fan-Powered Terminal Unit – Variable Speed – ASHRAE 62.1

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| VAV # | Group | Cooling Airflow  Max (cfm) | Series Fan Max Heating Airflow (cfm) | Max Heating  DAT  ΔT  (°F) | Zone Ventilation Details | | | | | | | | | CO2 Set point (ppm) |
| Area | | | Population | | | Effectiveness | | Vmin |
| Area (ft²) | Rate (cfm/ft²) | Airflow (cfm) | Pop. (prs) | Rate (cfm/prs) | Airflow (cfm) | Htg (EzH) | Clg (EzC) |
| Example | Suite 101 | 400 | 100 | 20 | 1500 | 0.05 | 75 | 5 | 5 | 25 | 0.8 | 1.0 | 100 | 894 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table 4.5.9: VAV Box Design Information – Parallel Fan-Powered Terminal Unit – Variable Speed - Title 24

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| VAV # | Group | Cooling Airflow  Max (cfm) | Series Fan Max Heating Airflow (cfm) | Max Heating  DAT  ΔT  (°F) | Zone Ventilation Details | | | | | | | CO2 Set point (ppm) |
| Area | | | Population | | | Vmin |
| Area (ft²) | Rate (cfm/ft²) | Airflow (cfm) | Pop. (prs) | Rate (cfm/prs) | Airflow (cfm) |
| Example | Suite 101 | 400 | 100 | 20 | 1500 | 0.15 | 225 | 5 | 15 | 75 | 225 | 894 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |

Table 4.5.10: VAV Box Design Information – Series Fan-Powered Terminal Unit – Constant Speed – ASHRAE 62.1

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| VAV # | Group | Cooling Airflow  Max (cfm) | Max Heating  DAT  ΔT  (°F) | Zone Ventilation Details | | | | | | | | | CO2 Set point (ppm) |
| Area | | | Population | | | Effectiveness | | Vmin |
| Area (ft²) | Rate (cfm/ft²) | Airflow (cfm) | Pop. (prs) | Rate (cfm/prs) | Airflow (cfm) | Htg (EzH) | Clg (EzC) |
| Example | Suite 101 | 400 | 20 | 1500 | 0.05 | 75 | 5 | 5 | 25 | 0.8 | 1.0 | 100 | 894 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table 4.5.11: VAV Box Design Information – Series Fan-Powered Terminal Unit – Constant Speed - Title 24

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| VAV # | Group | Cooling Airflow  Max (cfm) | Max Heating  DAT  ΔT  (°F) | Zone Ventilation Details | | | | | | | CO2 Set point (ppm) |
| Area | | | Population | | | Vmin |
| Area (ft²) | Rate (cfm/ft²) | Airflow (cfm) | Pop. (prs) | Rate (cfm/prs) | Airflow (cfm) |
| Example | Suite 101 | 400 | 20 | 1500 | 0.15 | 225 | 5 | 15 | 75 | 225 | 894 |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |

Table 4.5.12: VAV Box Design Information – Series Fan-Powered Terminal Unit – Variable Speed – ASHRAE 62.1

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| VAV # | Group | Cooling Airflow  Max (cfm) | Series Fan Max Heating Airflow (cfm) | Max Heating  DAT  ΔT  (°F) | Zone Ventilation Details | | | | | | | | | CO2 Set point (ppm) |
| Area | | | Population | | | Effectiveness | | Vmin |
| Area (ft²) | Rate (cfm/ft²) | Airflow (cfm) | Pop. (prs) | Rate (cfm/prs) | Airflow (cfm) | Htg (EzH) | Clg (EzC) |
| Example | Suite 101 | 400 | 100 | 20 | 1500 | 0.05 | 75 | 5 | 5 | 25 | 0.8 | 1.0 | 100 | 894 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table 4.5.13: VAV Box Design Information – Series Fan-Powered Terminal Unit – Variable Speed - Title 24

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| VAV # | Group | Cooling Airflow  Max (cfm) | Series Fan Max Heating Airflow (cfm) | Max Heating  DAT  ΔT  (°F) | Zone Ventilation Details | | | | | | | CO2 Set point (ppm) |
| Area | | | Population | | | Vmin |
| Area (ft²) | Rate (cfm/ft²) | Airflow (cfm) | Pop. (prs) | Rate (cfm/prs) | Airflow (cfm) |
| Example | Suite 101 | 400 | 100 | 20 | 1500 | 0.15 | 225 | 5 | 15 | 75 | 225 | 894 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |

Table 4.5.14: VAV Box Design Information – Dual Duct VAV Terminal Unit – ASHRAE 62.1

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| VAV # | Group | Cooling Airflow | | Heating Airflow | | Zone Ventilation Details | | | | | | | | | CO2 Set point (ppm) |
| Max (cfm) | Min (cfm) | Max (cfm) | Min (cfm) | Area | | | Population | | | Effectiveness | | Vmin |
| Area (ft²) | Rate (cfm/ft²) | Airflow (cfm) | Pop. (prs) | Rate (cfm/prs) | Airflow (cfm) | Htg (EzH) | Clg (EzC) |
| Example | Suite 101 | 400 | 100 | 180 | 100 | 1500 | 0.05 | 75 | 5 | 5 | 25 | 0.8 | 1.0 | 100 | 894 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table 4.5.15: VAV Box Design Information – Dual Duct VAV Terminal Unit – Title 24

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| VAV # | Group | Cooling Airflow | | Heating Airflow | | Zone Ventilation Details | | | | | | | CO2 Set point (ppm) |
| Max (cfm) | Min (cfm) | Max (cfm) | Min (cfm) | Area | | | Population | | | Vmin |
| Area (ft²) | Rate (cfm/ft²) | Airflow (cfm) | Pop. (prs) | Rate (cfm/prs) | Airflow (cfm) |
| Example | Suite 101 | 400 | 100 | 180 | 100 | 1500 | 0.15 | 225 | 5 | 15 | 75 | 225 | 894 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Table 4.5.16: Multizone Air Handler Design Variables

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Unit ID | Temperature Setpoints | | | | Ventilation Setpoints | | Economizer High Limit |
| Min\_ClgSAT | Max\_ClgSAT | OAT\_Min | OAT\_Max | DesVou | DesVot |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |

Table 4.5.17: Dual Duct, Cooling-Only Air Handler Design Variables

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Unit ID | Temperature Setpoints | | | | | Ventilation Setpoints | | Economizer High Limit |
| Min\_ClgSAT | Max\_ClgSAT | OAT\_Min | OAT\_Max | Max\_HtgSAT | DesVou | DesVot |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |

Table 4.5.18: Dual Duct, Heating-Only Ventilating Air Handler Design Variables

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Unit ID | Temperature Setpoints | | | | Ventilation Setpoints | | Economizer High Limit |
| Min\_HtgSAT | Max\_HtgSAT | OAT\_Min | OAT\_Max | DesVou | DesVot |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |

Table 4.5.19: Dual Duct, Heating-Only Recirculating Air Handler Design Variables

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Unit ID | Temperature Setpoints | | | |
| Min\_HtgSAT | Max\_HtgSAT | OAT\_Min | OAT\_Max |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

Table 4.5.20: VAV Single-Zone Air Handler Design Variables

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Unit ID | Temperature Setpoints | | | Ventilation Setpoints | | Economizer High Limit |
| Cool\_SAT | Heat\_SAT | MaxDPT | DesVou | DesVot |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |

* + 1. Zone Group Assignments

For the purposes of these sequences we draw a distinction between the “occupied” and “populated”. A building, zone-group, or zone is “occupied” when occupants are expected to be present (e.g. normal business hours). A building, zone-group, or zone is “populated” when a sensor detects a person is present (usually via occupancy sensor, possibly by CO2 sensor).

The building operator or client should determine what the occupancy period is for each space type and update this section as appropriate.

Table 4.5.21: Zone Groups & Occupancy Schedules

|  |  |  |  |
| --- | --- | --- | --- |
| Zone Group Name | AH Tag | Terminal Unit Tags | Occupancy Schedule |
| Suite 101 | AH-1 | VAV 1-1 thru 1-10 | M-F: 7 a.m. to 8 p.m.  S-S: N/A  Holiday: N/A |
| Suite 102 | AH-1 | VAV 1-11 thru 1-17 | M-F: 7 a.m. to 8 p.m.  Sat: 8 a.m. to 1 p.m.  Sun: N/A  Holiday: N/A |
| Suite 2 Server Closet | HP-1 | N/A | 24/7 |
| Entrance Lobby | AH-4 | N/A | M-F 4 a.m. to 12 a.m.  S-S: 7 a.m. to 8 p.m.  Holiday: N/A |

Note, operating modes like warm-up or setback mode will be handled algorithmically.

Zones must be assigned to zone groups, such as by using a table (see example Informative Table 4.5.21) 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 m2 (25,000 ft2) (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.

* + 1. Multiple-zone VAV Air Handler Design Information
       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.

* + - * 1. 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.

* + - * 1. Max\_ClgSAT, highest cooling supply air temperature set point

The Max\_ClgSAT variable is typically 65°F in mild and dry climates and 60°F or lower in humid climates. It should not typically be greater than 65°F because this may lead to excessive fan energy that can off-set the mechanical cooling savings from economizer operation.

* + - * 1. OAT\_Min, the lower value of the OAT reset range
        2. 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 = 60°F and

OAT\_Max = 70°F,

selected to maximize economizer operation and minimize reheat losses, offset partially by higher fan energy. A lower range, e.g., 65°F and 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.

* + - 1. Ventilation Set Points
         1. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1:

DesVou, the uncorrected design outdoor air rate, including diversity where applicable

DesVot, design total outdoor air rate (Vou adjusted for ventilation efficiency)

* + - * 1. For projects complying with California Title 24 Ventilation Standards:

AbsMinOA, the design outdoor air rate when all zones with CO2 sensors or occupancy sensors are unpopulated

DesMinOA, the design minimum outdoor airflow with areas served by the system are occupied at their design population, including diversity where applicable

* + - 1. Economizer High Limit (Economizer Lockout)
         1. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1, the fixed dry bulb high limit shall be 75°F.
         2. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1, the fixed dry bulb high limit shall be 70°F.
         3. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1, the fixed dry bulb high limit shall be 65°F.
         4. For projects complying with California Title 24 Ventilation Standards, the fixed dry bulb high limit shall be 75°F.
         5. For projects complying with California Title 24 Ventilation Standards, the fixed dry bulb high limit shall be 73°F.
         6. For projects complying with California Title 24 Ventilation Standards, the fixed dry bulb high limit shall be 71°F.
         7. For projects complying with California Title 24 Ventilation Standards, the fixed dry bulb high limit shall be 69°F.
         8. The high limit shall be determined by fixed dry bulb temperature, as listed in the following tables by climate zone.

Table 4.5.22 lists the requirements for ASHRAE/IES 90.1-2016

Table 4.5.23 lists the requirements for Title 24-2016.

Note, we’ve selected fixed dry bulb as the only economizer control strategy. Enthalpy control sequences (combining sensible/dry-bulb and latent/humidity) approaches are available in ASHRAE Guideline 36; however, we’ve elected to exclude them due to the notorious inaccuracies associated with humidity sensing. The required recalibration interval does not lend itself to reliable control. Humidity controls should be avoided unless absolutely necessary for the overall success of the project (e.g. Museums, healthcare, etc.).

Table 4.5.22: ASHRAE/IES 90.1-2016 Economizer Control Strategies

|  |  |  |
| --- | --- | --- |
| Economizer Control Strategy | ASHRAE Climate Zones Allowed to Use this Strategy (ASHRAE 90.1-2016) | Required High Limit  (Economizer OFF when) |
| Fixed Dry Bulb | 1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8 | TOA > 75°F |
| 5a, 6a | TOA > 70°F |
| 1a, 2a, 3a, 4a | TOA > 65°F |

Table 4.5.23: Title 24-2016 Economizer Control Strategies

|  |  |  |
| --- | --- | --- |
| Economizer Control Strategy | California Climate Zones Allowed to Use this Strategy (Title 24-2016) | Required High Limit  (Economizer OFF when) |
| Fixed Dry Bulb | 1, 3, 5, 11, 12, 13, 14, 15, 16 | TOA > 75°F |
| 2, 4, 10 | TOA > 73°F |
| 6, 8, 9 | TOA > 71°F |
| 7 | TOA > 69°F |

* + 1. Dual-Fan, Dual Duct – Cooling Only VAV Air Handler Design Information
       1. Temperature Set Points
          1. 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.

* + - * 1. Max\_ClgSAT, highest cooling supply air temperature set point

The Max\_ClgSAT variable is typically 65°F in mild and dry climates and 60°F or lower in humid climates. It should not typically be greater than 65°F because this may lead to excessive fan energy that can off-set the mechanical cooling savings from economizer operation.

* + - * 1. OAT\_Min, the lower value of the OAT reset range
        2. OAT\_Max, the higher value of the OAT reset range
        3. Max\_HtgSAT, highest heating supply air temperature, typically design heating coil leaving air temperature

Max\_HtgSAT can be no higher than 20°F above space temperature set point per Standard 90.1-2016 (e.g., no more than 90°F at 70°F space temperature set point) for systems supplying air greater than 6 ft above floor, e.g., ceiling supply systems. Zone air distribution effectiveness EzH can be improved if Max\_HtgSAT is less than 15°F, provided that the 150 fpm supply air jet reaches to within 4.5 ft of floor level as indicated in ASHRAE Standard 62.1-2016, Table 6.2.2.2.

* + - 1. Ventilation Set Points
         1. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1:

DesVou, the uncorrected design outdoor air rate, including diversity where applicable

DesVot, design total outdoor air rate (Vou adjusted for ventilation efficiency)

* + - * 1. For projects complying with California Title 24 Ventilation Standards:

AbsMinOA, the design outdoor air rate when all zones with CO2 sensors or occupancy sensors are unpopulated

DesMinOA, the design minimum outdoor airflow with areas served by the system are occupied at their design population, including diversity where applicable

* + - 1. Economizer High Limit (Economizer Lockout)
         1. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1, the fixed dry bulb high limit shall be 75°F.
         2. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1, the fixed dry bulb high limit shall be 70°F.
         3. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1, the fixed dry bulb high limit shall be 65°F.
         4. For projects complying with California Title 24 Ventilation Standards, the fixed dry bulb high limit shall be 75°F.
         5. For projects complying with California Title 24 Ventilation Standards, the fixed dry bulb high limit shall be 73°F.
         6. For projects complying with California Title 24 Ventilation Standards, the fixed dry bulb high limit shall be 71°F.
         7. For projects complying with California Title 24 Ventilation Standards, the fixed dry bulb high limit shall be 69°F.
         8. The high limit shall be determined by fixed dry bulb temperature, as listed in the following tables by climate zone.

Table 4.5.22 lists the requirements for ASHRAE/IES 90.1-2016

Table 4.5.23 lists the requirements for Title 24-2016.

Note, we’ve selected fixed dry bulb as the only economizer control strategy. Enthalpy control sequences (combining sensible/dry-bulb and latent/humidity) approaches are available in ASHRAE Guideline 36; however, we’ve elected to exclude them due to the notorious inaccuracies associated with humidity sensing. The required recalibration interval does not lend itself to reliable control. Humidity controls should be avoided unless absolutely necessary for the overall success of the project (e.g. Museums, healthcare, etc.).

Table 4.5.24: ASHRAE/IES 90.1-2016 Economizer Control Strategies

|  |  |  |
| --- | --- | --- |
| Economizer Control Strategy | ASHRAE Climate Zones Allowed to Use this Strategy (ASHRAE 90.1-2016) | Required High Limit  (Economizer OFF when) |
| Fixed Dry Bulb | 1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8 | TOA > 75°F |
| 5a, 6a | TOA > 70°F |
| 1a, 2a, 3a, 4a | TOA > 65°F |

Table 4.5.25: Title 24-2016 Economizer Control Strategies

|  |  |  |
| --- | --- | --- |
| Economizer Control Strategy | California Climate Zones Allowed to Use this Strategy (Title 24-2016) | Required High Limit  (Economizer OFF when) |
| Fixed Dry Bulb | 1, 3, 5, 11, 12, 13, 14, 15, 16 | TOA > 75°F |
| 2, 4, 10 | TOA > 73°F |
| 6, 8, 9 | TOA > 71°F |
| 7 | TOA > 69°F |

* + 1. Dual-Fan, Dual Duct – Heating Only Ventilating VAV Air Handler Design Information
       1. Temperature Set Points
          1. Min\_HtgSAT, 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.

* + - * 1. Max\_HtgSAT, highest cooling supply air temperature set point

The Max\_ClgSAT variable is typically 65°F in mild and dry climates and 60°F or lower in humid climates. It should not typically be greater than 65°F because this may lead to excessive fan energy that can off-set the mechanical cooling savings from economizer operation.

* + - * 1. OAT\_Min, the lower value of the OAT reset range
        2. OAT\_Max, the higher value of the OAT reset range

Max\_HtgSAT can be no higher than 20°F above space temperature set point per Standard 90.1-2016 (e.g., no more than 90°F at 70°F space temperature set point) for systems supplying air greater than 6 ft above floor, e.g., ceiling supply systems. Zone air distribution effectiveness EzH can be improved if Max\_HtgSAT is less than 15°F, provided that the 150 fpm supply air jet reaches to within 4.5 ft of floor level as indicated in ASHRAE Standard 62.1-2016, Table 6.2.2.2.

* + - 1. Ventilation Set Points
         1. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1:

DesVou, the uncorrected design outdoor air rate, including diversity where applicable

DesVot, design total outdoor air rate (Vou adjusted for ventilation efficiency)

* + - * 1. For projects complying with California Title 24 Ventilation Standards:

AbsMinOA, the design outdoor air rate when all zones with CO2 sensors or occupancy sensors are unpopulated

DesMinOA, the design minimum outdoor airflow with areas served by the system are occupied at their design population, including diversity where applicable

* + - 1. Economizer High Limit (Economizer Lockout)
         1. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1, the fixed dry bulb high limit shall be 75°F.
         2. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1, the fixed dry bulb high limit shall be 70°F.
         3. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1, the fixed dry bulb high limit shall be 65°F.
         4. For projects complying with California Title 24 Ventilation Standards, the fixed dry bulb high limit shall be 75°F.
         5. For projects complying with California Title 24 Ventilation Standards, the fixed dry bulb high limit shall be 73°F.
         6. For projects complying with California Title 24 Ventilation Standards, the fixed dry bulb high limit shall be 71°F.
         7. For projects complying with California Title 24 Ventilation Standards, the fixed dry bulb high limit shall be 69°F.
         8. The high limit shall be determined by fixed dry bulb temperature, as listed in the following tables by climate zone.

Table 4.5.22 lists the requirements for ASHRAE/IES 90.1-2016

Table 4.5.23 lists the requirements for Title 24-2016.

Note, we’ve selected fixed dry bulb as the only economizer control strategy. Enthalpy control sequences (combining sensible/dry-bulb and latent/humidity) approaches are available in ASHRAE Guideline 36; however, we’ve elected to exclude them due to the notorious inaccuracies associated with humidity sensing. The required recalibration interval does not lend itself to reliable control. Humidity controls should be avoided unless absolutely necessary for the overall success of the project (e.g. Museums, healthcare, etc.).

Table 4.5.26: ASHRAE/IES 90.1-2016 Economizer Control Strategies

|  |  |  |
| --- | --- | --- |
| Economizer Control Strategy | ASHRAE Climate Zones Allowed to Use this Strategy (ASHRAE 90.1-2016) | Required High Limit  (Economizer OFF when) |
| Fixed Dry Bulb | 1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8 | TOA > 75°F |
| 5a, 6a | TOA > 70°F |
| 1a, 2a, 3a, 4a | TOA > 65°F |

Table 4.5.27: Title 24-2016 Economizer Control Strategies

|  |  |  |
| --- | --- | --- |
| Economizer Control Strategy | California Climate Zones Allowed to Use this Strategy (Title 24-2016) | Required High Limit  (Economizer OFF when) |
| Fixed Dry Bulb | 1, 3, 5, 11, 12, 13, 14, 15, 16 | TOA > 75°F |
| 2, 4, 10 | TOA > 73°F |
| 6, 8, 9 | TOA > 71°F |
| 7 | TOA > 69°F |

* + 1. Dual-Fan, Dual Duct – Heating Only Recirculating VAV Air Handler Design Information
       1. Temperature Set Points
          1. Min\_HtgSAT, 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.

* + - * 1. Max\_HtgSAT, highest cooling supply air temperature set point

The Max\_ClgSAT variable is typically 65°F in mild and dry climates and 60°F or lower in humid climates. It should not typically be greater than 65°F because this may lead to excessive fan energy that can off-set the mechanical cooling savings from economizer operation.

* + - * 1. OAT\_Min, the lower value of the OAT reset range
        2. OAT\_Max, the higher value of the OAT reset range

Max\_HtgSAT can be no higher than 20°F above space temperature set point per Standard 90.1-2016 (e.g., no more than 90°F at 70°F space temperature set point) for systems supplying air greater than 6 ft above floor, e.g., ceiling supply systems. Zone air distribution effectiveness EzH can be improved if Max\_HtgSAT is less than 15°F, provided that the 150 fpm supply air jet reaches to within 4.5 ft of floor level as indicated in ASHRAE Standard 62.1-2016, Table 6.2.2.2.

* + 1. Single-Zone VAV Air-Handler Design Information
       1. Temperature & Humidity Set Points
          1. Cool\_SAT, lowest cooling supply air temperature set point
          2. Heat\_SAT, highest heating supply air temperature set point

Cool\_SAT is typically the design coil leaving air temperature. Heat\_SAT is typically the design coil leaving air temperature, no more than 20°F above the active heating set point.

* + - * 1. MaxDPT, maximum supply air dew-point temperature
      1. Ventilation Set Points
         1. For projects complying with Ventilation Rate Procedures of ASHRAE Standard 62.1:

MinOA, the design outdoor air rate when the zone with a CO2 sensor served by the system is unpopulated. MinOA shall equal Vbz-A/EzC.

DesOA, the design outdoor air rate when the zone served by the system is occupied at its design population, including diversity where applicable. DesOA shall equal (Vbz-A+Vbz-P)/EzH.

* + - * 1. For projects complying with the California Title 24 ventilation standards:

MinOA, the design outdoor air rate when the zone with a CO2 sensor served by the system is unpopulated. MinOA shall equal Varea-min.

DesOA, the design outdoor air rate when the zone is served by the system is occupied at its design population, including diversity where applicable. DesOA shall equal larger of Varea-min and Vocc-min.

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 62°F. For mild and dry climates, a high set point (e.g. 75°F) should be entered for maximum efficiency.

* + - 1. Economizer High Limit (Economizer Lockout)
         1. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1, the fixed dry bulb high limit shall be 75°F.
         2. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1, the fixed dry bulb high limit shall be 70°F.
         3. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1, the fixed dry bulb high limit shall be 65°F.
         4. For projects complying with California Title 24 Ventilation Standards, the fixed dry bulb high limit shall be 75°F.
         5. For projects complying with California Title 24 Ventilation Standards, the fixed dry bulb high limit shall be 73°F.
         6. For projects complying with California Title 24 Ventilation Standards, the fixed dry bulb high limit shall be 71°F.
         7. For projects complying with California Title 24 Ventilation Standards, the fixed dry bulb high limit shall be 69°F.
         8. The high limit shall be determined by fixed dry bulb temperature, as listed in the following tables by climate zone.

Table 4.5.22 lists the requirements for ASHRAE/IES 90.1-2016

Table 4.5.23 lists the requirements for Title 24-2016.

Note, we’ve selected fixed dry bulb as the only economizer control strategy. Enthalpy control sequences (combining sensible/dry-bulb and latent/humidity) approaches are available in ASHRAE Guideline 36; however, we’ve elected to exclude them due to the notorious inaccuracies associated with humidity sensing. The required recalibration interval does not lend itself to reliable control. Humidity controls should be avoided unless absolutely necessary for the overall success of the project (e.g. Museums, healthcare, etc.).

Table 4.5.28: ASHRAE/IES 90.1-2016 Economizer Control Strategies

|  |  |  |
| --- | --- | --- |
| Economizer Control Strategy | ASHRAE Climate Zones Allowed to Use this Strategy (ASHRAE 90.1-2016) | Required High Limit  (Economizer OFF when) |
| Fixed Dry Bulb | 1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8 | TOA > 75°F |
| 5a, 6a | TOA > 70°F |
| 1a, 2a, 3a, 4a | TOA > 65°F |

Table 4.5.29: Title 24-2016 Economizer Control Strategies

|  |  |  |
| --- | --- | --- |
| Economizer Control Strategy | California Climate Zones Allowed to Use this Strategy (Title 24-2016) | Required High Limit  (Economizer OFF when) |
| Fixed Dry Bulb | 1, 3, 5, 11, 12, 13, 14, 15, 16 | TOA > 75°F |
| 2, 4, 10 | TOA > 73°F |
| 6, 8, 9 | TOA > 71°F |
| 7 | TOA > 69°F |

## Testing, Adjusting, and Balancing Variables

* + 1. Multiple-Zone Air Handler Information
       1. Duct Design Maximum Static Pressure
       2. Minimum Fan Speed
          1. 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:

Supply fan

Return fan

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 equipment 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.

* + - 1. Ventilation Plenum Pressures (For minimum outdoor air control with separate outdoor air damper and differential pressure [DP] control, see the AHU sequence of operations.)
         1. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1:

DesMinDP, the design minimum outdoor air damper DP that provides the design minimum outdoor airflow DesVot

* + - * 1. For projects complying with California Title 24 Ventilation Standards:

AbsMinDP, the absolute minimum outdoor air damper DP that provides an outdoor airflow equal to the absolute minimum outdoor airflow AbsMinOA

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.

* + - 1. Return-Fan Discharge Static Pressure Setpoints (For return-fan direct building pressure control, see see the AHU sequence of operations.)
         1. 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.
         2. RFDSPmax. That required to exhaust enough air to maintain building static pressure at set point 0.05 in. of water when the supply air fan is at design airflow and on 100% outdoor air.
      2. Return-Fan Air-Flow Differential
         1. S-R-DIFF. The airflow differential between supply air and return air fans required to maintain building pressure at desired pressure (e.g., 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.
    1. Dual Duct Air Handler Information
       1. Duct Design Maximum Static Pressure
       2. Minimum Fan Speed
          1. 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:

Supply fan

Return fan

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 equipment 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.

* + - 1. Ventilation Plenum Pressures (For minimum outdoor air control with separate outdoor air damper and differential pressure [DP] control, see the AHU sequence of operations)
         1. For projects complying with the Ventilation Rate Procedure of ASHRAE Standard 62.1:

DesMinDP, the design minimum outdoor air damper DP that provides the design minimum outdoor airflow DesVot

* + - * 1. For projects complying with California Title 24 Ventilation Standards:

AbsMinDP, the absolute minimum outdoor air damper DP that provides an outdoor airflow equal to the absolute minimum outdoor airflow AbsMinOA

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.

* + - 1. Return-Fan Discharge Static Pressure Setpoints (For return-fan direct building pressure control, see see the AHU sequence of operations.)
         1. 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.
         2. RFDSPmax. That required to exhaust enough air to maintain building static pressure at set point 0.05 in. of water when the supply air fan is at design airflow and on 100% outdoor air.
      2. Return-Fan Air-Flow Differential
         1. S-R-DIFF. The airflow differential between supply air and return air fans required to maintain building pressure at desired pressure (e.g., 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.
    1. Single-Zone Air Handler Information
       1. Supply-Fan Speed Setpoints
          1. MinSpeed. The speed that provides supply airflow equal to DesOA (see Section 4.6 C. 2) with the economizer out-door air damper fully open.
          2. 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.
          3. MaxCoolSpeed. The speed that provides supply airflow equal to the design cooling airflow scheduled on plans.
       2. Minimum Outside Air Damper Position (for systems without outdoor airflow measuring stations)

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).

* + - * 1. MinPosMin. The outdoor air damper position required to provide MinOA when the supply fan is at MinSpeed.
        2. MinPosMax. The outdoor air damper position required to provide MinOA when the supply fan is at MaxCoolSpeed.
        3. DesPosMin. The outdoor air damper position required to provide DesOA when the supply fan is at MinSpeed.
        4. DesPosMax. The outdoor air damper position required to provide DesOA when the supply fan is at MaxCoolSpeed.
      1. Relief-Damper Positions (for relief using motorized dampers)
         1. MinRelief. The relief-damper position that maintains a building pressure of 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).
         2. MaxRelief. The relief-damper position that maintains a building pressure of 0.05 in. of water while the economizer damper is fully open and the fan speed is at cooling maximum.
      2. Return-Fan Speed Differential (for Return Fan Speed Tracking Control). The speed differential between supply air and return air fans S-R-SPD-DIFF, required to maintain building pressure at desired pressure (e.g., 0.05 in. of water) using a hand-held sensor if a permanent sensor is not provided. All exhaust fans that normally operate with the air handler should be on.
      3. Return fan discharge static pressure setpoints (for Return Fan Direct Building Pressure Control):
         1. 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 setpoint shall be no less than 2.4 Pa (0.01 inches) to ensure outdoor air is not drawn backwards through the relief damper.
         2. RFDSPmax: That required to exhaust enough air to maintain building static pressure at setpoint 12 Pa (0.05 inches) when the supply air fan is at design airflow and on 100% outdoor air.

## HVAC General Sequence Information

* + 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.

* + 1. Unless otherwise indicated, control loops shall be enabled and disabled based on the status of the system being controlled to prevent windup.
    2. 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.
    3. 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.
    4. 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.
       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.
       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. 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.
    6. 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).
    7. 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.
       1. Use proportional only (P-only) loops for limiting loops (such as zone CO2 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.

* + - 1. 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.

* + 1. 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.
    2. 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.
    3. 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.

* + 1. 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 post-suppression 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 4.7 R, that serves the equipment in alarm.

* + - 1. There shall be 4 levels of alarm
         1. Level 1: Life-safety message
         2. Level 2: Critical equipment message
         3. Level 3: Urgent message
         4. Level 4: Normal message
      2. Maintenance Mode. Operators shall have the ability to put any device (e.g., AHU) in/out of maintenance mode.
         1. All alarms associated with a device in maintenance mode will be suppressed. Exception: Life safety alarms shall not be suppressed.
         2. 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.
      3. Exit Hysteresis
         1. Each alarm shall have an adjustable time delay (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 delay.
         2. 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.

* + - 1. Latching. 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:
         1. Level1 alarms: latching
         2. Level 2 alarms: latching
         3. Level 3 alarms: nonlatching
         4. Level 4 alarms: nonlatching
      2. Postexit Suppression Period. To limit alarms, any alarm may have an adjustable suppression period such that once the alarm is exited, its post-exit suppression timer is trig-gered and the alarm may not trigger again until the post-exit suppression timer has expired. Default suppression periods are as follows:
         1. Level 1 alarms: 0 minutes
         2. Level 2 alarms: 5 minutes
         3. Level 3 alarms: 24 hours
         4. Level 4 alarms: 7 days

Note that post-suppression 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.

* + 1. 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 pro-tect 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.

* + - 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.

* + - 1. For each piece of equipment, the minimum speed shall be stored in a single software point; 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 4.6 A. 2 for minimum speed set points. The active minimum speed parameter shall be read every 60 minutes via the drive’s network interface. When a mismatch between the drive’s active minimum speed and the minimum speed stored in the software point is detected, the minimum speed stored in the software point shall be written to the VFD via the network interface to restore the active minimum speed parameter to its default value, and generate a Level 4 alarm.
    1. 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 for multi-zoned systems. 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 4.7 N. 4 for an example of T&R implementation.

* + - 1. T&R set-point reset logic and zone/system reset requests, where referenced in sequences, shall be implemented as described below.
      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.
         1. 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:

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.

Request-Hours Accumulator. Provided SystemOK (see Section 4.7S4.7 S) 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.

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.

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.

The Request-Hours Accumulator and System Run-Hours Total are reset to zero as follows:

Reset automatically for an individual zone/system when the System Run-Hours Total exceeds 400 hours.

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

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.

* + - * 1. See zone and air-handling system control sequences for logic to generate requests.
        2. 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.
      1. 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 4.7.1

Table 4.7.1: Trim & Response Variables

|  |  |
| --- | --- |
| Variable | Definition |
| Device | Associated Device |
| SP0 | Initial T&R set point |
| SPmin | Minimum allowed T&R set point |
| SPmax | Maximum allowed T&R set point |
| Td | Delay timer |
| T | Time step |
| I | Number of ignored requests |
| R | Number of requests from downstream devices |
| SPtrim | T&R set point trim amount (when downstream devices are satisfied) |
| SPres | T&R set point response amount (when downstream devices are unsatisfied) |
| SPrex-max | Maximum allowed T&R set point response amount per time step |

The number of ignored requests (I) can be set to zero. This should be done for spaces with critical loads or occupants.

* + - 1. 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.   
         If R <= I, change setpoint by SPtrim  
         If R > I, change set point by (R – I)\*SPres but no larger than SPres-max
    1. Equipment Staging and Rotation
       1. Parallel equipment shall be lead/lag or lead/standby rotated to maintain even wear.
       2. Two runtime points shall be defined for each equipment:
          1. Lifetime Runtime: The cumulative runtime of the equipment since equipment start-up. This point shall not be readily resettable by operators.

Lifetime Runtime should be stored to a software point on the control system server so the recorded value is not lost due to controller reset, loss of power, programming file update, etc.

* + - * 1. Staging Runtime: An operator resettable runtime point that stores cumulative runtime since the last operator reset.

Staging Runtime provides a resettable runtime counter, which allows for reset of the staging runtime hours used for lead/lag or lead/standby rotation between maintenance intervals or equipment replacement while maintaining a separate log of the Lifetime Runtime. If runtime were not resettable, and logic relied only on Lifetime Runtime for determining staging lead/lag position, newly added equipment could run for years as the lead equipment before swapping rotation positions with older equipment per the logic below.

* + - 1. Lead/lag equipment: Unless otherwise noted, identical parallel staged equipment (such as CHW pumps and cooling towers) shall be lead/lag alternated when more than one is off or more than one is on so that the equipment with the most operating hours as determined by Staging Runtime is made the last stage equipment and the one with the least number of hours is made the lead stage equipment.

This strategy effectively makes it such that equipment are not “hot swapped”, e.g., a pump would not be started and another stopped during operation just for runtime equalization. For example, assume there are two equipment and only one is on, but the operating equipment has exceeded the run hours of the disabled equipment. The equipment will not rotate positions until either a stage up or down occurs. If the plant stages up, then both equipment will be on and lead/lag position will switch; when the plant next stages down, the former lead equipment with more run hours will then turn off.

Expanding further, for a plant with three equipment, if all three are off or all are on, the staging order will simply be based on run hours from lowest to highest. If two equipment are on, the one with more hours will be set to be stage 2 while the other is set to stage 1; this may be the reverse of the operating order when the equipment were started. If two of the equipment are off, the one with the more hours will be set to be stage 3 while the other is set to stage 2; this may be the reverse of the operating order when the equipment were stopped.

Example with three pumps:

1. P-1 (1000 hours), 2 (950 hours), and 3 (900 hours) are all off. Staging logic makes lead/lag order: 3, 2, 1.

2. P-3 starts. Logic does not change its order since it is on by itself.

3. P-3 runs for 51 hours. Since it is on and others off, the lead/lag order does not change. It can run this way indefinitely and the order does not change.

4. There is then a stage-up command. P-2 (the next in lead/lag order) is started. So, both P-2 and P-3 are on. P-3 now has more run hours than P-2. So, the Lead/lag order changes to: 2, 3, 1.

5. These two pumps run another 51 hours. Run times are P-1 (1000 hours), P-2 (1001), and P-3 (1002). No changes are made to lead/lag order because P-1 is off alone.

6. There is a stage down command. P-2 is now lead so it stays on. P-3 is shut off. The order for the two off pumps is now adjusted because P-1 has fewest run hours. Lead/lag order is now: 2, 1, 3.

7. P-2 runs for 100 more hours. It now has the longest runtime, but order does not change since it is on alone. Order is still 2, 1, 3.

8. There is a stage down or plant-off command. P-2 shuts off. Run times are P-1 (1000 hours), P-2 (1101), and P-3 (1002). Since all are off, order is switched to: 1, 3, 2.

* + - 1. Lead/standby equipment:
         1. Unless equipment runs continuously, parallel equipment that are 100% redundant shall be lead/standby alternated when more than one of the equipment is off so that the equipment with the most operating hours as determined by Staging Runtime is made the last stage equipment and the one with the least number of hours is made the earlier stage equipment.
         2. If equipment runs continuously, lead/standby positions shall switch at an adjustable day of the week and time (e.g., every Tuesday at 10:00 am) based on Staging Runtime; standby equipment shall first be started and proven on before former lead equipment is changed to standby and shut off.

Variable speed fans and pumps shall have a deceleration rate of 1 Hz/second or slower set in BAS logic when disabled to prevent nuisance trips of operating equipment (e.g., chillers).

* + - 1. Exceptions to Lead/lag and Lead/standby rotation
         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.

Staging order changes initiated via operator override shall be instituted as part of normal staging events.

Staging order shall remain overridden until released by operators.

* + - * 1. Faulted Equipment:

A faulted equipment is any equipment commanded to run that is either not running or unable to perform its required duty. If an operating equipment has any fault condition described subsequently, a Level 2 alarm shall be generated, and a response shall be triggered as defined below.

Fans and pumps

Status point not matching its on/off point for 3 seconds after a time delay of 15 seconds while the device equipment is commanded on

Chillers

Safety shutdown alarm condition either through network or hardwired alarm contact, or

Chiller is manually shut off as indicated by the status of the Local/Auto switch from chiller gateway, or

Chiller status remains off 5 minutes after command to start (note: this condition only applies when a chiller first starts, i.e., once status is proven, then status is no longer used as a fault condition because status will come and go if chiller cycles on low load), or

CHW isolation valve feedback indicates valve is not open 90 seconds after valve is commanded open, or

CHW isolation valve feedback indicates valve is not closed 90 seconds after valve is commanded closed, or

CW isolation valve feedback indicates valve is not open 90 seconds after valve is commanded open, or

For 10 minutes, chilled water return temperature has been at least 3°C (5°F) above the CHWST setpoint, and delta-T across the chiller, as determined based on the difference between chilled water return temperature and chilled water supply temperature measured at the chiller (i.e., not common CHWST), has been less than 2°C (3°F).

Boilers

Safety shutdown alarm condition either through network or hardwired alarm contact, or

HW isolation valve feedback indicates valve is not open 90 seconds after valve is commanded open, or

If boiler leaving water temperature remains 8.3°C (15°F) below setpoint for 15 minutes and delta-T across the boiler, as determined based on the difference between hot water supply temperature and hot water return temperature measured at the boiler (i.e., not common HWST), has been less than 6°C (10°F).

Cooling Towers

Tower fan has failed as defined above, or

Inlet end switch indicates valve is not open 90 seconds after valve is commanded open, or

Outlet end switch indicates valve is not open 90 seconds after valve is commanded open.

Upon identification of a fault condition:

For fans, pumps, and cooling towers:

The next commanded off equipment in the staging order, Equipment “B,” shall be commanded on while alarming Equipment “A” remains commanded on.

If Equipment “B” fails to prove status (i.e., it also goes into alarm), it shall remain commanded on, and the preceding step shall be repeated until the quantity of equipment called for by the current stage has proven on, or there are no more available equipment.

Set alarming equipment to the last positions in the lead/lag or lead/standby staging order sequenced reverse chronologically (i.e., the equipment that alarmed most recently is sent to last position).

Staging order of non-alarming equipment shall follow the even wear logic. Equipment in alarm can only automatically move up on the staging order if another equipment goes into alarm.

Equipment in alarm shall run if so called for by the lead/lag or lead/standby staging order and present stage.

Both this and the subsequent chiller and boiler sequence do not lock out equipment that are in alarm. Instead, they move all equipment in alarm to the end of the rotation sequence such that they will be the last equipment called to run. The sequences will only call for the equipment in alarm if all of the equipment not in alarm are already enabled and there is a call for a stageup. Equipment in alarm will respond if called to run only if it can do so (e.g., not locked out on internal safety, locked out on an HOA switch at the starter, or otherwise disabled). It is important to note that this staging does not override the equipment’s internal safeties so it will not damage equipment.

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

Example: For a set of (4) lead/lag equipment, the current staging order is Equipment A, B, C, then D. The current stage requires two of the equipment, so A and B are running. Then A goes into alarm. C is then commanded on and starts with no alarm. Since the required quantity of equipment has proven on (2), A is moved to the end of staging order since it is in alarm and disabled. The staging order is now B, C, D, A. Equipment B and C are running with no alarms.

Then the staging logic calls for a third equipment. D is commanded on but goes into alarm. Then A is commanded on. Since D entered an alarm state after A and all equipment are commanded on, D is set to last in the lead/lag staging order. The staging order is now B, C, A, D, and all equipment remain enabled since (3) are called but only (2) are running without alarms.

For chillers and boilers

The next commanded off equipment in the staging order, Equipment “B”, shall be commanded on while alarming Equipment “A” is commanded off and set to the last position in the lead/lag staging order.

If Equipment B fails to prove status (i.e., it also goes into alarm), repeat the preceding step until the quantity of equipment called for by the lead/lag logic have proven on or until all equipment has been tried.

If all equipment has been tried and the quantity of non-alarming equipment is less than called for, then the most recently alarmed equipment will remain commanded on.

Staging order of non-alarming equipment shall follow the even wear logic. Equipment in alarm can only automatically move up in the staging order if another equipment goes into alarm.

Equipment in alarm shall run if so called for by the lead/lag staging order and present stage.

The sequence for chillers and boilers differs from that used for pumps and cooling towers in that the alarming equipment does not remain commanded on until the next equipment proves status. The pump and tower logic mitigates the risk of lost loads and/or chain reaction trips of chillers and boilers by still taking advantage of any capacity the alarming equipment may provide until the lag equipment proves. This approach does not however typically work for chillers and boilers because bringing on the lag equipment while still commanding the alarming equipment to run may prevent a successful startup of the lag equipment. For example, in a parallel variable primary chilled water plant under low load conditions, starting a lag chiller while keeping the alarming chiller enabled may cause both chillers to trip on either low chilled water flow or low condenser water flow unless the minimum chilled water flow setpoint is changed to maintain minimum chilled water flow and condenser water pumps are staged to

maintain minimum condenser flow through both chillers.

Example: For a set of (4) lead/lag equipment, the current staging order is Equipment A, B, C, then D. The current stage requires two equipment, so A and B are running. Then A goes into alarm. A is then commanded off at the same time as C is commanded on. If C then goes into alarm, it is commanded off at the same time that D is commanded on. If D then goes into alarm, it remains commanded on since all equipment has been tried. If B (the last equipment not in alarm) also goes into alarm, then it remains commanded on (as the last alarming equipment with no non-alarming equipment available). At this point, all equipment are in alarm and only B and D will remain commanded on until an equipment comes out of alarm. The staging order is B, D, A, C

* + - * 1. Hand Operation. If an equipment is ON-in-hand (e.g., via an HOA switch or local control of VFD), the equipment shall be set to the lead equipment, and a Level 4 alarm shall be generated. The equipment will remain as lead untilplaced back into AUTO. Hand operation is determined by the following:

Any condition in which a equipment 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).

Fans and pumps

Status point not matching its on/off point for 15 seconds after a time delay of 60 seconds whenwhile the device equipment is commanded off

Logic for hand operation of chillers, boilers, and cooling towers is not provided because sequences cannot stably respond to overrides by operators in all possible scenarios. For example, if a chiller is turned on in hand in a variable primary system with only one other chiller currently running, the control system would need to react by opening the isolation valves of the chiller placed in hand and either (1) immediately shutting down the former lead chiller or (2) changing the minimum chilled water flow setpoint, opening isolation valves, and possibly staging on condenser water pumps and cooling towers. Chillers, boilers, and cooling towers should only be placed in hand by changing the staging sequence manually via the control system interface; they cannot be safely or stably operated in hand at the chiller/boiler/tower controllers.

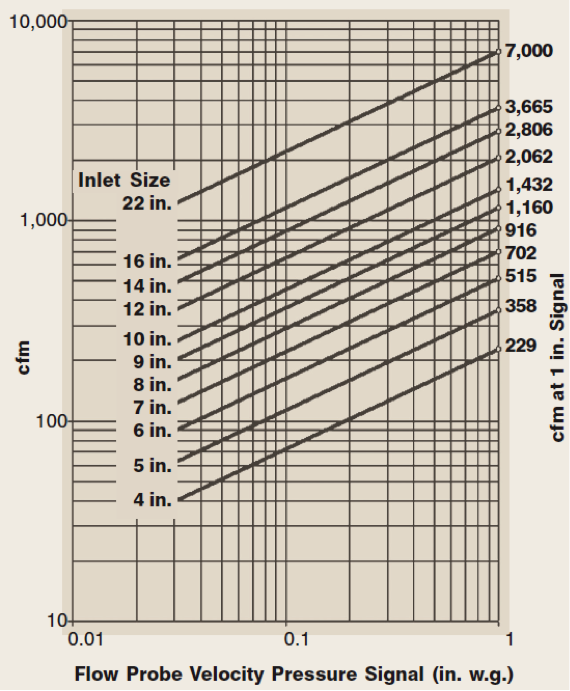
* + 1. VAV Box Controllable Minimum
       1. This section is used to determine the lowest possible VAV box airflow set point (other than zero) allowed by the controls (Vm) used in VAV box control sequences. The minimums shall be stored as software points.
       2. Option 1. If the VAV box controls 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.

* + - 1. Option 2. The minimum set point Vm shall be determined as follows:
         1. Determine the velocity pressure sensor reading VPm in inches of water column 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.
         2. 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

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

The process above can be accomplished using the flow probe velocity pressure signal chart often printed on the side of a VAV box or available from the flow probe manufacturer. The chart below is representative of what is available, but it will need to be evaluate for each combination of flow cross and duct diameter.



where A is the nominal duct area (ft2), equal to

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

* + - * 1. Calculate the minimum airflow set point allowed by the controls (Vm) for each VAV box size as
    1. Air Economizer High Limits
       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) as defined in Section 4.5D.3.
       2. The economizer shall have set points consistent with the energy code applicable for the project site.
    2. Damper/Valve Position
       1. Knowledge of damper and valve position are required for proper generation of T&R reset requests.
       2. The following are acceptable methods for determining position:

We have excluded the floating-point actuator from consideration due to the inaccuracies between indicated position and actual position. The inaccuracy leads to greater uncertainty in assessing whether the system is functioning correctly and issuing trim and respond sequence requests. Analog actuators reduce uncertainty due to their one-to-one position-versus-signal response.

If a floating-point actuator is absolutely the only function that will work, make sure to include a position feedback (AI) signal to provide robust actuator status. Pulse-open and pulse-close feedback should not be used in lieu of position feedback.

* + - * 1. Analog actuator. Position may be assumed to be equal to analog signal to actuator.
    1. 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 sup-press 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.

* + - 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.

* + - * 1. A component is a “source” if it provides resources to a downstream component, such as a chiller providing chilled water (CHW) to an AHU.
        2. A component is a “load” if it receives resources from an upstream component, such as an AHU that receives CHW from a chiller.
        3. The same component may be both a load (receiving resources from an upstream source) and a source (providing resources to a downstream load).
        4. A set of components is a “system” if they share a load in common (i.e., collectively act as a source to downstream equipment, such as a set of chillers in a lead/lag relation-ship serving air handlers).

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.

For equipment with associated pumps (chillers, boilers, cooling towers):

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.

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.

* + - 1. For each system as defined in Section 4.7 S. 5, there shall be a SystemOK flag, which is either TRUE or FALSE.
      2. SystemOK shall be TRUE when all of the following are true:
         1. The system is proven ON.
         2. The system is achieving its temperature and/or pressure set point(s) for at least 5 minutes
         3. The system is ready and able to serve its load
      3. 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.
         1. 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.
         2. The operator shall have the ability to individually deter-mine 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).

* + - 1. 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.
         1. If SystemOK is FALSE for a cooling water system (i.e., chiller, cooling tower, or associated pump), then only high-temperature alarms from the loads shall be suppressed.
         2. If SystemOK is FALSE for a heating water system (i.e., boiler or associated pump), then only low temperature alarms from the loads shall be suppressed.
         3. If SystemOK is FALSE for an air-side system (air handler, fan coil, VAV box, etc.), then all alarms from the loads shall be suppressed.
      2. 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, CO2) are suppressed for the zone served by that VAV box only. No other alarms are suppressed.

* + - 1. The following types of alarms will never be suppressed by this logic:
         1. Life/safety and Level 1 alarms
         2. Failure-to-start alarms (i.e., equipment is commanded ON, but status point shows equipment to be OFF)
         3. Failure-to-stop/hand alarms (i.e., equipment is com-manded OFF, but status point shows equipment to be ON)
    1. Time-Based Suppression
       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.

* + - * 1. For thermal zone temperature alarms: 18 minutes per °C (10 minutes per °F of difference but no longer than 120 minutes

For example, if set point changes from 68°F to 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.

* + - * 1. For thermal zone temperature cooling requests: 9 minutes per °C (5 minutes per °F of difference but no longer than 30 minutes.
        2. For thermal zone temperature heating requests: 9 minutes per °C (5 minutes per °F of difference but no longer than 30 minutes.

## 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.

* + 1. Zone Minimum Outdoor Air and Minimum Air-flow Set Points
       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.
       2. See Section 4.5 B 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 4.8 A. 3 and delete Section 4.8 A. 4.

• If the project is to comply with California Title 24 ventilation requirements, use Section 4.8 A. 4 and delete Section 4.8 A. 3.

* + - 1. 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:
         1. See Section 4.5 A. 2. a for zone ventilation set points.
         2. 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). 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).

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).

* + - * 1. Vbz-P\* is the population component of the required breathing zone outdoor airflow. The normal value of Vbz-P\* shall be Vbz-P. Vbz-A\* is the area component of the required breathing zone outdoor airflow. The normal value of the VbzA\* shall be Vbz-A.
        2. Vmin

Shall be equal to Voz as calculated in Section 4.8 A 3 (f) if Vmin in Section 4.5 B is AUTO and the associated air handler has been supplying 100% outdoor air (outdoor air damper fully open; return aur damper fully closed) for 10 minutes;

Else shall be equal to 1.5\*Voz as calculated in Section $.8 A 3 (f) if Vmin in Section 4.5 B is AUTO and the associated air handler is not supplying 100% outdoor air.

Else shall be equal Vmin as entered in Section 4.5 B.

* + - * 1. The occupied minimum airflow Vmin\* shall be equal to Vmin except as noted in Section 4.8 A. 3. f.
        2. 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:

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.

If the zone has an occupancy sensor, is unpopulated, and occupied-standby mode is permitted: Vbz-P\* = 0, Vbz-A = 0, and Vmin\* = 0

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.

If the zone has a CO2 sensor:

See Section 4.5 A. 3 for CO2 set points.

During occupied mode, a P-only loop shall maintain CO2 concentration at set point; reset from 0% at set point minus 200 PPM and to 100% at set point.

Loop is disabled and output set to zero when the zone is not in occupied mode.

CO2 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 out-door 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.

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:

1. The CO2 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 out-put. See Figure 4.8.1. The CO2 control loop graph in Figure 4.8.1 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\*.

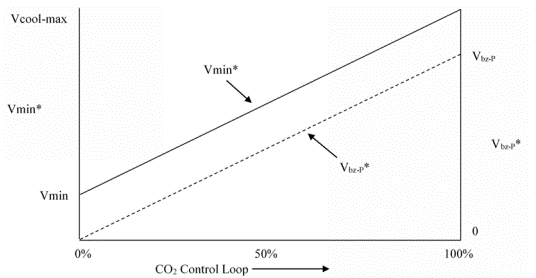


Figure 4.8.1 Vmin\* and Vbz-P\* reset CO2 control loop.

For parallel fan-powered terminal units:

(a) Determine VCO2-max as follows:

(1) When the zone state is cooling, VCO2-max is equal to the maximum cooling air-flow set point Vcool-max.

(2) When the zone state is heating or dead-band, VCO2-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 CO2 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 VCO2-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 out-put. Figure 4.8.2. The CO2 control loop graph in Figure 4.8.2s 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\*.

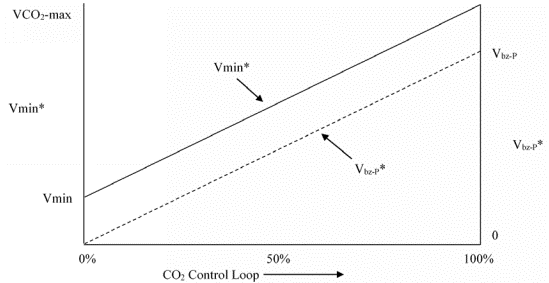


Figure 4.8.2 Vmin\* and Vbz-P\* reset CO2 control loop (parallel fan-powered).

For SZVAV AHUs:

(a) The minimum outdoor air set point MinOAsp is equal to Voz. The CO2 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 4.8.3.

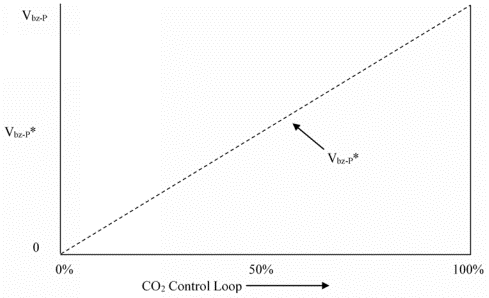


Figure 4.8.3 Vmin\* and Vbz-P\* reset CO2 control loop (SZVAV).

The engineer must select between ventilation logic options:

• If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, use Section 4.8 A. 3 and delete Section 4.8 A. 3. f. iv. 6. b.

• If the project is to comply with California Title 24 ventilation requirements, use Section 4.8 A. 3. f. iv. 6. band delete Section 4.8 A. 3.

* + - 1. For compliance with California Title 24, outdoor air set points shall be calculated as follows:
         1. See Section 4.5 A. 2. b for zone ventilation set points.
         2. 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.

Zone-Abs-OA-min is short for “Zone Absolute Outside Air Minimum”. This variable applies when the building is unoccupied and there are no people present – likely the absolute lowest ventilation rate required.

Zone-Abs-OA-min shall be reset based on the following conditions in order from highest to lowest priority:

Zero if the zone has a window switch and the window is open.

Zero if the zone has an occupancy sensor, is unpopulated, and is permitted to to be in occupied-standby mode.

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.”

Varea-min if the zone has a CO2 sensor.

Zone-Des-OA-min otherwise.

Zone-Des-OA-min is short for “Zone Design Outside Air Minimum”. This variable applies when the building is at design occupancy – as such, the population density may supersede the area ventilation rate on a zone-by-zone basis; therefore, we need to poll the zones to see if we need to increase the ventilation rate for population.

Zone-Des-OA-min is equal to the following, in order from highest to lowest priority:

Zero if the zone has a window switch and the window is open.

Zero if the zone has an occupancy sensor, is unpopulated, and is permitted to be in occupied standby mode per Section 4.5 A 2 b.

The larger of Varea-min and Vocc-min otherwise.

* + - * 1. Vmin

Shall be equal to Zone-Abs-OA-min if Vmin in Section 4.5 B is AUTO;

Else shall be equal to Vmin as entered in Section 4.5 B.

* + - * 1. The occupied minimum airflow Vmin\* shall be equal to Vmin except as noted below, in order from higher to lower priority:

If the zone has an occupancy sensor and is permitted to be in occupied standby mode per Section 4.5 A 2 b, Vmin\* shall be equal to 25% of Varea-min when the room is unpopulated.

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

If the zone has a CO2 sensor:

See Section 4.5 A. 3 for CO2 set points.

During occupied mode, a P-only loop shall maintain CO2 concentration at set point; reset from 0% at set point minus 200 PPM and to 100% at set point.

Loop is disabled and output set to zero when the zone is not in occupied mode.

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:

The CO2 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 4.8.4. The loop output from 50% to 100% will be used at the system level to reset outdoor air minimum; see AHU controls.

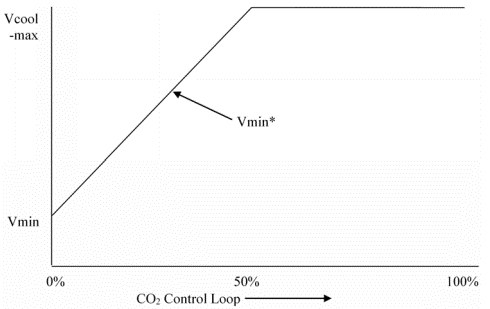


Figure 4.8.4: California Title 24 – CO2 Control Loop - Vmin\* reset

For parallel fan-powered terminal units:

Determine VCO2-max as follows:

When the zone state is cooling, VCO2-max is equal to the maximum cooling air-flow set point Vcool-max.

When the zone state is heating or dead-band, VCO2-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.

The CO2 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 VCO2-max at 50%, as shown in Figure 4.8.5. The loop output from 50% to 100% will be used at the system level to reset outdoor air minimum; see AHU controls.

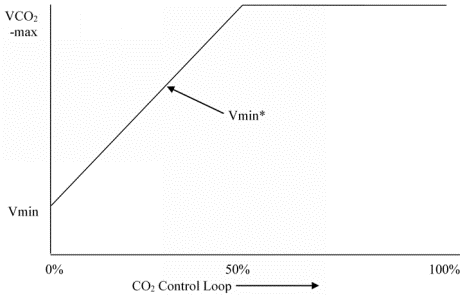


Figure 4.8.5: California Title 24 – CO2 Control Loop - Vmin\* reset – Parallel Fan-Powered

For SZVAV AHUs:

The minimum outdoor air set point MinOAsp shall be reset based on the zone CO2 control-loop signal from MinOA at 0% signal to DesOA at 100% signal. See Figure 4.8.6.

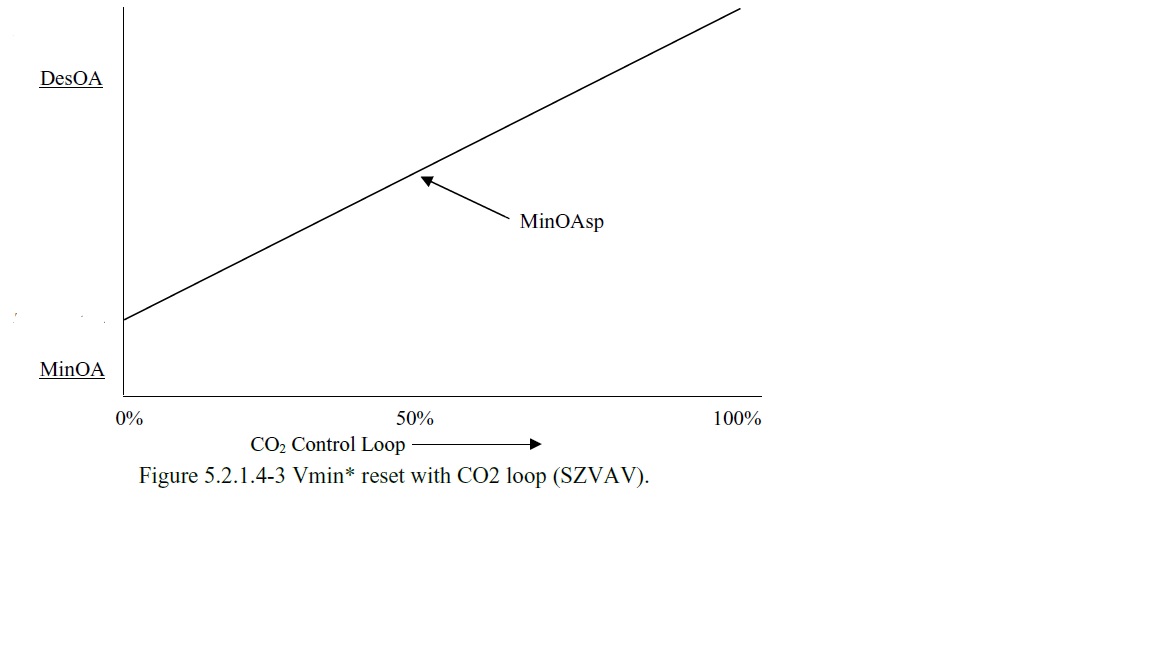


Figure 4.8.6: California Title 24 – CO2 Control Loop - Vmin\* reset – SZVAV

This concludes the section where the ventilation logic is selected. When the sequences are complete, only Section 4.8 A. 3 or Section 4.8 A. 3. f. iv. 6. b. should remain. The other section should be deleted, along with these flag notes.

* + 1. Time-Averaged Ventilation (TAV, Intermittent 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. Thus, this strategy may significantly improve occupant comfort by reducing overcooling.

The old rule of thumb for VAV boxes was that the minimum is 30% of the max cooling airflow. More recently, this has moved to a more common rule of thumb of about 20% of max cooling airflow. However, box minimum controls have been studied and shown to reliably control to even lower minimums, below 20%. Time-averaged ventilation control strategies make the actual box controlled minimum less relevant, because the airflow will be intermittent and controlled to a lower minimum by cycling the box closed.

Our recommendations are that you should look to reassess your VAV box minimum flows if they are at 30%. Minimums at 20% or below should be left alone (and time-averaged ventilation will reduce flow as needed). And, if your minimum airflows are around 10%, then you could decide to remove the time-averaged ventilation portion of the sequences because there will be little energy savings.

* + - 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:
         1. The time-averaged ventilation (TAV) ratio shall be deter-mined as TAVratio = Vspt/Vm
         2. The total cycle time (TCT) shall be 15 minutes (adjustable)
         3. 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:

1.5 minutes or

TCT multiplied by TAVratio

* + - * 1. 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.
        2. During TAV mode, each cycle shall consist of an open and closed period that alternate until Vspt is greater than Vm.

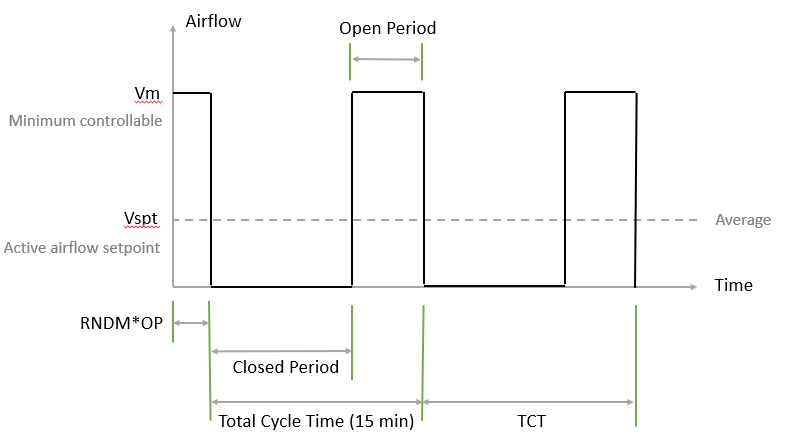
The following logic ensures that multiple zones do not enter TAV mode at the same time, avoiding the synchronized opening and closing of VAV dampers. Where there are a small number of zones and the majority may potentially be in TAV mode synchronously, avoiding this issue may be more reliably achieved 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.

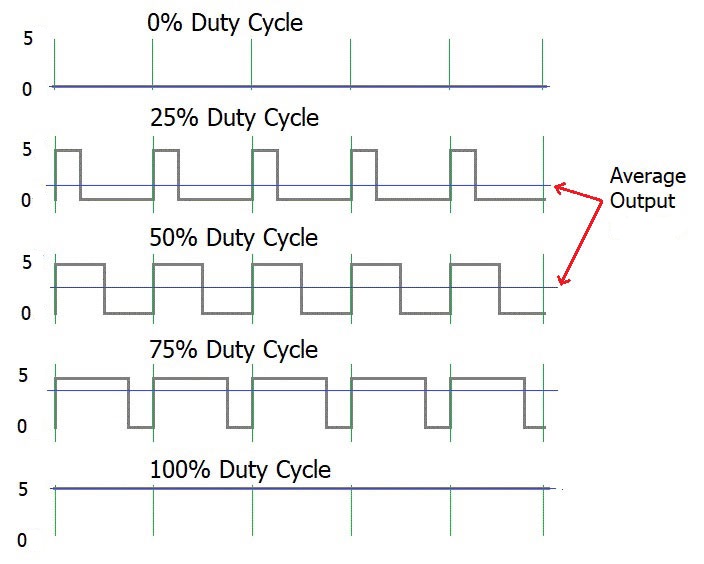
The random number is unique each time a zone enters TAV mode, and is not a random number selected at the time of programming.

* + - * 1. When first entering TAV mode, start with an initial open period duration RNDM\*OP, where RNDM is a random number uniquely generated for each TAV operating period between 0.0 and 1.0.
      1. When in TAV mode, the active airflow setpoint, Vspt, shall be overridden to Vspt\*.

Graphical depiction of time-averaged ventilation (i.e. pulse width modulation):



General diagram of pulse width modulation:



## Generic Thermal Zones

* + 1. This section applies to all single-zone systems and subzones of air-handling systems, such as VAV boxes, fan-powered boxes, etc.
    2. Set Points
       1. See Section 4.5 A. 1 for zone temperature set points.
       2. Each zone shall have separate occupied and unoccupied heating and cooling set points.
       3. The active set points shall be determined by the operating mode of the zone group (see Section 4.10).
          1. The set points shall be the occupied set points during occupied mode, warm-up mode, and cooldown mode.
          2. The set points shall be the unoccupied set points during unoccupied mode, setback mode, and setup mode.
       4. The software shall prevent the following:
          1. The heating set point from exceeding the cooling set point minus 1°F (i.e., the minimum difference between heating and cooling set points shall be 1°F).
          2. The unoccupied heating set point from exceeding the occupied heating set point.
          3. The unoccupied cooling set point from being less than the occupied cooling set point.
       5. Where the zone has a local set point adjustment knob/button:
          1. 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.
          2. 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.

As a default, the active occupied cooling set point shall be limited between 72°F and 80°F.

As a default, the active occupied heating set point shall be limited between 65°F and 71°F.

* + - * 1. The active heating and cooling set points shall be independently adjustable, respecting the limits and anti-overlap logic described in Section 4.9 B. 4 and Section 4.9 B. 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 4.9 B. 5. b.
        2. 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.
      1. Demand Limiting
         1. 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 (or Demand Response) can be triggered for different reasons, including initiating utility demand shed events, exceeding a pre-defined 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 4.9 B. 6. b and 4.9 B. 6. c) 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.

* + - * 1. 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.

At demand-limit Level 1, increase set point by 1°F.

At demand-limit Level 2, increase set point by 2°F.

At demand-limit Level 3, increase set point by 4°F.

* + - * 1. 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.

At demand-limit Level 1, decrease set point by 1°F.

At demand-limit Level 2, decrease set point by 2°F.

At demand-limit Level 3, decrease set point by 4°F.

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

* + - 1. Window Switches.
         1. 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 40°F and the cooling set point shall be temporarily set to 120°F.
         2. When the window switch indicates that the window is open during other than occupied mode, a Level 4 alarm shall be generated.
      2. Occupancy Sensors. For zones that have an occupancy switch:
         1. 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 1°F and the cooling set point shall be increased by 1°F.

The mild 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 rogue 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 set-back.

• 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.

* + - * 1. 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.

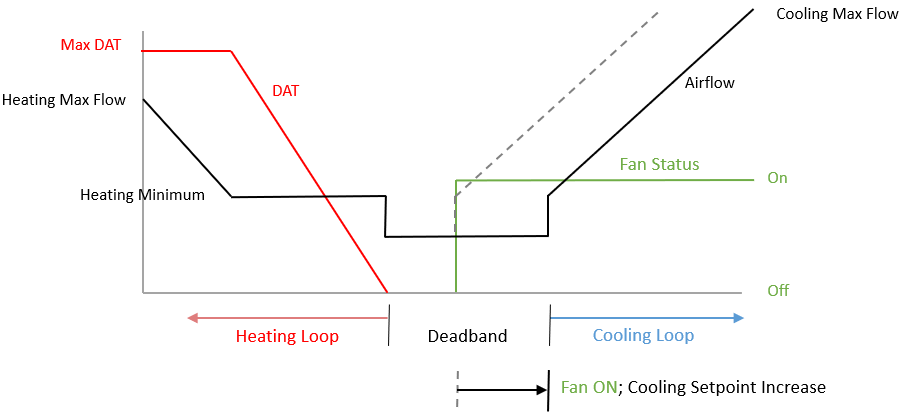
Occupancy sensors are often provided as part of the lighting control system due to ASHRAE/IES Standard 90.1 and California Title 24 requirements. The point can be tied into the HVAC BAS in several ways to avoid the cost of an additional occupancy sensor:

• 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.

* + - 1. Ceiling Fans

Ceiling fan control sequences adjust the cooling setpoint up by 4 °F when the fans are proven on (manually turned on). This approach is depicted in the diagram below.



Note that fan status is On/Off even though fans are multi-speed.

* + - * 1. When the ceiling fan is proven ON and the zone is in occupied-mode, the ceiling-fan adjustment factor shall be 4°F. The ceiling-fan cooling adjustment shall be added to the zone cooling setpoint.
        2. When the ceiling fan is proven OFF, the ceiling-fan adjustment factor shall decrease by 1°F every 5 minutes until the ceiling-fan adjustment factor is 0°F.
        3. When the zone is in other than occupied-mode, the ceiling-fan adjustment factor shall be 0°F.
        4. When the ceiling fan is proven ON and the zone is in other than occupied-mode, a Level 4 alarm shall be generated.
      1. Hierarchy of Set-Point Adjustments. The following adjustment restrictions shall prevail in order from highest to lowest priority:
         1. Set point overlap restriction (Section 4.9 B. 4)
         2. Absolute limits on local set point adjustment (Section 4.9 B. 5. b)
         3. Window switches
         4. Demand limit

Occupancy sensors. Change of set point by occupancy sensor is added to change of set point by any demand limits in effect.

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.

* + - * 1. Scheduled set points based on zone group mode
    1. 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.

* + 1. Control Loops
       1. Two separate control loops, the cooling loop and the heating loop, shall operate to maintain space temperature at set point.
          1. 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.
          2. 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.
       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).
       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).
       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. See other sections for how the outputs from these loops are used.
    2. Zone State
       1. Heating. When the output of the space heating control loop is non-zero and the output of the cooling loop is equal to zero.
       2. Cooling. When the output of the space cooling control loop is non-zero and the output of the heating loop is equal to zero.
       3. Deadband. When not in either heating or cooling.
    3. Zone Alarms
       1. Zone Temperature Alarms
          1. High-temperature alarm

If the zone is 3°F above cooling set point for 10 minutes, generate a Level 4 alarm.

If the zone is 5°F above cooling set point for 10 minutes, generate a Level 3 alarm.

* + - * 1. Low-temperature alarm

If the zone is 3°F below heating set point for 10 minutes, generate a Level 4 alarm.

If the zone is 5°F below heating set point for 10 minutes, generate a Level 3 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.

* + - * 1. Suppress zone temperature alarms as follows:

After zone set point is changed per Section 4.7 S.

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 4.10 for description of zone-group operating modes.

* + - 1. For zones with CO2 sensors:
         1. If the CO2 concentration is less than 300 ppm, or the zone is in unoccupied mode for more than 2 hours and zone CO2 concentration exceeds 600 ppm, generate a Level 3 alarm. The alarm text shall identify the sensor and indicate that it may be out of calibration.
         2. If the CO2 concentration exceeds set point plus 10% for more than 10 minutes, generate a Level 3 alarm.

## 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 enough 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.

* + 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 4.5 C for zone group assignments.
    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 equipment in addition to the HVAC system.

* + 1. All zones in each zone group shall be in the same zone-group operating mode as defined in Section 4.10. 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.

* + 1. A zone group may be in only one mode at a given time.
    2. 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.

* + 1. 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.

* + - 1. Occupied Mode. A zone group is in the occupied mode when any of the following is true:
         1. The time of day is between the zone group’s scheduled occupied start and stop times.
         2. The schedules have been overridden by the occupant over-ride 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.

* + - * 1. Any zone local override timer (initiated by local override button) is nonzero.

All subsequent modes imply that the facility is not primarily occupied and that regular employees are not present. Thus, they are all “unoccupied” even though only one mode is called “Unoccupied Mode.”

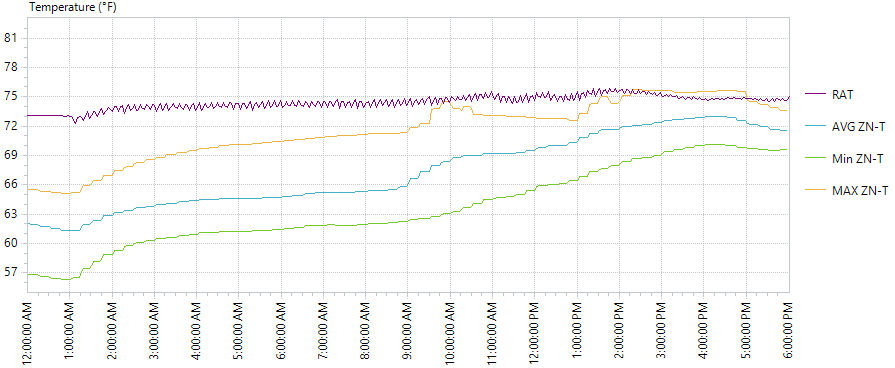
* + - 1. Warm-Up Mode. For each zone, the BAS shall calculate the required warm-up time based on the zone’s occupied heating set point, the current zone temperature, the outdoor air temperature, and a mass/capacity factor for each zone. Zones where the window switch indicates that a window is open shall 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.
      2. 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.

The preceding Warm-up and Cooldown modes (Section 4.10 F. 2 and 4.10 F. 3) include a performance-based sequence of operations for “Optimum Start”. Optimum Start is a common industry term for a computer-based algorithm that, at minimum, uses zone temperature data, outdoor air temperature, and the time required to meet the warm-up or cooldown setpoint (based on historic performance). The specific sequence of operations varies according to the system manufacturer, as the sequence is often a pre-programmed software “block” that is fed data and outputs a recommended start-up time.

It is key to note that this process occurs once each morning for **each zone**. Zone diversity may cause individual zones to be particularly sensitive to outdoor conditions. When a zone needs to start-up, the zone and all other zones served by the same air handler (per Section 4.10 C) will enter warm-up or cooldown mode (as appropriate). When the zones are in any mode besides unoccupied, the associated air handler will start up (per Section 4.21 A).

It is important to consider the ability of your air handling system to achieve the warm-up setpoint. Air side systems design often focuses on keeping spaces warm at between 68°F to 70°F. When the space is occupied, electric lighting, plug-loads, solar heat gain, and occupant body heat help the system achieve the desired heating setpoint. When air handlers are engaged in morning warm-up, all the zone-level heat loads are absent, which means the system may take longer to heat up. Consider the following strategies to shorten the morning warm-up period:

* **Command Automated Window Shades Closed During Warm-up:** Radiative heat transfer through windows to the early-morning sky works against the warm-up sequence. If your project includes automated window shades, schedule the window shades closed during the warm-up period to reduce the heat lost through the windows
* **Ensure Discharge Air Temperature Setpoints and Limits are Programmed and Functional:** The terminal unit sequences of operations included in this package call for limiting the difference between the zone air temperature and the discharge air temperature from the terminal units (see Section 4.5 B, MaxΔT variable definition). Limiting the discharge air temperature setpoint reduces the likelihood that the supplied warm air will stratify. Stratified supply air doesn’t effectively heat the zone and often bypasses the occupied zone and routes directly to the air return in the space. Good supply air mixing in the zone can shorten the morning warm-up period.
* **Consider a Warm-up Mode for Cooling-only Core-Zones:** Cooling-only zones generally won’t have a heating setpoint, since they do not require heating when the building is normally occupied; however, when HVAC zones attempt to recover from an extended off-period (e.g. weekends or holiday break periods), there may be complaints and requested to extend the warm-up period to allow the core zones to warm-up via transfer air. This approach is likely to extend the warm-up period dramatically and provide only modest benefit. If core-zones need warm-up in these buildings, consider a cooling-only zone warm-up mode, wherein the zone has a morning warm-up zone temperature and the return air is used to warm the room, but only when the return air temperature is higher than the zone air temperature and the zones with reheat are already in warm-up mode.
* **In Large Buildings, Separate Out Early-Arrival Tenant Groups:** If this standard is applied to large, multi-tenant buildings with a large centralized air handler, there may be a benefit to warming-up only part of the building when there are tenants with markedly off-set occupancy. For example, consider a building where most tenants arrive at 8:00 a.m. and a single floor of the building is occupied at 6:00 a.m. A variable speed-fan and DDC-controlled VAV terminal units could be used together to minimize the fan energy during the early warm-up for 6:00 a.m. tenants and thereby reduce energy use for a few hours. To successfully implement this strategy, the Section 4.10 C sequences will need to be adjusted to allow a fraction of the zones to remain unoccupied and the engineer and/or control contractor will need to determine how many VAV boxes need to be enabled during early warm-up to supply the fan and heating system with the minimum load required to operate safely.
* **Lower Morning Warm-up Zone Temperature Setpoints:** If after functional testing and trend review the morning warm-up sequence continues to call for early morning start-up, take a look at the zone temperature data during the warm-up mode. Systems with insufficiently large reheat coils or limited air flow may never be able to reach the occupied temperature setpoint prior to the arrival of occupants. The figure below is from a real project where the optimum start sequence continued to call for the earliest possible start-up time throughout the winter months in a mild climate.  
    
  In this scenario, the air handler started at 12:00 a.m. (midnight) after about 3 hours, most zones were near their steady-state temperature and while the zone temperature continued to rise over time, they have no appreciable effect and at the start of the occupied period, they were nowhere near the occupied temperature setpoint (68°F). If instead the sequence had set the warm-up temperature to 64°F, the system would have started at 3:00 a.m. and the system would have performed just as well. If the ability to heat the space during changes seasonally, consider a reset schedule for the warm-up zone temperature setpoint.



It is 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.

* + - 1. 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 set-back mode until all spaces in the zone group are 2°F above their unoccupied set points.
      2. Freeze Protection Setback Mode. During unoccupied mode, if any single zone falls below 40°F, the zone group shall enter setback mode until all zones are above 45°F, and a Level 3 alarm shall be set.
      3. 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 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.

* + - 1. Unoccupied Mode. When the zone group is not in any other mode.

## VAV Terminal Unit Cooling Only

The following tables describe the hardware points required for the VAV Terminal Unit Cooling Only system.

Table 4.11.1 lists the hardware points required. These points require physical hardware to be connected to the controller. As such, they will impact the system hardware selection early in the design process.

The hardware required is relatively minimal, unless additional features are defined. The engineer of record is responsible for deleting the ancillary devices, if not required by the scope of work.

Table 4.11.2 lists the software points. These points reflect software values that must be programmed into the system for the sequences defined below to operate effectively.

Note that some heating references are retained for consistency even though they are likely not used for this cooling-only application.

Table 4.11.1 VAV Terminal Unit Cooling Only – Hardware Points List

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Type | Device | Required |
|  | VAV Box Damper Position | AO | Modulating Actuator | R |
|  | Discharge Airflow | AI | Differential pressure transducer connected to a flow sensor | R |
|  | Zone Temperature | AI | Room Temperature Sensor, typically integrated into the thermostat | R |
|  | Local Override | DI | Zone thermostat override | Define |
|  | Occupancy Status | DI or Software | Occupancy Sensor | Define |
|  | Window Open/Closed | DI or Software | Window Switch | Define |
|  | Zone Temperature Adjustment | AI | Zone thermostat setpoint adjustment button or dial | Define |
|  | Zone CO2 Level | AI | Zone CO2 Sensor | Define |
|  | Zone Ceiling Fan Status | DI | Status indicator | Define |

Table 4.11.2 VAV Terminal Unit Cooling Only – Software Points List (Excluding Ventilation)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Define | Adjustable | Calculated |  |
|  | System OK | SystemOK | Binary | § 4.7 S |  |  | X |  |
|  | Zone State | ZoneState | - | § 4.9 E |  |  | X |  |
|  | Parent AHU System Mode |  |  | § 4.21 |  |  | X |  |
|  | Zone Cooling Setpoint |  | °F | § 4.5 A. 1 | X | X |  |  |
|  | Zone Heating Setpoint |  | °F | § 4.5 B | X | X |  | Likely not used |
|  | VAV Box Minimum Velocity Pressure Sensor Reading for Accuracy | VPm | in. w.c. | § 4.7 O. 5. c. i | X | X |  |  |
|  | VAV Box Minimum Velocity | vm | fpm | § 4.7 O. 5. c. i | X | X |  |  |
|  | VAV Box Flow Application Factor | F | - | § 4.7 O. 5. c. i | X | X |  |  |
|  | VAV Box Nominal Duct Diameter | D | In | § 4.7 O. 5. c. i | X | X |  |  |
|  | VAV Box Nominal Duct Area | A | in² | § 4.7 O. 5. c. i | X | X |  |  |
|  | VAV Box Minimum Controllable Airflow | Vm | cfm | § 4.7 O. 5. c. i | X | X |  |  |
|  | Zone Maximum Cooling Airflow Set point | Vcool-max | cfm | § 4.5 A. 1. b | X | X |  |  |
|  | Zone Minimum Airflow Set point | Vmin | cfm | § 4.5 A. 1. b | X | X |  |  |
|  | Zone Active Airflow Set point | Vspt | cfm | § 4.11 E |  |  | X |  |
|  | Zone Cooling Control Loop |  | - | § 4.11 E. 1 |  |  | X | 0 = no cooling, 100 = full cooling |
|  | Cooling Proportional Gain |  | - | § 4.7 H | X | X |  |  |
|  | Cooling Integral Gain |  | - | § 4.7 H | X | X |  |  |
|  | Cooling Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used |
|  | Zone Heating Control Loop |  | - | § 4.11 E. 2 |  |  | X | Likely not used |
|  | Heating Proportional Gain |  | - | § 4.7 H | X | X |  | Likely not used |
|  | Heating Integral Gain |  | - | § 4.7 H | X | X |  | Likely not used |
|  | Heating Derivative Gain |  | - | § 4.7 H | X | X |  | Likely not used |
|  | DSP Requests |  | - | § 4.11 I. 2 |  |  | X |  |
|  | DSP Importance-Multiplier |  | - | § 4.11 I. 2 | X | X |  |  |
|  | DSP Request-Hours Accumulator |  | hrs | § 4.11 I. 2 |  | X | X | User can reset |
|  | DSP System Run-Hours Total |  | hrs | § 4.11 I. 2 |  | X | X | User can reset |
|  | DSP Cumulative % Request-Hours |  | % | § 4.11 I. 2 |  | X | X | User can reset |
|  | SAT Requests |  | - | § 4.11 I. 1 |  |  | X |  |
|  | SAT Importance-Multiplier |  | - | § 4.11 I. 1 | X | X |  |  |
|  | SAT Request-Hours Accumulator |  | hrs | § 4.11 I. 1 |  | X | X | User can reset |
|  | SAT System Run-Hours Total |  | hrs | § 4.11 I. 1 |  | X | X | User can reset |
|  | SAT Cumulative % Request-Hours |  | % | § 4.11 I. 1 |  | X | X | User can reset |
|  | TAV Ratio | TAVratio | - | § 4.8 B |  |  | X |  |
|  | TAV Zone Lowest Possible Air Flow | Vm | cfm | § 4.8 B | X | X |  |  |
|  | TAV Total Cycle Time | TCT | min | § 4.8 B | X | X |  |  |
|  | TAV Open Period | OP | min | § 4.8 B |  |  | X |  |
|  | TAV Closed Period | CP | min | § 4.8 B |  |  | X |  |
|  | TAV Setpoint | Vspt\* | cfm | § 4.8 B |  |  | X |  |
|  | Window-switch Cooling Setback |  | °F | § 4.9 B. 7. a | X | X |  |  |
|  | Occupancy Cooling Setback |  | °F | § 4.9 B. 8 | X | X |  |  |
|  | Demand Limited Level 1 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling |
|  | Demand Limited Level 2 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling |
|  | Demand Limited Level 3 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling |
|  | Demand Limit Exempt |  | - | § 4.9 B. 6 | X | X |  | Yes/No |
|  | Ceiling Fan Offset |  | - |  | X | X |  |  |

Table 4.11.3 VAV Terminal Unit Cooling Only – Ventilation Software Points – Title 24

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Zone Occupancy Minimum Ventilation Rate | Vocc-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; 15 cfm/person |
| 2 | Zone Area Minimum Ventilation Rate | Varea-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; by space type |
| 3 | Absolute OA Minimum | Zone-Abs-OA-min | cfm | § 4.8 A. 4. b. i |  |  | X |  |
| 4 | Design OA Minimum | Zone-Des-OA-min | cfm | § 4.8 A. 4. b. ii |  |  | X |  |
| 5 | CO2 Loop Output |  | % | § 4.8 A. 4. d. iii |  |  | X | 0 = no demand 100 = full demand |
| 6 | CO2 Minimum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Varea-min |
| 7 | CO2 Maximum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Vcool-max |
| 8 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  Max CO2 - 200 |
| 9 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  CO2 Setpoint |
| 10 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 4. d. iii |  |  | X | Reset based on CO2 loop |
| 11 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

Table 4.11.4 VAV Terminal Unit Cooling Only – Ventilation Software Points – ASHRAE 62.1

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Ventilation, Area Component | Vbz-A | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 2 | Ventilation, People Component | Vbz-P | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 3 | Ventilation, Active Air Distribution Effectiveness | Ez | cfm | § 4.5 A. 1. b |  |  | X | Calculated |
| 5 | Ventilation, Cooling Air Distribution Effectiveness | EzC | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 6 | Ventilation, Required | Voz | cfm | § 4.8 A |  |  | X | Equals  (Vbz-A + Vbz-P)/Ez |
| 7 | CO2 People Component | Vbz-P\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Reset between 0 and Vbz-P |
| 8 | CO2 Loop Output |  | - | § 4.8 A. 3. f. iv |  |  | X | 0 = no demand 100 = full demand |
| 9 | CO2 Minimum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vbz-A |
| 10 | CO2 Maximum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vcool-max |
| 11 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals  Max CO2 - 200 |
| 12 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals CO2 Setpoint |
| 13 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals  (Vbz-A + Vbz-P\*)/Ez |
| 14 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

* + 1. See “Generic Thermal Zones” (Section 4.9) for set points, loops, control modes, alarms, etc.
    2. See “Generic Ventilation Zones” (Section 4.8) for calculation of zone minimum outdoor airflow.

CO2 DCV for cooling-only zones can lead to overcooling due to the faster rise in CO2 levels from people in the room versus the increase in cooling loads from people. Including heat in all zones with CO2 DCV is therefore recommended.

* + 1. See Section 4.5 B. 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 CO2 levels due to occupants rises much faster than the cooling load due to occupants because of thermal mass.

* + 1. Active endpoints used in the control logic depicted in Figure 4.11.1 below shall vary depending on the mode of the zone group the zone is a part of (see Table 4.11.5).

Table 4.11.5: Airflow Set Points as a Function of Zone Group Mode – VAV Terminal Unit Cooling Only

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Endpoint | 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 |

* + 1. Control logic is depicted schematically in Figure 4.11.1 and described in the following subsections.
       1. When the zone state is cooling, the cooling-loop output shall be mapped to the active airflow set point from the minimum endpoint to the cooling maximum endpoint.
          1. If supply air temperature from the air handler is greater than room temperature, the active airflow set point shall be no higher than the minimum endpoint.
       2. When the zone state is deadband, the active airflow set point shall be the minimum endpoint.
       3. When the Zone State is Heating, the active airflow setpoint shall be the minimum endpoint.

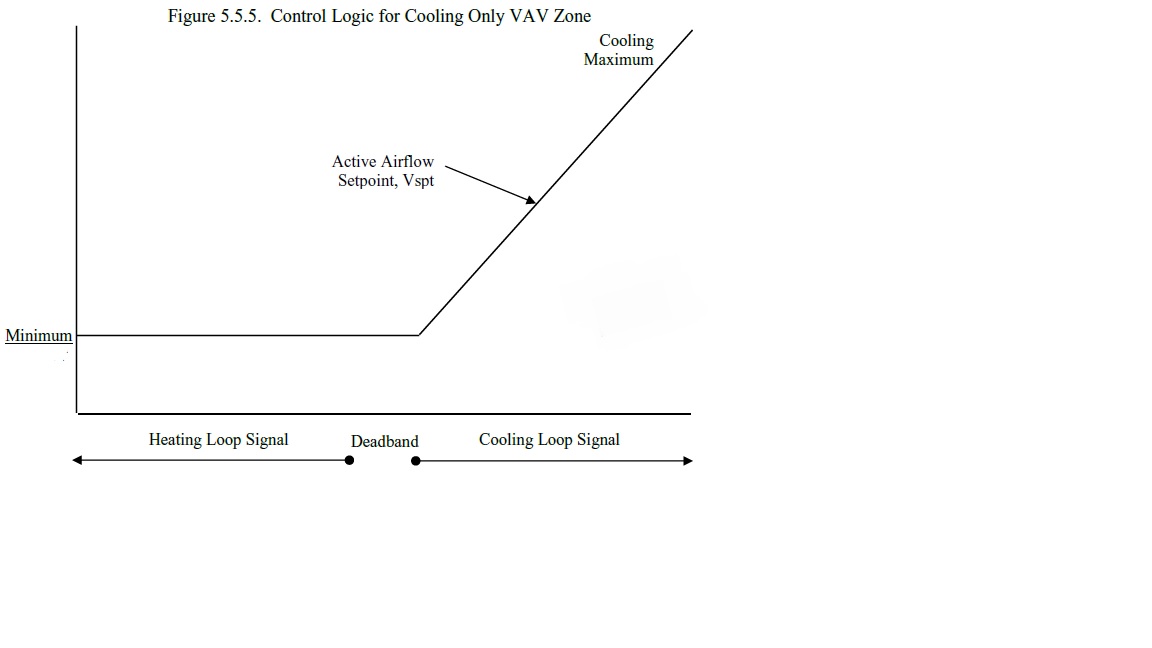


Figure 4.11.1: Control Logic – VAV Terminal Unit Cooling Only

* + 1. The VAV damper shall be modulated by a control loop to maintain the measured airflow at the active set point.
    2. Alarms

Table 4.11.6 Alarm List - VAV Terminal Unit Cooling Only

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Level | Definition | Applicable Spec Section |
|  | High Zone Temp I | 3 | Zone temperature is 3°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. i |
|  | High Zone Temp II | 2 | Zone temperature is 5°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. ii |
|  | Low Zone Temp I | 3 | Zone temperature is 3°F below heating setpoint for 10 minutes | 4.9 F. 1. b. i |
|  | Low Zone Temp II | 2 | Zone temperature is 5°F below heating setpoint for 10 minutes | 4.9 F. 1. b. ii |
|  | Low CO2, Calibration Needed | 3 | CO2 concentration is less than 300 ppm | 4.9 F. 2. a |
|  | High Vacant CO2, Calibration Needed | 3 | CO2 concentration is above 600 ppm and in unoccupied mode for 2 hours | 4.9 F. 2. a |
|  | High Occupied CO2 | 3 | CO2 concentration is exceeds set point by 10% for more than 10 minutes. | 4.9 F. 2. b |
|  | Zone Low Airflow I | 3 | Measured airflow 70% less than active airflow set point for 5 minutes | 4.11 G. 1. a |
|  | Zone Low Airflow II | 2 | Measured airflow 50% less than active airflow set point for 5 minutes | 4.11 G. 1. b |
|  | Zone Airflow Calibration | 3 | Fan serving zone is off for 10 minutes and measured airflow 10% above active airflow set point. | 4.11 G. 2 |
|  | Zone Leaking Damper | 4 | Damper position is 0%, measured is 10% above active airflow set point for 10 minutes, fan serving zone is proven on. | 4.11 G. 3 |
|  | Window Left Open | 4 | When other than occupied mode and window switch indicates window is open. | 4.9 B. 7. b |
|  | Ceiling Fan Left On | 4 | When other than occupied mode and ceiling fan is proven ON. | 4.9 B. 9. d |

* + - 1. Low Airflow
         1. 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.
         2. 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.
         3. If a zone has an importance multiplier of 0 (see Section 4.7 N. 2. a. i) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.
      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.
      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.
    1. Testing/Commissioning Overrides. Provide software switches that interlock to a system-level point to
       1. force zone airflow set point to zero,
       2. force zone airflow set point to Vcool-max,
       3. force zone airflow set point to Vmin,
       4. force damper full closed/open, and
       5. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 4.7K, 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 4.10E.

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.

* + 1. System Requests
       1. Cooling SAT Reset Requests
          1. If the zone temperature exceeds the zone’s cooling set point by 5°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 3 requests.
          2. Else if the zone temperature exceeds the zone’s cooling set point by 3°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 2 requests.
          3. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
          4. Else if the cooling loop is less than 95%, send 0 requests.
       2. Static Pressure Reset Requests
          1. 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.
          2. 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.
          3. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
          4. 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.

## VAV Terminal Unit with Reheat

Table 4.12.1 VAV Terminal Unit with Reheat – Hardware Points List

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Type | Device | Required |
|  | VAV Box Damper Position | AO | Modulating Actuator | R |
|  | Discharge Airflow | AI | Differential pressure transducer connected to a flow sensor | R |
|  | Zone Temperature | AI | Room Temperature Sensor, typically integrated into the thermostat | R |
|  | Valve Position | AO | Reheat Coil Valve Position | R |
|  | Discharge Air Temp | AI | Discharge Air Temperature (after RH Coil) | R |
|  | Local Override | DI | Zone thermostat override | Define |
|  | Occupancy Status | DI or Software | Occupancy Sensor | Define |
|  | Window Open/Closed | DI or Software | Window Switch | Define |
|  | Zone Temperature Adjustment | AI | Zone thermostat setpoint adjustment button or dial | Define |
|  | Zone CO2 Level | AI | Zone CO2 Sensor | Define |
|  | Zone Ceiling Fan Status | DI | Status indicator | Define |

Table 4.12.2 VAV Terminal Unit with Reheat – Software Points List (Excluding Ventilation)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | System OK | SystemOK | Binary | § 4.7 S |  |  | X |  | |
|  | Zone State | ZoneState | - | § 4.9 E |  |  | X |  | |
|  | Parent AHU System Mode |  |  | § 4.21 |  |  | X |  | |
|  | Zone Cooling Setpoint |  | °F | § 4.5 A. 1 | X | X |  |  | |
|  | Zone Heating Setpoint |  | °F | § 4.5 B | X | X |  |  | |
|  | Discharge Air Temperature Setpoint |  | °F | § 4.12 E. 3. c |  |  | X |  | |
|  | Discharge Air Temperature Loop |  | - | § 4.12 E. 3. a |  |  | X |  | |
|  | DAT Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | DAT Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | DAT Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | VAV Box Minimum Velocity Pressure Sensor Reading for Accuracy | VPm | in. w.c. | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Velocity | vm | fpm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Flow Application Factor | F | - | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Diameter | D | In | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Area | A | in² | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Controllable Airflow | Vm | cfm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | Zone Maximum Cooling Airflow Set point | Vcool-max | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Minimum Airflow Set point | Vmin | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Active Airflow Set point | Vspt | cfm | § 4.12 E |  |  | X |  | |
|  | Zone Cooling Control Loop |  | - | § 4.12 E. 1 |  |  | X | 0 = no cooling, 100 = full cooling | |
|  | Cooling Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | Zone Heating Control Loop |  | - | § 4.12 E. 3 |  |  | X | 0 = no heating, 100 = full heating | |
|  | Heating Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | SAT Requests |  | - | § 4.12 I. 1 |  |  | X |  | |
|  | SAT Importance-Multiplier |  | - | § 4.12 I. 1 | X | X |  |  | |
|  | SAT Request-Hours Accumulator |  | hrs | § 4.12 I. 1 |  | X | X | User can reset | |
|  | SAT System Run-Hours Total |  | hrs | § 4.12 I. 1 |  | X | X | User can reset | |
|  | SAT Cumulative % Request-Hours |  | % | § 4.12 I. 1 |  | X | X | User can reset | |
|  | DSP Requests |  | - | § 4.12 I. 2 |  |  | X |  | |
|  | DSP Importance-Multiplier |  | - | § 4.12 I. 2 | X | X |  |  | |
|  | DSP Request-Hours Accumulator |  | hrs | § 4.12 I. 2 |  | X | X | User can reset | |
|  | DSP System Run-Hours Total |  | hrs | § 4.12 I. 2 |  | X | X | User can reset | |
|  | DSP Cumulative % Request-Hours |  | % | § 4.12 I. 2 |  | X | X | User can reset | |
|  | HHW Requests |  | - | § 4.12 I. 3 |  |  | X |  | |
|  | HHW Importance-Multiplier |  | - | § 4.12 I. 3 | X | X |  |  | |
|  | HHW Request-Hours Accumulator |  | hrs | § 4.12 I. 3 |  | X | X | User can reset | |
|  | HHW System Run-Hours Total |  | hrs | § 4.12 I. 3 |  | X | X | User can reset | |
|  | HHW Cumulative % Request-Hours |  | % | § 4.12 I. 3 |  | X | X | User can reset | |
|  | HHW Plant Requests |  | - | § 4.12 I. 4 |  |  | X |  | |
|  | HHW Plant Importance-Multiplier |  | - | § 4.12 I. 4 | X | X |  |  | |
|  | HHW Plant Request-Hours Accumulator |  | hrs | § 4.12 I. 4 |  | X | X | User can reset | |
|  | HHW Plant System Run-Hours Total |  | hrs | § 4.12 I. 4 |  | X | X | User can reset | |
|  | HHW Plant Cumulative % Request-Hours |  | % | § 4.12 I. 4 |  | X | X | User can reset | |
|  | TAV Ratio | TAVratio | - | § 4.8 B |  |  | X |  | |
|  | TAV Zone Lowest Possible Air Flow | Vm | cfm | § 4.8 B | X | X |  |  | |
|  | TAV Total Cycle Time | TCT | min | § 4.8 B | X | X |  |  | |
|  | TAV Open Period | OP | min | § 4.8 B |  |  | X |  | |
|  | TAV Closed Period | CP | min | § 4.8 B |  |  | X |  | |
|  | TAV Setpoint | Vspt\* | cfm | § 4.8 B |  |  | X |  | |
|  | Window-switch Cooling Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Window-switch Heating Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Occupancy Cooling Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Occupancy Heating Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Demand Limited Level 1 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 2 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 3 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limit Exempt |  | - | § 4.9 B. 6 | X | X |  | Yes/No | |
|  | Ceiling Fan Offset |  | - | § 4.9 B. 9 | X | X |  |  | |

Table 4.12.3 VAV Terminal Unit with Reheat – Ventilation Software Points – Title 24

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Zone Occupancy Minimum Ventilation Rate | Vocc-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; 15 cfm/person |
| 2 | Zone Area Minimum Ventilation Rate | Varea-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; by space type |
| 3 | Absolute OA Minimum | Zone-Abs-OA-min | cfm | § 4.8 A. 4. b. i |  |  | X |  |
| 4 | Design OA Minimum | Zone-Des-OA-min | cfm | § 4.8 A. 4. b. ii |  |  | X |  |
| 5 | CO2 Loop Output |  | % | § 4.8 A. 4. d. iii |  |  | X | 0 = no demand 100 = full demand |
| 6 | CO2 Minimum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Varea-min |
| 7 | CO2 Maximum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Vcool-max |
| 8 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  Max CO2 - 200 |
| 9 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  CO2 Setpoint |
| 10 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 4. d. iii |  |  | X | Reset based on CO2 loop |
| 11 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

Table 4.12.4 VAV Terminal Unit with Reheat – Ventilation Software Points – ASHRAE 62.1

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Ventilation, Area Component | Vbz-A | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 2 | Ventilation, People Component | Vbz-P | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 3 | Ventilation, Active Air Distribution Effectiveness | Ez | cfm | § 4.5 A. 1. b |  |  | X | Calculated |
| 4 | Ventilation, Heating Air Distribution Effectiveness | EzH | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 5 | Ventilation, Cooling Air Distribution Effectiveness | EzC | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 6 | Ventilation, Required | Voz | cfm | § 4.8 A |  |  | X | Equals  (Vbz-A + Vbz-P)/Ez |
| 7 | CO2 People Component | Vbz-P\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Reset between 0 and Vbz-P |
| 8 | CO2 Loop Output |  | - | § 4.8 A. 3. f. iv |  |  | X | 0 = no demand 100 = full demand |
| 9 | CO2 Minimum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vbz-A |
| 10 | CO2 Maximum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vcool-max |
| 11 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals  Max CO2 - 200 |
| 12 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals CO2 Setpoint |
| 13 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals  (Vbz-A + Vbz-P\*)/Ez |
| 14 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

* + 1. See “Generic Thermal Zones” (Section 4.9) for set points, loops, control modes, alarms, etc.
    2. See “Generic Ventilation Zones” (Section 4.8) for calculation of zone minimum outdoor airflow.
    3. See Section 4.5 B. 2 for zone minimum airflow set points Vmin, zone maximum cooling airflow set point Vcool-max, zone maximum heating airflow set point Vheat-max, zone minimum heating airflow setpoint Vheat-min, and the maximum DAT rise above heating set point MaxΔT.
    4. Active endpoints used in the control logic depicted in Figure 4.12.1 shall vary depending on the mode of the zone group the zone is a part of (see Figure 4.12.1).

Table 4.12.5: Airflow Set Points as a Function of Zone Group Mode – VAV Terminal Unit with Reheat

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Endpoint | 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 |
| Deadband Minimum | Vmin\* | 0 | 0 | 0 | 0 | 0 |
| Heating Maximum | Max (Vheat-min,Vmin\*) | Vheat-min | 0 | Vheat-max | Vheat-max | 0 |
| Heating Minimum | Max (Vheat-max,Vmin\*) | Vheat-max | 0 | Vcool-max | Vcool-max | 0 |

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

* + 1. Control logic is depicted schematically in Figure 4.12.1 and described in the following subsections.
       1. When the zone state is cooling, the cooling-loop output shall be mapped to the active airflow set point from the cooling minimum endpoint to the cooling maximum endpoint. Heating coil is disabled unless the DAT is below the minimum set point (see Section 4.12 E. 4).
          1. If supply air temperature from the air handler is greater than room temperature, the active airflow set point shall be no higher than the minimum endpoint.
       2. When the zone state is deadband, the active airflow set point shall be the minimum endpoint. Heating coil is disabled unless the DAT is below the minimum set point (see Section 4.12 E. 4).
       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.

* + - * 1. 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 active airflow set point shall be the heating minimum endpoint.
        2. From 51% to 100%, if the DAT is greater than room temperature plus 5°F, the heating-loop output shall reset the active airflow set point from the heating minimum endpoint to the heating maximum endpoint.
        3. 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). When the airflow set point has time-averaged ventilation (TAV) adjustments per Section 4.8 B, the heating coil and PID loop shall be disabled, with output set to 0 during closed periods.
      1. In occupied mode, the heating coil shall be modulated to maintain a DAT no lower than 50°F.

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

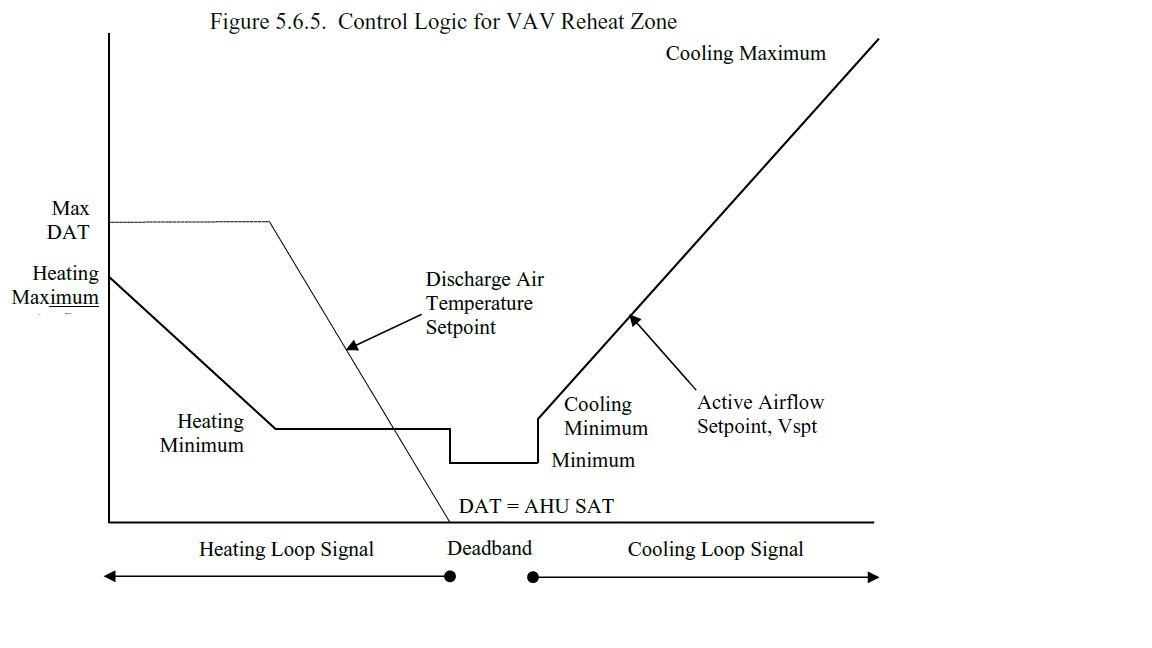


Figure 4.12.1: Control Logic – VAV Terminal Unit with Reheat

* + 1. The VAV damper shall be modulated by a control loop to maintain the measured airflow at the active setpoint.
    2. 5.6.6 Alarms

Table 4.12.6 Alarm List - VAV Terminal Unit with Reheat

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Level | Definition | Applicable Spec Section |
|  | Window Left Open | 4 | When other than occupied mode and window switch indicates window is open. | 4.9 B. 7. b |
|  | Ceiling Fan Left On | 4 | When other than occupied mode and ceiling fan is proven ON. | 4.9 B. 9. d |
|  | High Zone Temp I | 3 | Zone temperature is 3°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. i |
|  | High Zone Temp II | 2 | Zone temperature is 5°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. ii |
|  | Low Zone Temp I | 3 | Zone temperature is 3°F below heating setpoint for 10 minutes | 4.9 F. 1. b. i |
|  | Low Zone Temp II | 2 | Zone temperature is 5°F below heating setpoint for 10 minutes | 4.9 F. 1. b. ii |
|  | Low CO2, Calibration Needed | 3 | CO2 concentration is less than 300 ppm | 4.9 F. 2. a |
|  | High Vacant CO2, Calibration Needed | 3 | CO2 concentration is above 600 ppm and in unoccupied mode for 2 hours | 4.9 F. 2. a |
|  | High Occupied CO2 | 3 | CO2 concentration is exceeds set point by 10% for more than 10 minutes. | 4.9 F. 2. b |
|  | Zone Low Airflow I | 3 | Measured airflow 70% less than active airflow set point for 5 minutes | 4.12 G. 1. a |
|  | Zone Low Airflow II | 2 | Measured airflow 50% less than active airflow set point for 5 minutes | 4.12 G. 1. b |
|  | Low Discharge Temp I | 3 | Discharge temperature is 15°F below heating setpoint for 10 minutes. | 4.12 G. 2. a |
|  | Low Discharge Temp II | 2 | Discharge temperature is 30°F below heating setpoint for 10 minutes. | 4.12 G. 2. b |
|  | Bypassing Reheat Valve | 4 | Valve position is 0% for 15 minutes, parent AHU is ON and DAT exceeds parent AHU SAT by 5°F. | 4.12 G. 5 |
|  | Zone Airflow Calibration | 3 | Fan serving zone is off for 10 minutes and measured airflow 10% above active airflow set point. | 4.12 G. 3 |
|  | Zone Leaking Damper | 4 | Damper position is 0%, measured is 10% above active airflow set point for 10 minutes, fan serving zone is proven on. | 4.12 G. 4 |

* + - 1. Low Airflow
         1. If the measured airflow is less than 70% of set point for 10 minutes while set point is greater than zero, generate a Level 4 alarm.
         2. If the measured airflow is less than 50% of set point for 10 minutes while set point is greater than zero, generate a Level 3 alarm.
         3. If a zone has an Importance-Multiplier of 0 (see Section 4.7 N. 2. a. i) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.
      2. Low-Discharge Air Temperature
         1. If heating hot-water plant is proven ON, and the DAT is 15°F less than set point for 10 minutes, generate a Level 4 alarm.
         2. If heating hot-water plant is proven ON, and the DAT is 30°F less than set point for 10 minutes, generate a Level 3 alarm.
         3. If a zone has an Importance-Multiplier of 0 (see Section 4.7 N. 2. a. i) for its hot-water reset T&R control loop, low-DAT alarms shall be suppressed for that zone.
      3. Airflow Sensor Calibration. If the fan serving the zone is OFF, and airflow sensor reading is above the alrger of 10% of the cooling maximum airflow set point or 50 cfm for 30 minutes, generate a Level 3 alarm.
      4. Leaking Damper. If the damper position is 0%, and airflow sensor reading is above the larger of 10% of the cooling maximum airflow set point or 50 cfm for 10 minutes while the fan serving the zone is proven ON, generate a Level 4 alarm.
      5. Leaking Valve. If the valve position is 0% for 15 minutes, DAT is above AHU SAT by 5°F, and the fan serving the zone is proven ON, generate a Level 4 alarm.
    1. Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to
       - 1. force zone airflow set point to zero,
         2. force zone airflow set point to Vcool-max,
         3. force zone airflow set point to Vmin,
         4. force zone airflow set point to Vheat-max,
         5. force damper full closed/open,
         6. force heating to OFF/closed, and
         7. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 1.5K, 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 1.8E.

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.

* + 1. System Requests
       1. Cooling SAT Reset Requests
          1. If the zone temperature exceeds the zone’s cooling set point by 5°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 3 requests.
          2. Else if the zone temperature exceeds the zone’s cooling set point by 3°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 2 requests.
          3. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
          4. Else if the cooling loop is less than 95%, send 0 requests.
       2. Static Pressure Reset Requests
          1. 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.
          2. 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.
          3. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
          4. Else if the damper position is less than 95%, send 0 requests.

If There Is a Hot-Water Coil,

* + - 1. Hot-Water Reset Requests
         1. If the DAT is 30°F less than set point for 5 minutes, send 3 requests.
         2. Else if the DAT is 15°F less than set point for 5 minutes, send 2 requests.
         3. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
         4. Else if the HW valve position is less than 95%, send 0 requests.

If There Is a Hot-Water Coil and Heating Hot-Water Plant,

* + - 1. Heating Hot-Water Plant Requests. Send the heating hot-water plant that serves the zone a heating hot-water plant request as follows:
         1. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%. else if the HW valve position is less than 95%, send 0 requests.

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

Parallel Fan-Powered Terminal Unit – Constant Volume – Hardware Points List

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Type | Device | Required |
|  | VAV Box Damper Position | AO | Modulating Actuator | R |
|  | Primary Airflow | AI | Differential pressure transducer connected to a flow sensor | R |
|  | Zone Temperature | AI | Room Temperature Sensor, typically integrated into the thermostat | R |
|  | Valve Position | AO | Reheat Coil Valve Position | R |
|  | Discharge Air Temp | AI | Discharge Air Temperature (after RH Coil) | R |
|  | Fan Start/Stop | DO | Parallel Fan Start/Stop | R |
|  | Fan Status | DI | Parallel Fan Status | R |
|  | Local Override | DI | Zone thermostat override | Define |
|  | Occupancy Status | DI or Software | Occupancy Sensor | Define |
|  | Window Open/Closed | DI or Software | Window Switch | Define |
|  | Zone Temperature Adjustment | AI | Zone thermostat setpoint adjustment button or dial | Define |
|  | Zone CO2 Level | AI | Zone CO2 Sensor | Define |
|  | Zone Ceiling Fan Status | DI | Status indicator | Define |

Table 4.13.1 Parallel Fan-Powered Terminal Unit – Constant Volume – Software Points List (Excluding Ventilation)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | System OK | SystemOK | Binary | § 4.7 S |  |  | X |  | |
|  | Zone State | ZoneState | - | § 4.9 E |  |  | X |  | |
|  | Parent AHU System Mode |  |  | § 4.21 |  |  | X |  | |
|  | Zone Cooling Setpoint |  | °F | § 4.5 A. 1 | X | X |  |  | |
|  | Zone Heating Setpoint |  | °F | § 4.5 B | X | X |  |  | |
|  | Discharge Air Temperature Setpoint |  | °F | § 4.13 E. 4 |  |  | X |  | |
|  | Discharge Air Temperature Loop |  | - | § 4.13 E. 4. c |  |  | X |  | |
|  | DAT Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | DAT Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | DAT Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally not used | |
|  | VAV Box Minimum Velocity Pressure Sensor Reading for Accuracy | VPm | in. w.c. | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Velocity | vm | fpm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Flow Application Factor | F | - | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Diameter | D | In | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Area | A | in² | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Controllable Airflow | Vm | cfm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | Zone Maximum Cooling Airflow Set point | Vcool-max | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Minimum Airflow Set point | Vmin | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Active Airflow Set point | Vspt | cfm | § 4.12 E |  |  | X |  | |
|  | Zone Cooling Control Loop |  | - | § 4.13 E. 2 |  |  | X | 0 = no cooling, 100 = full cooling | |
|  | Cooling Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | Zone Heating Control Loop |  | - | § 4.13 E. 4 |  |  | X | 0 = no heating, 100 = full heating | |
|  | Heating Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | SAT Requests |  | - | § 4.13 H. 1 |  |  | X |  | |
|  | SAT Importance-Multiplier |  | - | § 4.13 H. 1 | X | X |  |  | |
|  | SAT Request-Hours Accumulator |  | hrs | § 4.13 H. 1 |  | X | X | User can reset | |
|  | SAT System Run-Hours Total |  | hrs | § 4.13 H. 1 |  | X | X | User can reset | |
|  | SAT Cumulative % Request-Hours |  | % | § 4.13 H. 1 |  | X | X | User can reset | |
|  | DSP Requests |  | - | § 4.13 H. 2 |  |  | X |  | |
|  | DSP Importance-Multiplier |  | - | § 4.13 H. 2 | X | X |  |  | |
|  | DSP Request-Hours Accumulator |  | hrs | § 4.13 H. 2 |  | X | X | User can reset | |
|  | DSP System Run-Hours Total |  | hrs | § 4.13 H. 2 |  | X | X | User can reset | |
|  | DSP Cumulative % Request-Hours |  | % | § 4.13 H. 2 |  | X | X | User can reset | |
|  | HHW Requests |  | - | § 4.13 H. 3 |  |  | X |  | |
|  | HHW Importance-Multiplier |  | - | § 4.13 H. 3 | X | X |  |  | |
|  | HHW Request-Hours Accumulator |  | hrs | § 4.13 H. 3 |  | X | X | User can reset | |
|  | HHW System Run-Hours Total |  | hrs | § 4.13 H. 3 |  | X | X | User can reset | |
|  | HHW Cumulative % Request-Hours |  | % | § 4.13 H. 3 |  | X | X | User can reset | |
|  | HHW Plant Requests |  | - | § 4.13 H. 4 |  |  | X |  | |
|  | HHW Plant Importance-Multiplier |  | - | § 4.13 H. 4 | X | X |  |  | |
|  | HHW Plant Request-Hours Accumulator |  | hrs | § 4.13 H. 4 |  | X | X | User can reset | |
|  | HHW Plant System Run-Hours Total |  | hrs | § 4.13 H. 4 |  | X | X | User can reset | |
|  | HHW Plant Cumulative % Request-Hours |  | % | § 4.13 H. 4 |  | X | X | User can reset | |
|  | TAV Ratio | TAVratio | - | § 4.8 B |  |  | X |  | |
|  | TAV Zone Lowest Possible Air Flow | Vm | cfm | § 4.8 B | X | X |  |  | |
|  | TAV Total Cycle Time | TCT | min | § 4.8 B | X | X |  |  | |
|  | TAV Open Period | OP | min | § 4.8 B |  |  | X |  | |
|  | TAV Closed Period | CP | min | § 4.8 B |  |  | X |  | |
|  | TAV Setpoint | Vspt\* | cfm | § 4.8 B |  |  | X |  | |
|  | Window-switch Cooling Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Window-switch Heating Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Occupancy Cooling Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Occupancy Heating Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Demand Limited Level 1 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 2 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 3 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limit Exempt |  | - | § 4.9 B. 6 | X | X |  | Yes/No | |
|  | Ceiling Fan Offset |  | - | § 4.9 B. 9 | X | X |  |  | |

Table 4.13.2 Parallel Fan-Powered Terminal Unit – Constant Volume – Ventilation Software Points – Title 24

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Zone Occupancy Minimum Ventilation Rate | Vocc-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; 15 cfm/person |
| 2 | Zone Area Minimum Ventilation Rate | Varea-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; by space type |
| 3 | Absolute OA Minimum | Zone-Abs-OA-min | cfm | § 4.8 A. 4. b. i |  |  | X |  |
| 4 | Design OA Minimum | Zone-Des-OA-min | cfm | § 4.8 A. 4. b. ii |  |  | X |  |
| 5 | CO2 Loop Output |  | % | § 4.8 A. 4. d. iii |  |  | X | 0 = no demand 100 = full demand |
| 6 | CO2 Minimum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Varea-min |
| 7 | CO2 Maximum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Vcool-max |
| 8 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  Max CO2 - 200 |
| 9 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  CO2 Setpoint |
| 10 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 4. d. iii |  |  | X | Reset based on CO2 loop |
| 11 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

Table 4.13.3 Parallel Fan-Powered Terminal Unit – Ventilation Software Points – ASHRAE 62.1

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Ventilation, Area Component | Vbz-A | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 2 | Ventilation, People Component | Vbz-P | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 3 | Ventilation, Active Air Distribution Effectiveness | Ez | cfm | § 4.5 A. 1. b |  |  | X | Calculated |
| 4 | Ventilation, Heating Air Distribution Effectiveness | EzH | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 5 | Ventilation, Cooling Air Distribution Effectiveness | EzC | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 6 | Ventilation, Required | Voz | cfm | § 4.8 A |  |  | X | Equals  (Vbz-A + Vbz-P)/Ez |
| 7 | CO2 People Component | Vbz-P\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Reset between 0 and Vbz-P |
| 8 | CO2 Loop Output |  | - | § 4.8 A. 3. f. iv |  |  | X | 0 = no demand 100 = full demand |
| 9 | CO2 Minimum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vbz-A |
| 10 | CO2 Maximum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vcool-max |
| 11 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals  Max CO2 - 200 |
| 12 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals CO2 Setpoint |
| 13 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals  (Vbz-A + Vbz-P\*)/Ez |
| 14 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

* + 1. See “Generic Thermal Zones” (Section 4.9) for set points, loops, control modes, alarms, etc.
    2. See “Generic Ventilation Zones” (Section 4.8) for calculation of zone minimum outdoor airflow.
    3. See Section 4.5 B. 3 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.
    4. Active endpoints used in the control logic depicted in Figure 4.13.1 and Figure 4.13.2 below shall vary depending on the mode of the zone group the zone is a part of (see Table 4.13.4).

Table 4.13.4: Airflow Set Points as a Function of Zone Group Mode – Constant-Volume Parallel Fan-Powered VAV

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Endpoint | 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 |

* + 1. Control logic is depicted schematically in Figure 4.13.1 and Figure 4.13.2 and described in the following subsections.
       1. In Figure 4.13.1 and Figure 4.13.2, OA-min is Voz (if using ASHRAE Standard 62.1 ventilation logic) or Zone-Abs-OA-min (if using California Title 24 ventilation logic).
       2. When the Zone State Is Cooling
          1. The cooling-loop output shall be mapped to the active primary airflow set point from the minimum endpoint to the cooling maximum endpoint.

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

* + - * 1. Heating coil is OFF.
      1. When the Zone State Is Deadband
         1. The active primary airflow set point shall be the minimum endpoint.
         2. Heating coil is OFF.
      2. When Zone State Is Heating
         1. The active primary airflow setpoint shall be the minimum endpoint.
         2. 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 20°F above space temperature (e.g., 90°F at 70°F space temperature set point) to minimize stratification.

* + - * 1. 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).
      1. The VAV damper shall be modulated to maintain the measured primary airflow at set point.
      2. Fan Control
         1. Fan shall run whenever zone state is heating.
         2. 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 it shall shut off when primary air volume is above Voz by 10% for 3 minutes.
         3. 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.

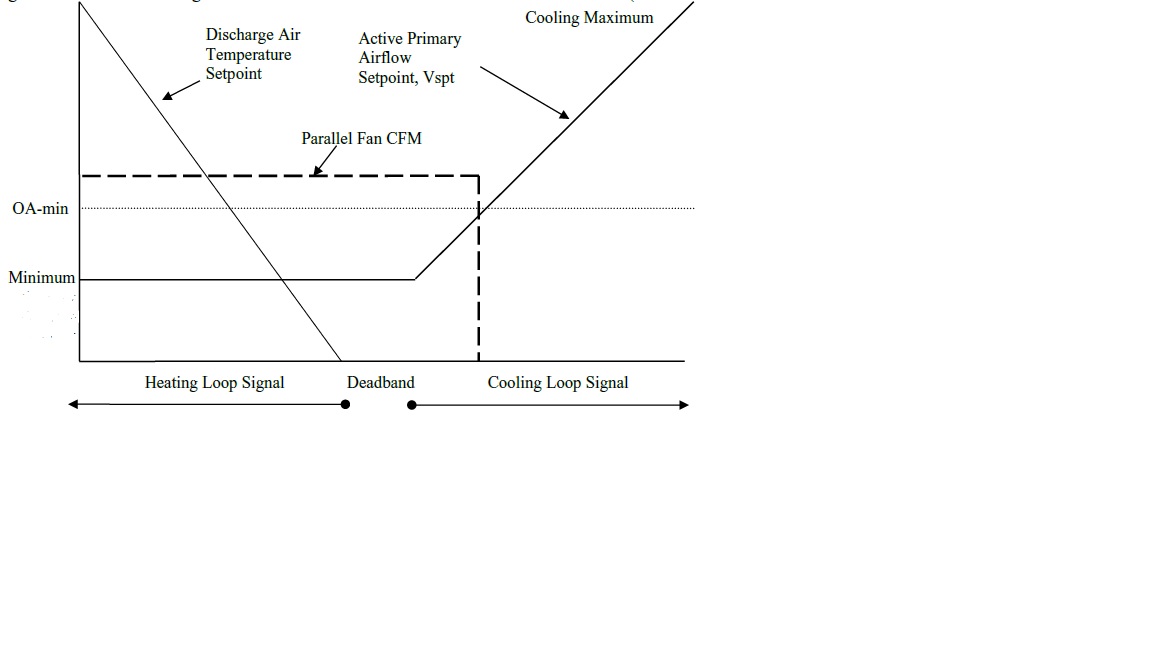


Figure 4.13.1: Control Logic – OA-min > Vmin – Constant Volume Parallel Fan-Powered VAV

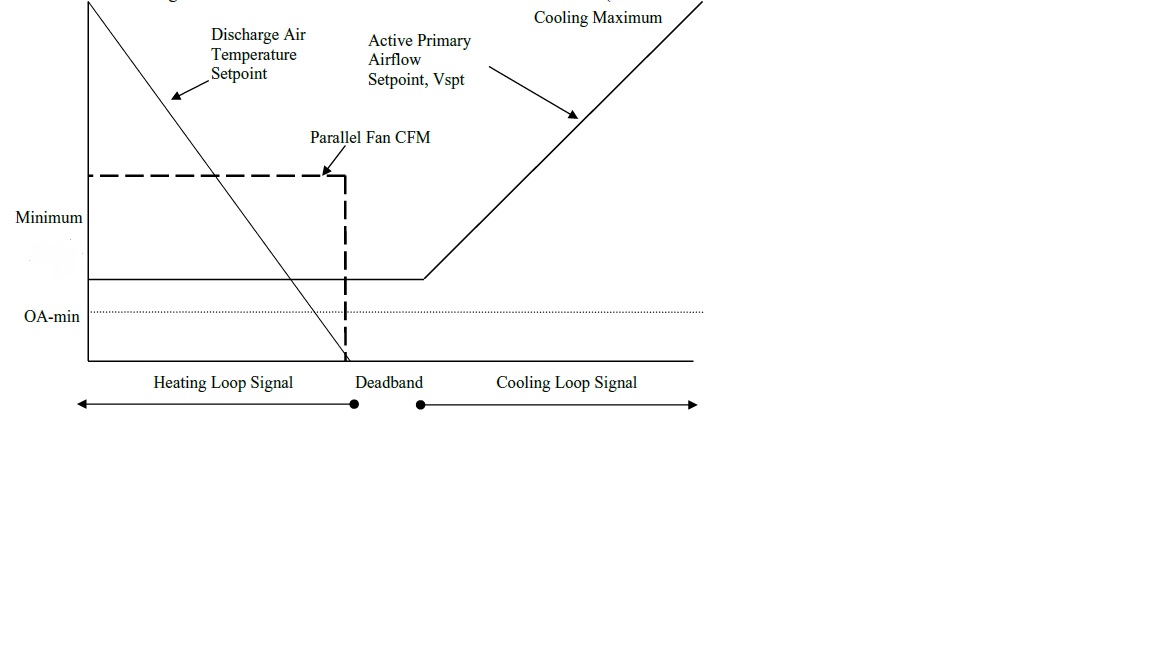


Figure 4.13.2: Control Logic – OA-min < Vmin – Constant Volume Parallel Fan-Powered VAV

* + 1. Alarms

Table 4.13.5 Alarm List - VAV Terminal Unit with Reheat

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Level | Definition | Applicable Spec Section |
|  | Window Left Open | 4 | When other than occupied mode and window switch indicates window is open. | 4.9 B. 7. b |
|  | Ceiling Fan Left On | 4 | When other than occupied mode and ceiling fan is proven ON. | 4.9 B. 9. d |
|  | High Zone Temp I | 3 | Zone temperature is 3°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. i |
|  | High Zone Temp II | 2 | Zone temperature is 5°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. ii |
|  | Low Zone Temp I | 3 | Zone temperature is 3°F below heating setpoint for 10 minutes | 4.9 F. 1. b. i |
|  | Low Zone Temp II | 2 | Zone temperature is 5°F below heating setpoint for 10 minutes | 4.9 F. 1. b. ii |
|  | Low CO2, Calibration Needed | 3 | CO2 concentration is less than 300 ppm | 4.9 F. 2. a |
|  | High Vacant CO2, Calibration Needed | 3 | CO2 concentration is above 600 ppm and in unoccupied mode for 2 hours | 4.9 F. 2. a |
|  | High Occupied CO2 | 3 | CO2 concentration is exceeds set point by 10% for more than 10 minutes. | 4.9 F. 2. b |
|  | Zone Low Primary Airflow I | 3 | Measured airflow 70% less than active airflow set point for 5 minutes | 4.13 F. 1. a |
|  | Zone Low Primary Airflow II | 2 | Measured airflow 50% less than active airflow set point for 5 minutes | 4.13 F. 1. b |
|  | Fan Remains On | 4 | Fan commanded OFF, Status ON | 4.13 F. 3. b |
|  | Fan Remains Off | 2 | Fan commanded ON, Status OFF | 4.13 F. 3. a |
|  | Low Discharge Temp I | 3 | Discharge temperature is 15°F below heating setpoint for 10 minutes. | 4.13 F. 2. a |
|  | Low Discharge Temp II | 2 | Discharge temperature is 30°F below heating setpoint for 10 minutes. | 4.13 F. 2. b |
|  | Bypassing Reheat Valve | 4 | Valve position is 0% for 15 minutes, parent AHU is ON and DAT exceeds parent AHU SAT by 5°F. | 4.13 F. 6 |
|  | Zone Airflow Calibration | 3 | Fan serving zone is off for 10 minutes and measured airflow 10% above active airflow set point. | 4.13 F. 4 |
|  | Zone Leaking Damper | 4 | Damper position is 0%, measured is 10% above active airflow set point for 10 minutes, fan serving zone is proven on. | 4.13 F. 5 |

* + - 1. Low Primary Airflow
         1. If the measured airflow is less than 70% of set point for 10 minutes while set point is greater than zero, generate a Level 4 alarm.
         2. If the measured airflow is less than 50% of set point for 10 minutes while set point is greater than zero, generate a Level 3 alarm.
         3. If a zone has an Importance-Multiplier of 0 (see Section 4.7 N. 2. a. i) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.
      2. Low-Discharge Air Temperature
         1. If heating hot-water plant is proven ON, and the DAT is 15°F less than set point for 10 minutes, generate a Level 4 alarm.
         2. If heating hot-water plant is proven ON, and the DAT is 30°F less than set point for 10 minutes, generate a Level 3 alarm.
         3. If a zone has an Importance-Multiplier of 0 (see Section 4.7 N. 2. a. i) for its hot-water reset T&R control loop, low-DAT alarms shall be suppressed for that zone.
      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.
         1. Commanded ON, status OFF: Level 2
         2. Commanded OFF, status ON: Level 4
      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. Leaking Damper. If the damper position is 0%, and airflow sensor reading is above the larger of 10% of the cooling maximum airflow set point or 50 cfm for 10 minutes while the fan serving the zone is proven ON, generate a Level 4 alarm.
      6. Leaking Valve. If the valve position is 0% for 15 minutes, DAT is above AHU SAT by 5°F, and the fan serving the zone is proven ON, generate a Level 4 alarm.
    1. Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to
       1. force zone airflow set point to zero,
       2. force zone airflow set point to Vcool-max,
       3. force zone airflow set point to Vmin,
       4. force damper full closed/open,
       5. force heating to OFF/closed,
       6. turn fan ON/OFF, and
       7. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 1.5K, 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 1.8E.

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.

* + 1. System Requests
       1. Cooling SAT Reset Requests
          1. If the zone temperature exceeds the zone’s cooling set point by 5°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 3 requests.
          2. Else if the zone temperature exceeds the zone’s cooling set point by 3°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 2 requests.
          3. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
          4. Else if the cooling loop is less than 95%, send 0 requests.
       2. Static Pressure Reset Requests
          1. 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.
          2. 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.
          3. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
          4. Else if the damper position is less than 95%, send 0 requests.

If There Is a Hot-Water Coil

* + - 1. If There Is a Hot-Water Coil, Hot-Water Reset Requests
         1. If the DAT is 30°F less than set point for 5 minutes, send 3 requests.
         2. Else if the DAT is 15°F less than set point for 5 minutes, send 2 requests.
         3. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
         4. Else if the HW valve position is less than 95%, send 0 requests.

If There Is a Hot-Water Coil and a Heating Plant

* + - 1. 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:
         1. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.
         2. Else if the HW valve position is less than 95%, send 0 requests.

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

Table 4.14.1 Parallel Fan-Powered Terminal Unit – Variable Volume – Hardware Points List

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Type | Device | Required |
|  | VAV Box Damper Position | AO | Modulating Actuator | R |
|  | Primary Airflow | AI | Differential pressure transducer connected to a flow sensor | R |
|  | Zone Temperature | AI | Room Temperature Sensor, typically integrated into the thermostat | R |
|  | Valve Position | AO | Reheat Coil Valve Position | R |
|  | Discharge Air Temp | AI | Discharge Air Temperature (after RH Coil) | R |
|  | Fan Start/Stop | DO | Parallel Fan Start/Stop | Define |
|  | Fan Speed Feedback | DI | Parallel Fan Speed Feedback | R |
|  | Fan Speed | AO | Parallel Fan Speed | R |
|  | Local Override | DI | Zone thermostat override | Define |
|  | Occupancy Status | DI or Software | Occupancy Sensor | Define |
|  | Window Open/Closed | DI or Software | Window Switch | Define |
|  | Zone Temperature Adjustment | AI | Zone thermostat setpoint adjustment button or dial | Define |
|  | Zone CO2 Level | AI | Zone CO2 Sensor | Define |
|  | Zone Ceiling Fan Status | DI | Status indicator | Define |

Table 4.14.2 Parallel Fan-Powered Terminal Unit – Variable Volume – Software Points List (Excluding Ventilation)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | System OK | SystemOK | Binary | § 4.7 S |  |  | X |  | |
|  | Zone State | ZoneState | - | § 4.9 E |  |  | X |  | |
|  | Parent AHU System Mode |  |  | § 4.21 |  |  | X |  | |
|  | Zone Cooling Setpoint |  | °F | § 4.5 A. 1 | X | X |  |  | |
|  | Zone Heating Setpoint |  | °F | § 4.5 B | X | X |  |  | |
|  | Discharge Air Temperature Setpoint |  | °F | § 4.14 E. 3. e |  |  | X |  | |
|  | Discharge Air Temperature Loop |  | - | § 4.14 E. 3. c |  |  | X |  | |
|  | DAT Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | DAT Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | DAT Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | VAV Box Minimum Velocity Pressure Sensor Reading for Accuracy | VPm | in. w.c. | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Velocity | vm | fpm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Flow Application Factor | F | - | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Diameter | D | In | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Area | A | in² | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Controllable Airflow | Vm | cfm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | Zone Maximum Cooling Airflow Set point | Vcool-max | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Minimum Airflow Set point | Vmin | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Active Airflow Set point | Vspt | cfm | § 4.14 E |  |  | X |  | |
|  | Zone Cooling Control Loop |  | - | § 4.14 E. 1 |  |  | X | 0 = no cooling, 100 = full cooling | |
|  | Cooling Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | Zone Heating Control Loop |  | - | § 4.14 E. 3 |  |  | X | 0 = no heating, 100 = full heating | |
|  | Heating Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | SAT Requests |  | - | § 4.14 H. 1 |  |  | X |  | |
|  | SAT Importance-Multiplier |  | - | § 4.14 H. 1 | X | X |  |  | |
|  | SAT Request-Hours Accumulator |  | hrs | § 4.14 H. 1 |  | X | X | User can reset | |
|  | SAT System Run-Hours Total |  | hrs | § 4.14 H. 1 |  | X | X | User can reset | |
|  | SAT Cumulative % Request-Hours |  | % | § 4.14 H. 1 |  | X | X | User can reset | |
|  | DSP Requests |  | - | § 4.14 H. 2 |  |  | X |  | |
|  | DSP Importance-Multiplier |  | - | § 4.14 H. 2 | X | X |  |  | |
|  | DSP Request-Hours Accumulator |  | hrs | § 4.14 H. 2 |  | X | X | User can reset | |
|  | DSP System Run-Hours Total |  | hrs | § 4.14 H. 2 |  | X | X | User can reset | |
|  | DSP Cumulative % Request-Hours |  | % | § 4.14 H. 2 |  | X | X | User can reset | |
|  | HHW Reset Requests |  | - | § 4.14 H. 3 |  |  | X |  | |
|  | HHW Reset Importance-Multiplier |  | - | § 4.14 H. 3 | X | X |  |  | |
|  | HHW Reset Request-Hours Accumulator |  | hrs | § 4.14 H. 3 |  | X | X | User can reset | |
|  | HHW Reset System Run-Hours Total |  | hrs | § 4.14 H. 3 |  | X | X | User can reset | |
|  | HHW Reset Cumulative % Request-Hours |  | % | § 4.14 H. 3 |  | X | X | User can reset | |
|  | HHW Plant Requests |  | - |  |  |  | X |  | |
|  | HHW Plant Importance-Multiplier |  | - |  | X | X |  |  | |
|  | HHW Plant Request-Hours Accumulator |  | hrs |  |  | X | X | User can reset | |
|  | HHW Plant System Run-Hours Total |  | hrs |  |  | X | X | User can reset | |
|  | HHW Plant Cumulative % Request-Hours |  | % |  |  | X | X | User can reset | |
|  | TAV Ratio | TAVratio | - | § 4.8 B |  |  | X |  | |
|  | TAV Zone Lowest Possible Air Flow | Vm | cfm | § 4.8 B | X | X |  |  | |
|  | TAV Total Cycle Time | TCT | min | § 4.8 B | X | X |  |  | |
|  | TAV Open Period | OP | min | § 4.8 B |  |  | X |  | |
|  | TAV Closed Period | CP | min | § 4.8 B |  |  | X |  | |
|  | TAV Setpoint | Vspt\* | cfm | § 4.8 B |  |  | X |  | |
|  | Window-switch Cooling Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Window-switch Heating Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Occupancy Cooling Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Occupancy Heating Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Demand Limited Level 1 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 2 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 3 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limit Exempt |  | - | § 4.9 B. 6 | X | X |  | Yes/No | |
|  | Ceiling Fan Offset |  | - | § 4.9 B. 9 | X | X |  |  | |

Table 4.14.3 Parallel Fan-Powered Terminal Unit – Variable Volume – Ventilation Software Points – Title 24

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Zone Occupancy Minimum Ventilation Rate | Vocc-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; 15 cfm/person |
| 2 | Zone Area Minimum Ventilation Rate | Varea-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; by space type |
| 3 | Absolute OA Minimum | Zone-Abs-OA-min | cfm | § 4.8 A. 4. b. i |  |  | X |  |
| 4 | Design OA Minimum | Zone-Des-OA-min | cfm | § 4.8 A. 4. b. ii |  |  | X |  |
| 5 | CO2 Loop Output |  | % | § 4.8 A. 4. d. iii |  |  | X | 0 = no demand 100 = full demand |
| 6 | CO2 Minimum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Varea-min |
| 7 | CO2 Maximum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Vcool-max |
| 8 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  Max CO2 - 200 |
| 9 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  CO2 Setpoint |
| 10 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 4. d. iii |  |  | X | Reset based on CO2 loop |
| 11 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

Table 4.14.4 Parallel Fan-Powered Terminal Unit – Variable Volume – Ventilation Software Points – ASHRAE 62.1

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Ventilation, Area Component | Vbz-A | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 2 | Ventilation, People Component | Vbz-P | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 3 | Ventilation, Active Air Distribution Effectiveness | Ez | cfm | § 4.5 A. 1. b |  |  | X | Calculated |
| 4 | Ventilation, Heating Air Distribution Effectiveness | EzH | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 5 | Ventilation, Cooling Air Distribution Effectiveness | EzC | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 6 | Ventilation, Required | Voz | cfm | § 4.8 A |  |  | X | Equals  (Vbz-A + Vbz-P)/Ez |
| 7 | CO2 People Component | Vbz-P\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Reset between 0 and Vbz-P |
| 8 | CO2 Loop Output |  | - | § 4.8 A. 3. f. iv |  |  | X | 0 = no demand 100 = full demand |
| 9 | CO2 Minimum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vbz-A |
| 10 | CO2 Maximum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vcool-max |
| 11 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals  Max CO2 - 200 |
| 12 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals CO2 Setpoint |
| 13 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals  (Vbz-A + Vbz-P\*)/Ez |
| 14 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

* + 1. See “Generic Thermal Zones” (Section 4.9) for set points, loops, control modes, alarms, etc.
    2. See “Generic Ventilation Zones” (Section 4.8) for calculation of zone minimum outdoor airflow.
    3. See Section 4.5 B. 3 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.
    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. Active endpoints used in the control logic depicted in Figure 4.14.1 shall vary depending on the mode of the zone group the zone is a part of (see Table 4.14.5).

Table 4.14.5: Airflow Set Points as a Function of Zone Group Mode – Variable-Volume Parallel Fan-Powered VAV

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Endpoint | 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 |

Control logic is depicted schematically in Figure 4.14.1 and described in the following subsections.

In Figure 4.14.1, 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.

* + - 1. When the Zone State Is Cooling
         1. The cooling-loop output shall be mapped to the active airflow set point from the minimum to the cooling maximum endpont.

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

* + - * 1. Heating coil is OFF.

Select whether ASHRAE 62.1 or CA Title 24.

4.14 E. 1. c – ASHRAE 62.1

4.14 E. 1. d – CA Title 24

* + - * 1. 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.
        2. 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.

* + - 1. When the Zone State Is Deadband
         1. The active primary airflow set point shall be the minimum endpoint.
         2. Heating coil is OFF.

Select whether ASHRAE 62.1 or CA Title 24.

4.14 E. 2. c – ASHRAE 62.1

4.14 E. 2. d – CA Title 24

* + - * 1. 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.
        2. 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.

* + - 1. When Zone State is Heating

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

* + - * 1. The active primary airflow setpoint shall be the minimum endpoint.
        2. Parallel fan shall run.
        3. 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 20°F above space temperature (e.g., 90°F at 70°F space temperature set point) to minimize stratification.

* + - * 1. 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 dead-band set point is less than Pfan-z) proportionally up to the maximum heating-fan airflow set point (Pfan-htgmax).
        2. 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).
      1. The VAV damper shall be modulated to maintain the measured primary airflow at the primary airflow set point.

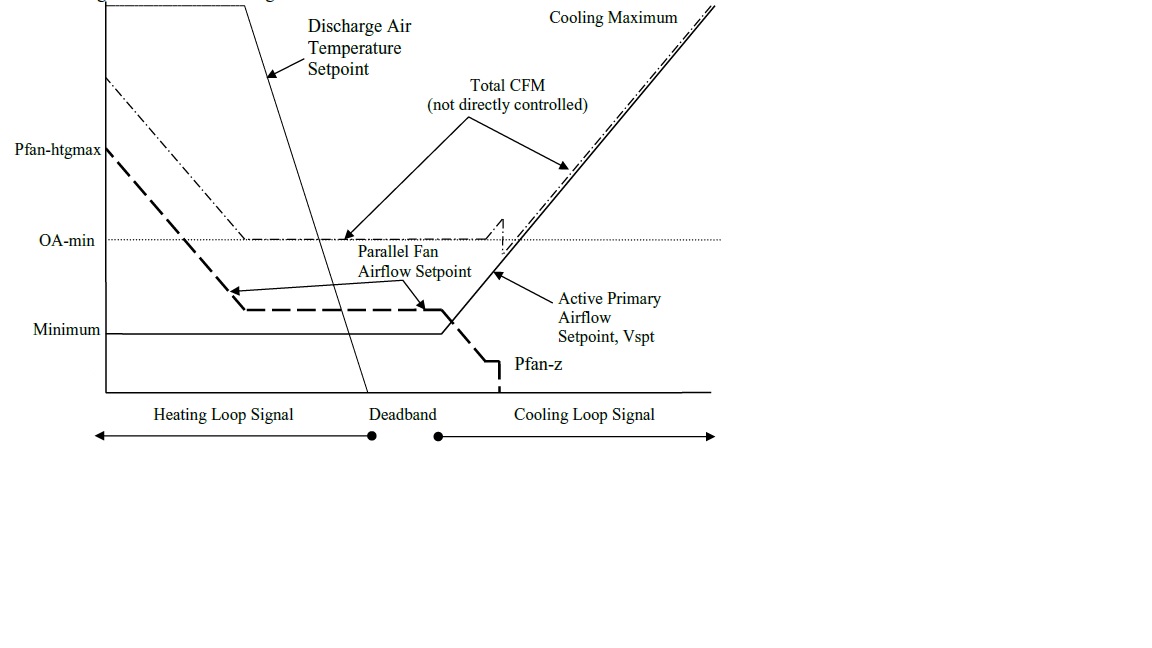


Figure 4.14.1: Control Logic – Variable-Volume Parallel Fan-Powered VAV

* + 1. Alarms

Table 4.14.6 Alarm List - VAV Terminal Unit with Reheat

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Level | Definition | Applicable Spec Section |
|  | Window Left Open | 4 | When other than occupied mode and window switch indicates window is open. | 4.9 B. 7. b |
|  | Ceiling Fan Left On | 4 | When other than occupied mode and ceiling fan is proven ON. | 4.9 B. 9. d |
|  | High Zone Temp I | 3 | Zone temperature is 3°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. i |
|  | High Zone Temp II | 2 | Zone temperature is 5°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. ii |
|  | Low Zone Temp I | 3 | Zone temperature is 3°F below heating setpoint for 10 minutes | 4.9 F. 1. b. i |
|  | Low Zone Temp II | 2 | Zone temperature is 5°F below heating setpoint for 10 minutes | 4.9 F. 1. b. ii |
|  | Low CO2, Calibration Needed | 3 | CO2 concentration is less than 300 ppm | 4.9 F. 2. a |
|  | High Vacant CO2, Calibration Needed | 3 | CO2 concentration is above 600 ppm and in unoccupied mode for 2 hours | 4.9 F. 2. a |
|  | High Occupied CO2 | 3 | CO2 concentration is exceeds set point by 10% for more than 10 minutes. | 4.9 F. 2. b |
|  | Zone Low Primary Airflow I | 3 | Measured airflow 70% less than active airflow set point for 5 minutes | 4.14 F. 1. a |
|  | Zone Low Primary Airflow II | 2 | Measured airflow 50% less than active airflow set point for 5 minutes | 4.14 F. 1. b |
|  | Fan Remains On | 4 | Fan commanded OFF, Status ON | 4.14 F. 3. b |
|  | Fan Remains Off | 2 | Fan commanded ON, Status OFF | 4.14 F. 3. a |
|  | Low Discharge Temp I | 3 | Discharge temperature is 15°F below heating setpoint for 10 minutes. | 4.14 F. 2. a |
|  | Low Discharge Temp II | 2 | Discharge temperature is 30°F below heating setpoint for 10 minutes. | 4.14 F. 2. b |
|  | Bypassing Reheat Valve | 4 | Valve position is 0% for 15 minutes, parent AHU is ON and DAT exceeds parent AHU SAT by 5°F. | 4.14 F. 6 |
|  | Zone Airflow Calibration | 3 | Fan serving zone is off for 10 minutes and measured airflow 10% above active airflow set point. | 4.14 F. 4 |
|  | Zone Leaking Damper | 4 | Damper position is 0%, measured is 10% above active airflow set point for 10 minutes, fan serving zone is proven on. | 4.14 F. 5 |

* + - 1. Low Primary Airflow
         1. If the measured airflow is less than 70% of set point for 10 minutes while set point is greater than zero, generate a Level 4 alarm.
         2. If the measured airflow is less than 50% of set point for 10 minutes while set point is greater than zero, generate a Level 3 alarm.
         3. If a zone has an Importance-Multiplier of 0 (see Section 4.7 N. 2. a. i) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.
      2. Low-Discharge Air Temperature
         1. If heating hot-water plant is proven ON, and the DAT is 15°F less than set point for 10 minutes, generate a Level 4 alarm.
         2. If heating hot-water plant is proven ON, and the DAT is 30°F less than set point for 10 minutes, generate a Level 3 alarm.
         3. If a zone has an Importance-Multiplier of 0 (see Section 1.5 N. 2. a. i) for its hot-water reset T&R control loop, low-DAT alarms shall be suppressed for that zone.
      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.
         1. Commanded ON, status OFF Level 2
         2. Commanded OFF, status ON: Level 4
      4. Airflow Sensor Calibration. If the fan serving the zone is ON and airflow sensor reading is above the larger of 10% of the maximum airflow set point or 50 cfm for 30 minutes, generate a Level 3 alarm.
      5. Leaking Damper. If the damper position is 0%, and airflow sensor reading is above the larger of 10% of the cooling maximum airflow set point or 50 cfm for 10 minutes while fan serving the zone is proven ON, generate a Level 4 alarm.
      6. Leaking Valve. If the valve position is 0% for 15 minutes, and DAT is above AHU SAT by 5°F, generate a Level 4 alarm.
    1. Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to
       - 1. force zone airflow set point to zero,
         2. force zone airflow set point to Vcool-max,
         3. force zone airflow set point to Vmin,
         4. force damper full closed/open,
         5. force heating to off/closed,
         6. turn fan on/off, and
         7. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 1.5K, 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 1.8E.

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.

* + 1. System Requests
       1. Cooling SAT Reset Requests
          1. If the zone temperature exceeds the zone’s cooling set point by 5°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 3 requests.
          2. Else if the zone temperature exceeds the zone’s cooling set point by 3°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 2 requests.
          3. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
          4. Else if the cooling loop is less than 95%, send 0 requests.
       2. Static Pressure Reset Requests
          1. 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.
          2. 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.
          3. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
          4. Else if the damper position is less than 95%, send 0 requests.

If There Is a Hot-Water Coil

* + - 1. Hot-Water Reset Requests
         1. If the DAT is 30°F less than set point for 5 minutes, send 3 requests.
         2. Else if the DAT is 15°F less than set point for 5 minutes, send 2 requests.
         3. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
         4. Else if the HW valve position is less than 95%, send 0 requests.

If There Is a Hot-Water Coil and a Heating Hot-Water Plant,

* + - 1. Heating-Hot Water Plant Requests. Send the heating hot-water plant that serves the zone a heating hot-water plant request as follows:
         1. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.
         2. Else if the HW valve position is less than 95%, send 0 requests.

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

Table 4.15.1 Series Fan-Powered Terminal Unit – Constant Volume – Hardware Points List

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Type | Device | Required |
|  | VAV Box Damper Position | AO | Modulating Actuator | R |
|  | Primary Airflow | AI | Differential pressure transducer connected to a flow sensor | R |
|  | Zone Temperature | AI | Room Temperature Sensor, typically integrated into the thermostat | R |
|  | Valve Position | AO | Reheat Coil Valve Position | R |
|  | Discharge Air Temp | AI | Discharge Air Temperature (after RH Coil) | R |
|  | Fan Start/Stop | DO | Parallel Fan Start/Stop | R |
|  | Fan Status | DI | Parallel Fan Status | R |
|  | Local Override | DI | Zone thermostat override | Define |
|  | Occupancy Status | DI or Software | Occupancy Sensor | Define |
|  | Window Open/Closed | DI or Software | Window Switch | Define |
|  | Zone Temperature Adjustment | AI | Zone thermostat setpoint adjustment button or dial | Define |
|  | Zone CO2 Level | AI | Zone CO2 Sensor | Define |
|  | Zone Ceiling Fan Status | DI | Status indicator | Define |

Table 4.15.2 Series Fan-Powered Terminal Unit – Constant Volume – Software Points List (Excluding Ventilation)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | System OK | SystemOK | Binary | § 4.7 S |  |  | X |  | |
|  | Zone State | ZoneState | - | § 4.9 E |  |  | X |  | |
|  | Parent AHU System Mode |  |  | § 4.21 |  |  | X |  | |
|  | Zone Cooling Setpoint |  | °F | § 4.5 A. 1 | X | X |  |  | |
|  | Zone Heating Setpoint |  | °F | § 4.5 B | X | X |  |  | |
|  | Discharge Air Temperature Setpoint |  | °F | § 4.15 E. 3. c |  |  | X |  | |
|  | Discharge Air Temperature Loop |  | - | § 4.15 E. 3. c |  |  | X |  | |
|  | DAT Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | DAT Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | DAT Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | VAV Box Minimum Velocity Pressure Sensor Reading for Accuracy | VPm | in. w.c. | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Velocity | vm | fpm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Flow Application Factor | F | - | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Diameter | D | In | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Area | A | in² | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Controllable Airflow | Vm | cfm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | Zone Maximum Cooling Airflow Set point | Vcool-max | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Minimum Airflow Set point | Vmin | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Active Airflow Set point | Vspt | cfm | § 4.15 E |  |  | X |  | |
|  | Zone Cooling Control Loop |  | - | § 4.15 E. 1 |  |  | X | 0 = no cooling, 100 = full cooling | |
|  | Cooling Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | Zone Heating Control Loop |  | - | §4.15 E. 3 |  |  | X | 0 = no heating, 100 = full heating | |
|  | Heating Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | SAT Requests |  | - | § 4.15 H. 1 |  |  | X |  | |
|  | SAT Importance-Multiplier |  | - | § 4.15 H. 1 | X | X |  |  | |
|  | SAT Request-Hours Accumulator |  | hrs | § 4.15 H. 1 |  | X | X | User can reset | |
|  | SAT System Run-Hours Total |  | hrs | § 4.15 H. 1 |  | X | X | User can reset | |
|  | SAT Cumulative % Request-Hours |  | % | § 4.15 H. 1 |  | X | X | User can reset | |
|  | DSP Requests |  | - | §4.15 H. 2 |  |  | X |  | |
|  | DSP Importance-Multiplier |  | - | §4.15 H. 2 | X | X |  |  | |
|  | DSP Request-Hours Accumulator |  | hrs | §4.15 H. 2 |  | X | X | User can reset | |
|  | DSP System Run-Hours Total |  | hrs | §4.15 H. 2 |  | X | X | User can reset | |
|  | DSP Cumulative % Request-Hours |  | % | §4.15 H. 2 |  | X | X | User can reset | |
|  | HHW Reset Requests |  | - | §4.15 H. 3 |  |  | X |  | |
|  | HHW Reset Importance-Multiplier |  | - | §4.15 H. 3 | X | X |  |  | |
|  | HHW Reset Request-Hours Accumulator |  | hrs | §4.15 H. 3 |  | X | X | User can reset | |
|  | HHW Reset System Run-Hours Total |  | hrs | §4.15 H. 3 |  | X | X | User can reset | |
|  | HHW Reset Cumulative % Request-Hours |  | % | §4.15 H. 3 |  | X | X | User can reset | |
|  | HHW Plant Requests |  | - | §4.15 H. 4 |  |  | X |  | |
|  | HHW Plant Importance-Multiplier |  | - | §4.15 H. 4 | X | X |  |  | |
|  | HHW Plant Request-Hours Accumulator |  | hrs | §4.15 H. 4 |  | X | X | User can reset | |
|  | HHW Plant System Run-Hours Total |  | hrs | §4.15 H. 4 |  | X | X | User can reset | |
|  | HHW Plant Cumulative % Request-Hours |  | % | §4.15 H. 4 |  | X | X | User can reset | |
|  | TAV Ratio | TAVratio | - | § 4.8 B |  |  | X |  | |
|  | TAV Zone Lowest Possible Air Flow | Vm | cfm | § 4.8 B | X | X |  |  | |
|  | TAV Total Cycle Time | TCT | min | § 4.8 B | X | X |  |  | |
|  | TAV Open Period | OP | min | § 4.8 B |  |  | X |  | |
|  | TAV Closed Period | CP | min | § 4.8 B |  |  | X |  | |
|  | TAV Setpoint | Vspt\* | cfm | § 4.8 B |  |  | X |  | |
|  | Window-switch Cooling Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Window-switch Heating Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Occupancy Cooling Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Occupancy Heating Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Demand Limited Level 1 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 2 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 3 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limit Exempt |  | - | § 4.9 B. 6 | X | X |  | Yes/No | |
|  | Ceiling Fan Offset |  | - | § 4.9 B. 9 | X | X |  |  | |

Table 4.15.3 Series Fan-Powered Terminal Unit – Constant Volume – Ventilation Software Points – Title 24

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Zone Occupancy Minimum Ventilation Rate | Vocc-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; 15 cfm/person |
| 2 | Zone Area Minimum Ventilation Rate | Varea-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; by space type |
| 3 | Absolute OA Minimum | Zone-Abs-OA-min | cfm | § 4.8 A. 4. b. i |  |  | X |  |
| 4 | Design OA Minimum | Zone-Des-OA-min | cfm | § 4.8 A. 4. b. ii |  |  | X |  |
| 5 | CO2 Loop Output |  | % | § 4.8 A. 4. d. iii |  |  | X | 0 = no demand 100 = full demand |
| 6 | CO2 Minimum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Varea-min |
| 7 | CO2 Maximum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Vcool-max |
| 8 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  Max CO2 - 200 |
| 9 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  CO2 Setpoint |
| 10 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 4. d. iii |  |  | X | Reset based on CO2 loop |
| 11 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

Table 4.15.4 Series Fan-Powered Terminal Unit – Constant Volume – Ventilation Software Points – ASHRAE 62.1

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Ventilation, Area Component | Vbz-A | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 2 | Ventilation, People Component | Vbz-P | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 3 | Ventilation, Active Air Distribution Effectiveness | Ez | cfm | § 4.5 A. 1. b |  |  | X | Calculated |
| 4 | Ventilation, Heating Air Distribution Effectiveness | EzH | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 5 | Ventilation, Cooling Air Distribution Effectiveness | EzC | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 6 | Ventilation, Required | Voz | cfm | § 4.8 A |  |  | X | Equals  (Vbz-A + Vbz-P)/Ez |
| 7 | CO2 People Component | Vbz-P\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Reset between 0 and Vbz-P |
| 8 | CO2 Loop Output |  | - | § 4.8 A. 3. f. iv |  |  | X | 0 = no demand 100 = full demand |
| 9 | CO2 Minimum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vbz-A |
| 10 | CO2 Maximum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vcool-max |
| 11 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals  Max CO2 - 200 |
| 12 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals CO2 Setpoint |
| 13 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals  (Vbz-A + Vbz-P\*)/Ez |
| 14 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

* + 1. See “Generic Thermal Zones” (Section 4.9) for set points, loops, control modes, alarms, etc.
    2. See “Generic Ventilation Zones” (Section 4.8) for calculation of zone minimum outdoor airflow.
    3. See Section 4.5 B. 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.
    4. Active endpoints used in the control logic depicted in Figure 4.15.1 shall vary depending on the mode of the zone group the zone is a part of (see Table 4.15.5).

Table 4.15.5: Airflow Set Points as a Function of Zone Group Mode – Constant-Volume Series Fan-Powered VAV

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Endpoint | 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 |

* + 1. Control logic is depicted schematically in Figure 4.15.1 and described in the following subsections.
       1. When the Zone State Is Cooling
          1. The cooling-loop output shall be mapped to the active primary airflow set point from the minimum endpoint to the cooling maximum endpoint.

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.

* + - * 1. Heating coil is OFF.
      1. When the Zone State Is Deadband
         1. The active primary airflow set point shall be the minimum endpoint.
         2. Heating coil is OFF.
      2. When Zone State Is Heating

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

* + - * 1. The active primary airflow setpoint shall be the minimum endpoint.
        2. 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.
        3. 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).
      1. The VAV damper shall be modulated to maintain the measured airflow at set point.
      2. 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.

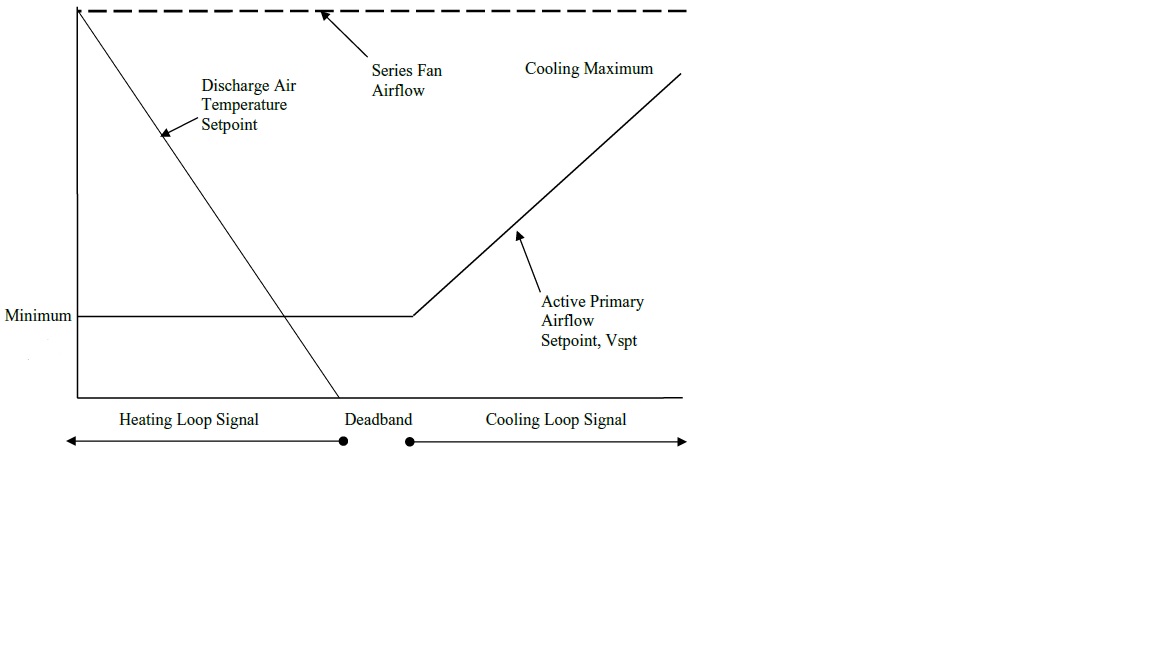


Figure 4.15.1: Control Logic – Constant-Volume Series Fan-Powered VAV

* + 1. Alarms

Table 4.15.6 Alarm List - VAV Terminal Unit with Reheat

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Level | Definition | Applicable Spec Section |
|  | Window Left Open | 4 | When other than occupied mode and window switch indicates window is open. | 4.9 B. 7. b |
|  | Ceiling Fan Left On | 4 | When other than occupied mode and ceiling fan is proven ON. | 4.9 B. 9. d |
|  | High Zone Temp I | 3 | Zone temperature is 3°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. i |
|  | High Zone Temp II | 2 | Zone temperature is 5°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. ii |
|  | Low Zone Temp I | 3 | Zone temperature is 3°F below heating setpoint for 10 minutes | 4.9 F. 1. b. i |
|  | Low Zone Temp II | 2 | Zone temperature is 5°F below heating setpoint for 10 minutes | 4.9 F. 1. b. ii |
|  | Low CO2, Calibration Needed | 3 | CO2 concentration is less than 300 ppm | 4.9 F. 2. a |
|  | High Vacant CO2, Calibration Needed | 3 | CO2 concentration is above 600 ppm and in unoccupied mode for 2 hours | 4.9 F. 2. a |
|  | High Occupied CO2 | 3 | CO2 concentration is exceeds set point by 10% for more than 10 minutes. | 4.9 F. 2. b |
|  | Zone Low Primary Airflow I | 3 | Measured airflow 70% less than active airflow set point for 5 minutes | 4.15 F. 1. a |
|  | Zone Low Primary Airflow II | 2 | Measured airflow 50% less than active airflow set point for 5 minutes | 4.15 F. 1. b |
|  | Fan Remains On | 4 | Fan commanded OFF, Status ON | 4.15 F. 3. b |
|  | Fan Remains Off | 2 | Fan commanded ON, Status OFF | 4.15 F. 3. a |
|  | Low Discharge Temp I | 3 | Discharge temperature is 15°F below heating setpoint for 10 minutes. | 4.15 F. 2. a |
|  | Low Discharge Temp II | 2 | Discharge temperature is 30°F below heating setpoint for 10 minutes. | 4.15 F. 2. b |
|  | Bypassing Reheat Valve | 4 | Valve position is 0% for 15 minutes, parent AHU is ON and DAT exceeds parent AHU SAT by 5°F. | 4.15 F. 6 |
|  | Zone Airflow Calibration | 3 | Fan serving zone is off for 10 minutes and measured airflow 10% above active airflow set point. | 4.15 F. 4 |
|  | Zone Leaking Damper | 4 | Damper position is 0%, measured is 10% above active airflow set point for 10 minutes, fan serving zone is proven on. | 4.15 F. 5 |

* + - 1. Low Primary Airflow
         1. If the measured airflow is less than 70% of set point for 10 minutes while set point is greater than zero, generate a Level 4 alarm.
         2. If the measured airflow is less than 50% of set point for 10 minutes while set point is greater than zero, generate a Level 3 alarm.
         3. If a zone has an Importance-Multiplier of 0 (see Section 4.7 N. 2. a. i) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.
      2. Low-Discharge Air Temperature
         1. If heating hot-water plant is proven ON, and the DAT is 15°F less than set point for 10 minutes, generate a Level 4 alarm.
         2. If heating hot-water plant is proven ON, and the DAT is 30°F less than set point for 10 minutes, generate a Level 3 alarm.
         3. If a zone has an Importance-Multiplier of 0 (see Section 4.7 N. 2. a. i) for its hot-water reset T&R control loop, low-DAT alarms shall be suppressed for that zone.
      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.
         1. Commanded ON, status OFF: Level 2
         2. Commanded OFF, status ON: Level 4
      4. Airflow Sensor Calibration. If the fan serving the zone has been OFF for 10 minutes, and airflow sensor reading is above the larger of 10% of the cooling maximum airflow set point or 50 cfm for 30 minutes, generate a Level 3 alarm.
      5. Leaking Damper. If the damper position is 0%, and airflow sensor reading is above the larger of 10% of the cooling maximum airflow set point or 50 cfm for 10 minutes while the fan serving the zone is proven ON, generate a Level 4 alarm.
      6. Leaking Valve. If the valve position is 0% for 15 minutes, and DAT is above AHU SAT by 5°F, generate a Level 4 alarm.
    1. Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to
       1. force zone airflow set point to zero,
       2. force zone airflow set point to Vcool-max,
       3. force zone airflow set point to Vmin,
       4. force damper full closed/open,
       5. force heating to ON/closed,
       6. turn fan ON/OFF, and
       7. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 1.5K, 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 1.8E.

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.

* + 1. System Requests
       1. Cooling SAT Reset Requests
          1. If the zone temperature exceeds the zone’s cooling set point by 5°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 3 requests.
          2. Else if the zone temperature exceeds the zone’s cooling set point by 3°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 2 requests.
          3. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
          4. Else if the cooling loop is less than 95%, send 0 requests.
       2. Static Pressure Reset Requests
          1. 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.
          2. 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.
          3. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
          4. Else if the damper position is less than 95%, send 0 requests.

If There Is a Hot-Water Coil, retain this section; else delete

* + - 1. If There Is a Hot-Water Coil, Hot-Water Reset Requests
         1. If the DAT is 30°F less than set point for 5 minutes, send 3 requests.
         2. Else if the DAT is 15°F less than set point for 5 minutes, send 2 requests.
         3. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
         4. Else if the HW valve position is less than 95%, send 0 requests.

If There Is a Hot-Water Coil and a Heating Hot-Water Plant, retain this section; else delete

* + - 1. Heating Hot-Water Plant Requests. Send the heating hot-water plant that serves the zone a heating hot-water plant request as follows:
         1. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.
         2. Else if the HW valve position is less than 95%, send 0 requests.

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

Table 4.16.1 Series Fan-Powered Terminal Unit – Variable Volume – Hardware Points List

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Type | Device | Required |
|  | VAV Box Damper Position | AO | Modulating Actuator | R |
|  | Primary Airflow | AI | Differential pressure transducer connected to a flow sensor | R |
|  | Zone Temperature | AI | Room Temperature Sensor, typically integrated into the thermostat | R |
|  | Valve Position | AO | Reheat Coil Valve Position | R |
|  | Discharge Air Temp | AI | Discharge Air Temperature (after RH Coil) | R |
|  | Fan Start/Stop | DO | Parallel Fan Start/Stop | Define |
|  | Fan Speed Feedback | DI | Parallel Fan Speed Feedback | R |
|  | Fan Speed | AO | Parallel Fan Speed | R |
|  | Local Override | DI | Zone thermostat override | Define |
|  | Occupancy Status | DI or Software | Occupancy Sensor | Define |
|  | Window Open/Closed | DI or Software | Window Switch | Define |
|  | Zone Temperature Adjustment | AI | Zone thermostat setpoint adjustment button or dial | Define |
|  | Zone CO2 Level | AI | Zone CO2 Sensor | Define |
|  | Zone Ceiling Fan Status | DI | Status indicator | Define |

Table 4.16.2 Series Fan-Powered Terminal Unit – Variable Volume – Software Points List (Excluding Ventilation)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | System OK | SystemOK | Binary | § 4.7 S |  |  | X |  | |
|  | Zone State | ZoneState | - | § 4.9 E |  |  | X |  | |
|  | Parent AHU System Mode |  |  | § 4.21 |  |  | X |  | |
|  | Zone Cooling Setpoint |  | °F | § 4.5 A. 1 | X | X |  |  | |
|  | Zone Heating Setpoint |  | °F | § 4.5 B | X | X |  |  | |
|  | Discharge Air Temperature Setpoint |  | °F | § 4.16 E. 4. c |  |  | X |  | |
|  | Discharge Air Temperature Loop |  | - | § 4.16 E. 4. a |  |  | X |  | |
|  | DAT Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | DAT Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | DAT Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | VAV Box Minimum Velocity Pressure Sensor Reading for Accuracy | VPm | in. w.c. | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Velocity | vm | fpm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Flow Application Factor | F | - | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Diameter | D | In | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Area | A | in² | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Controllable Airflow | Vm | cfm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | Zone Maximum Cooling Airflow Set point | Vcool-max | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Minimum Airflow Set point | Vmin | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Active Airflow Set point | Vspt | cfm | § 4.16 E |  |  | X |  | |
|  | Zone Cooling Control Loop |  | - | § 4.16 E. 2 |  |  | X | 0 = no cooling, 100 = full cooling | |
|  | Cooling Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | Zone Heating Control Loop |  | - | § 4.16 E. 4 |  |  | X | 0 = no heating, 100 = full heating | |
|  | Heating Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | SAT Requests |  | - | § 4.16 H. 1 |  |  | X |  | |
|  | SAT Importance-Multiplier |  | - | § 4.16 H. 1 | X | X |  |  | |
|  | SAT Request-Hours Accumulator |  | hrs | § 4.16 H. 1 |  | X | X | User can reset | |
|  | SAT System Run-Hours Total |  | hrs | § 4.16 H. 1 |  | X | X | User can reset | |
|  | SAT Cumulative % Request-Hours |  | % | § 4.16 H. 1 |  | X | X | User can reset | |
|  | DSP Requests |  | - | § 4.16 H. 2 |  |  | X |  | |
|  | DSP Importance-Multiplier |  | - | § 4.16 H. 2 | X | X |  |  | |
|  | DSP Request-Hours Accumulator |  | hrs | § 4.16 H. 2 |  | X | X | User can reset | |
|  | DSP System Run-Hours Total |  | hrs | § 4.16 H. 2 |  | X | X | User can reset | |
|  | DSP Cumulative % Request-Hours |  | % | § 4.16 H. 2 |  | X | X | User can reset | |
|  | HHW Reset Requests |  | - | § 4.16 H. 3 |  |  | X |  | |
|  | HHW Reset Importance-Multiplier |  | - | § 4.16 H. 3 | X | X |  |  | |
|  | HHW Reset Request-Hours Accumulator |  | hrs | § 4.16 H. 3 |  | X | X | User can reset | |
|  | HHW Reset System Run-Hours Total |  | hrs | § 4.16 H. 3 |  | X | X | User can reset | |
|  | HHW Reset Cumulative % Request-Hours |  | % | § 4.16 H. 3 |  | X | X | User can reset | |
|  | HHW Plant Requests |  | - | § 4.16 H. 4 |  |  | X |  | |
|  | HHW Plant Importance-Multiplier |  | - | § 4.16 H. 4 | X | X |  |  | |
|  | HHW Plant Request-Hours Accumulator |  | hrs | § 4.16 H. 4 |  | X | X | User can reset | |
|  | HHW Plant System Run-Hours Total |  | hrs | § 4.16 H. 4 |  | X | X | User can reset | |
|  | HHW Plant Cumulative % Request-Hours |  |  | § 4.16 H. 4 |  |  |  |  | |
|  | TAV Ratio | TAVratio | - | § 4.8 B |  |  | X |  | |
|  | TAV Zone Lowest Possible Air Flow | Vm | cfm | § 4.8 B | X | X |  |  | |
|  | TAV Total Cycle Time | TCT | min | § 4.8 B | X | X |  |  | |
|  | TAV Open Period | OP | min | § 4.8 B |  |  | X |  | |
|  | TAV Closed Period | CP | min | § 4.8 B |  |  | X |  | |
|  | TAV Setpoint | Vspt\* | cfm | § 4.8 B |  |  | X |  | |
|  | Window-switch Cooling Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Window-switch Heating Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Occupancy Cooling Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Occupancy Heating Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Demand Limited Level 1 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 2 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 3 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limit Exempt |  | - | § 4.9 B. 6 | X | X |  | Yes/No | |
|  | Ceiling Fan Offset |  | - | § 4.9 B. 9 | X | X |  |  | |

Table 4.16.3 Series Fan-Powered Terminal Unit – Variable Volume – Ventilation Software Points – Title 24

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Zone Occupancy Minimum Ventilation Rate | Vocc-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; 15 cfm/person |
| 2 | Zone Area Minimum Ventilation Rate | Varea-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; by space type |
| 3 | Absolute OA Minimum | Zone-Abs-OA-min | cfm | § 4.8 A. 4. b. i |  |  | X |  |
| 4 | Design OA Minimum | Zone-Des-OA-min | cfm | § 4.8 A. 4. b. ii |  |  | X |  |
| 5 | CO2 Loop Output |  | % | § 4.8 A. 4. d. iii |  |  | X | 0 = no demand 100 = full demand |
| 6 | CO2 Minimum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Varea-min |
| 7 | CO2 Maximum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Vcool-max |
| 8 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  Max CO2 - 200 |
| 9 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  CO2 Setpoint |
| 10 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 4. d. iii |  |  | X | Reset based on CO2 loop |
| 11 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

Table 4.16.4 Series Fan-Powered Terminal Unit – Variable Volume – Ventilation Software Points – ASHRAE 62.1

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Ventilation, Area Component | Vbz-A | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 2 | Ventilation, People Component | Vbz-P | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 3 | Ventilation, Active Air Distribution Effectiveness | Ez | cfm | § 4.5 A. 1. b |  |  | X | Calculated |
| 4 | Ventilation, Heating Air Distribution Effectiveness | EzH | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 5 | Ventilation, Cooling Air Distribution Effectiveness | EzC | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 6 | Ventilation, Required | Voz | cfm | § 4.8 A |  |  | X | Equals  (Vbz-A + Vbz-P)/Ez |
| 7 | CO2 People Component | Vbz-P\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Reset between 0 and Vbz-P |
| 8 | CO2 Loop Output |  | - | § 4.8 A. 3. f. iv |  |  | X | 0 = no demand 100 = full demand |
| 9 | CO2 Minimum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vbz-A |
| 10 | CO2 Maximum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vcool-max |
| 11 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals  Max CO2 - 200 |
| 12 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals CO2 Setpoint |
| 13 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals  (Vbz-A + Vbz-P\*)/Ez |
| 14 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

* + 1. See “Generic Thermal Zones” (Section 4.9) for set points, loops, control modes, alarms, etc.
    2. See “Generic Ventilation Zones” (Section 4.8) for calculation of zone minimum outdoor airflow.
    3. See Section 4.5 B. 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.
    4. Active endpoints used in the control logic depicted in Figure 4.16.1 shall vary depending on the mode of the zone group the zone is a part of (see Table 4.16.5).

Table 4.16.5: Airflow Set Points as a Function of Zone Group Mode – Variable-Volume Series Fan-Powered VAV

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Set Point | Occupied | Cooldown | Setup | Warm-Up | Setback | Unoccupied |
| Cooling Maximum | Vcool-max | Vcool-max | Vcool-max | 0 | 0 | 0 |
| Deadband Minimum | Vmin\* | 0 | 0 | 0 | 0 | 0 |
| Heating Maximum | Vheat-max | 0 | 0 | Vheat-max | Vheat-max | 0 |

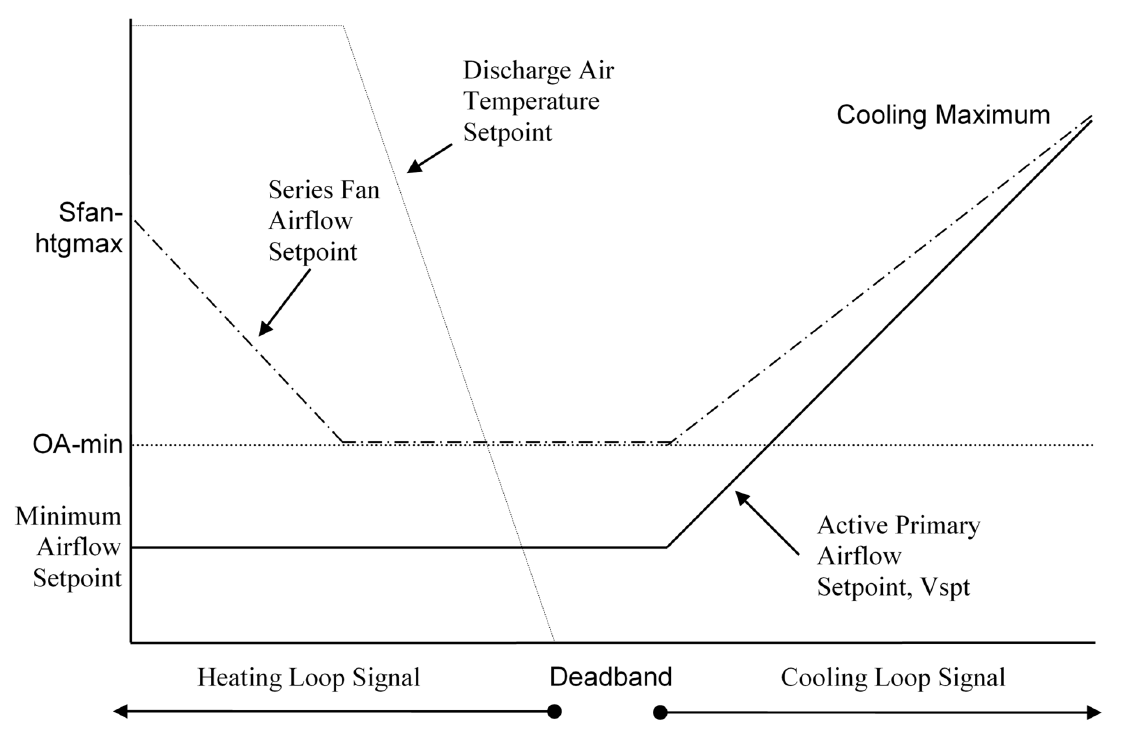


Figure 4.16.1: Control Logic – Variable-Volume Series Fan-Powered VAV

* + 1. Control logic is depicted schematically in Figure 4.16.1 and described in the following subsections.
       1. In Figure 4.16.1,
          1. OA-min is Voz (if using ASHRAE Standard 62.1 ventilation logic) or
          2. OA-min is 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.

* + - 1. When the Zone State Is Cooling
         1. The cooling-loop output shall be mapped to the active primary airflow set point from the minimum endpoint to the cooling maximum endpoint.

If supply air temperature from the air handler is greater than room temperature, active primary airflow set point shall be no higher than the minimum endpoint and the series fan airflow set point shall be no higher than OA-min.

* + - * 1. The cooling-loop output shall be mapped to the series fan airflow set point from the larger of OA-min and the primary airflow minimum endpoint to the cooling maximum endpoint.
        2. Heating coil is OFF.
      1. When the Zone State Is Deadband
         1. Theactive primary airflow set point shall be the minimumendpoint.
         2. The series fan airflow set point shall be equal to OA-min.
         3. Heating coil is OFF.
      2. When Zone State Is Heating

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

* + - * 1. 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 active primary airflow set point shall be the minimum endpoint, and the series fan airflow set point shall be OA-min.
        2. From 50% to 100%, the heating loop output shall reset the series fan airflow set point from OA-min to a Sfan-htgmax. The active primary airflow set point shall be the minimumendpoint.
        3. 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).
      1. The VAV damper shall be modulated to maintain the measured airflow at set point.
      2. 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.
    1. Alarms

Table 4.16.6 Alarm List - VAV Terminal Unit with Reheat

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Level | Definition | Applicable Spec Section |
|  | Window Left Open | 4 | When other than occupied mode and window switch indicates window is open. | 4.9 B. 7. b |
|  | Ceiling Fan Left On | 4 | When other than occupied mode and ceiling fan is proven ON. | 4.9 B. 9. d |
|  | High Zone Temp I | 3 | Zone temperature is 3°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. i |
|  | High Zone Temp II | 2 | Zone temperature is 5°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. ii |
|  | Low Zone Temp I | 3 | Zone temperature is 3°F below heating setpoint for 10 minutes | 4.9 F. 1. b. i |
|  | Low Zone Temp II | 2 | Zone temperature is 5°F below heating setpoint for 10 minutes | 4.9 F. 1. b. ii |
|  | Low CO2, Calibration Needed | 3 | CO2 concentration is less than 300 ppm | 4.9 F. 2. a |
|  | High Vacant CO2, Calibration Needed | 3 | CO2 concentration is above 600 ppm and in unoccupied mode for 2 hours | 4.9 F. 2. a |
|  | High Occupied CO2 | 3 | CO2 concentration is exceeds set point by 10% for more than 10 minutes. | 4.9 F. 2. b |
|  | Zone Low Primary Airflow I | 3 | Measured airflow 70% less than active airflow set point for 5 minutes | 4.16 F. 1. a |
|  | Zone Low Primary Airflow II | 2 | Measured airflow 50% less than active airflow set point for 5 minutes | 4.16 F. 1. b |
|  | Fan Remains On | 4 | Fan commanded OFF, Status ON | 4.16 F. 3. b |
|  | Fan Remains Off | 2 | Fan commanded ON, Status OFF | 4.16 F. 3. a |
|  | Low Discharge Temp I | 3 | Discharge temperature is 15°F below heating setpoint for 10 minutes. | 4.16 F. 2. a |
|  | Low Discharge Temp II | 2 | Discharge temperature is 30°F below heating setpoint for 10 minutes. | 4.16 F. 2. b |
|  | Bypassing Reheat Valve | 4 | Valve position is 0% for 15 minutes, parent AHU is ON and DAT exceeds parent AHU SAT by 5°F. | 4.16 F. 6 |
|  | Zone Airflow Calibration | 3 | Fan serving zone is off for 10 minutes and measured airflow 10% above active airflow set point. | 4.16 F. 4 |
|  | Zone Leaking Damper | 4 | Damper position is 0%, measured is 10% above active airflow set point for 10 minutes, fan serving zone is proven on. | 4.16 F. 5 |

* + - 1. Low Primary Airflow
         1. If the measured airflow is less than 70% of set point for 10 minutes while set point is greater than zero, generate a Level 4 alarm.
         2. If the measured airflow is less than 50% of set point for 10 minutes while set point is greater than zero, generate a Level 3 alarm.
         3. If a zone has an Importance-Multiplier of 0 (see Section 4.7 N. 2. a. i) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.
      2. Low-Discharge Air Temperature
         1. If heating hot-water plant is proven ON, and the DAT is 15°F less than set point for 10 minutes, generate a Level 4 alarm.
         2. If heating hot-water plant is proven ON, and the DAT is 30°F less than set point for 10 minutes, generate a Level 3 alarm.
         3. If a zone has an Importance-Multiplier of 0 (4.7 N. 2. a. i) for its hot-water reset T&R control loop, low-DAT alarms shall be suppressed for that zone.
      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.
         1. Commanded ON, status OFF: Level 2
         2. Commanded OFF, status ON: Level 4
      4. Airflow Sensor Calibration. If the fan serving the zone is OFF and airflow sensor reading is above the larger of 10% of the cooling maximum airflow set point or 50 cfm for 30 minutes, generate a Level 3 alarm.
      5. Leaking Damper. If the damper position is 0%, and airflow sensor reading is above the larger of 10% of the cooling maximum airflow set point or 50 cfm for 10 minutes while the fan serving the zone is proven ON, generate a Level 4 alarm.
      6. Leaking Valve. If the valve position is 0% for 15 minutes, and DAT is above AHU SAT by 5°F, generate a Level 4 alarm.
    1. Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to
       1. force zone airflow set point to zero,
       2. force zone airflow set point to Vcool-max,
       3. force zone airflow set point to Vmin,
       4. force damper full closed/open,
       5. force heating to OFF/closed,
       6. turn fan ON/OFF, and
       7. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 1.5K, 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 1.8E.

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.

* + 1. System Requests
       1. Cooling SAT Reset Requests
          1. If the zone temperature exceeds the zone’s cooling set point by 5°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 3 requests.
          2. Else if the zone temperature exceeds the zone’s cooling set point by 3°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 2 requests.
          3. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
          4. Else if the cooling loop is less than 95%, send 0 requests.
       2. Static Pressure Reset Requests
          1. 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.
          2. 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.
          3. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
          4. Else if the damper position is less than 95%, send 0 requests.

If There Is a Hot-Water Coil,

* + - 1. Hot Water Reset Requests
         1. If the DAT is 30°F less than set point for 5 minutes, send 3 requests.
         2. Else if the DAT is 15°F less than set point for 5 minutes, send 2 requests.
         3. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
         4. Else if the HW valve position is less than 95%, send 0 requests.

If There Is a Hot-Water Coil and a Heating Hot-Water Plant,

* + - 1. Heating Hot-Water Plant Requests. Send the heating hot-water plant that serves the zone a heating hot-water plant request as follows:
         1. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.
         2. Else if the HW valve position is less than 95%, send 0 requests.

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

Table 4.17.1 Dual Duct VAV Terminal Unit – Snap Acting Control – Hardware Points List

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Type | Device | Required |
|  | Hot Deck Damper Position | AO | Modulating Actuator | R |
|  | Cold Deck Damper Position | AO | Modulating Actuator | R |
|  | Hot Deck Supply Flow | AI | Differential pressure transducer connected to a flow sensor | Define |
|  | Cold Deck Supply Flow | AI | Differential pressure transducer connected to a flow sensor | Define |
|  | Discharge Supply Flow | AI | Differential pressure transducer connected to a flow sensor | Define |
|  | Zone Temperature | AI | Room Temperature Sensor, typically integrated into the thermostat | R |
|  | Valve Position | AO | Reheat Coil Valve Position | R |
|  | Discharge Air Temp | AI | Discharge Air Temperature | R |
|  | Fan Start/Stop | DO | Parallel Fan Start/Stop | R |
|  | Fan Status | DI | Parallel Fan Status | R |
|  | Local Override | DI | Zone thermostat override | Define |
|  | Occupancy Status | DI or Software | Occupancy Sensor | Define |
|  | Window Open/Closed | DI or Software | Window Switch | Define |
|  | Zone Temperature Adjustment | AI | Zone thermostat setpoint adjustment button or dial | Define |
|  | Zone CO2 Level | AI | Zone CO2 Sensor | Define |
|  | Zone Ceiling Fan Status | DI | Status indicator | Define |

Table 4.17.2 Dual Duct VAV Terminal Unit – Snap Acting Control – Software Points List (Excluding Ventilation)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | System OK | SystemOK | Binary | § 4.7 S |  |  | X |  | |
|  | Zone State | ZoneState | - | § 4.9 E |  |  | X |  | |
|  | Parent AHU System Mode |  |  | § 4.21 |  |  | X |  | |
|  | Zone Cooling Setpoint |  | °F | § 4.5 A. 1 | X | X |  |  | |
|  | Zone Heating Setpoint |  | °F | § 4.5 B | X | X |  |  | |
|  | VAV Box Minimum Velocity Pressure Sensor Reading for Accuracy | VPm | in. w.c. | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Velocity | vm | fpm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Flow Application Factor | F | - | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Diameter | D | In | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Area | A | in² | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Controllable Airflow | Vm | cfm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | Zone Maximum Cooling Airflow Set point | Vcool-max | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Minimum Airflow Set point | Vmin | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Active Airflow Set point | Vspt | cfm | § 4.17 E |  |  | X |  | |
|  | Zone Cooling Control Loop |  | - | § 4.17 E. 1. a |  |  | X | 0 = no cooling, 100 = full cooling | |
|  | Cooling Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | Zone Heating Control Loop |  | - | § 4.17 E. 1. c |  |  | X | 0 = no heating, 100 = full heating | |
|  | Heating Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | Cold SAT Requests |  | - | § 4.17 H. 1 |  |  | X |  | |
|  | Cold SAT Importance-Multiplier |  | - | § 4.17 H. 1 | X | X |  |  | |
|  | Cold SAT Request-Hours Accumulator |  | hrs | § 4.17 H. 1 |  | X | X | User can reset | |
|  | Cold SAT System Run-Hours Total |  | hrs | § 4.17 H. 1 |  | X | X | User can reset | |
|  | Cold SAT Cumulative % Request-Hours |  | % | § 4.17 H. 1 |  | X | X | User can reset | |
|  | Cold DSP Requests |  | - | § 4.17 H. 2 |  |  | X |  | |
|  | Cold DSP Importance-Multiplier |  | - | § 4.17 H. 2 | X | X |  |  | |
|  | Cold DSP Request-Hours Accumulator |  | hrs | § 4.17 H. 2 |  | X | X | User can reset | |
|  | Cold DSP System Run-Hours Total |  | hrs | § 4.17 H. 2 |  | X | X | User can reset | |
|  | Cold DSP Cumulative % Request-Hours |  | % | § 4.17 H. 2 |  | X | X | User can reset | |
|  | Hot SAT Requests |  | - | § 4.17 H. 3 |  |  | X |  | |
|  | Hot SAT Importance-Multiplier |  | - | § 4.17 H. 3 | X | X |  |  | |
|  | Hot SAT Request-Hours Accumulator |  | hrs | § 4.17 H. 3 |  | X | X | User can reset | |
|  | Hot SAT System Run-Hours Total |  | hrs | § 4.17 H. 3 |  | X | X | User can reset | |
|  | Hot SAT Cumulative % Request-Hours |  | % | § 4.17 H. 3 |  | X | X | User can reset | |
|  | Hot DSP Requests |  | - | § 4.17 H. 4 |  |  | X |  | |
|  | Hot DSP Importance-Multiplier |  | - | § 4.17 H. 4 | X | X |  |  | |
|  | Hot DSP Request-Hours Accumulator |  | hrs | § 4.17 H. 4 |  | X | X | User can reset | |
|  | Hot DSP System Run-Hours Total |  | hrs | § 4.17 H. 4 |  | X | X | User can reset | |
|  | Hot DSP Cumulative % Request-Hours |  | % | § 4.17 H. 4 |  | X | X | User can reset | |
|  | Heating Fan Requests |  | - | § 4.17 H. 5 |  |  | X |  | |
|  | Heating Fan Importance-Multiplier |  | - | § 4.17 H. 5 | X | X |  |  | |
|  | Heating Fan Request-Hours Accumulator |  | hrs | § 4.17 H. 5 |  | X | X | User can reset | |
|  | Heating Fan System Run-Hours Total |  | hrs | § 4.17 H. 5 |  | X | X | User can reset | |
|  | Heating Fan Cumulative % Request-Hours |  | % | § 4.17 H. 5 |  | X | X | User can reset | |
|  | TAV Ratio | TAVratio | - | § 4.8 B |  |  | X |  | |
|  | TAV Zone Lowest Possible Air Flow | Vm | cfm | § 4.8 B | X | X |  |  | |
|  | TAV Total Cycle Time | TCT | min | § 4.8 B | X | X |  |  | |
|  | TAV Open Period | OP | min | § 4.8 B |  |  | X |  | |
|  | TAV Closed Period | CP | min | § 4.8 B |  |  | X |  | |
|  | TAV Setpoint | Vspt\* | cfm | § 4.8 B |  |  | X |  | |
|  | Window-switch Cooling Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Window-switch Heating Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Occupancy Cooling Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Occupancy Heating Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Demand Limited Level 1 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 2 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 3 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limit Exempt |  | - | § 4.9 B. 6 | X | X |  | Yes/No | |
|  | Ceiling Fan Offset |  | - | § 4.9 B. 9 | X | X |  |  | |

Table 4.17.3 Dual Duct VAV Terminal Unit – Snap Acting Control – Ventilation Software Points – Title 24

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Zone Occupancy Minimum Ventilation Rate | Vocc-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; 15 cfm/person |
| 2 | Zone Area Minimum Ventilation Rate | Varea-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; by space type |
| 3 | Absolute OA Minimum | Zone-Abs-OA-min | cfm | § 4.8 A. 4. b. i |  |  | X |  |
| 4 | Design OA Minimum | Zone-Des-OA-min | cfm | § 4.8 A. 4. b. ii |  |  | X |  |
| 5 | CO2 Loop Output |  | % | § 4.8 A. 4. d. iii |  |  | X | 0 = no demand 100 = full demand |
| 6 | CO2 Minimum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Varea-min |
| 7 | CO2 Maximum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Vcool-max |
| 8 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  Max CO2 - 200 |
| 9 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  CO2 Setpoint |
| 10 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 4. d. iii |  |  | X | Reset based on CO2 loop |
| 11 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

Table 4.17.4 Dual Duct VAV Terminal Unit – Snap Acting Control – Ventilation Software Points – ASHRAE 62.1

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Ventilation, Area Component | Vbz-A | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 2 | Ventilation, People Component | Vbz-P | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 3 | Ventilation, Active Air Distribution Effectiveness | Ez | cfm | § 4.5 A. 1. b |  |  | X | Calculated |
| 4 | Ventilation, Heating Air Distribution Effectiveness | EzH | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 5 | Ventilation, Cooling Air Distribution Effectiveness | EzC | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 6 | Ventilation, Required | Voz | cfm | § 4.8 A |  |  | X | Equals  (Vbz-A + Vbz-P)/Ez |
| 7 | CO2 People Component | Vbz-P\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Reset between 0 and Vbz-P |
| 8 | CO2 Loop Output |  | - | § 4.8 A. 3. f. iv |  |  | X | 0 = no demand 100 = full demand |
| 9 | CO2 Minimum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vbz-A |
| 10 | CO2 Maximum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vcool-max |
| 11 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals  Max CO2 - 200 |
| 12 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals CO2 Setpoint |
| 13 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals  (Vbz-A + Vbz-P\*)/Ez |
| 14 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

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 CO2 control because it can cause the zone to oscillate between cooling and heating. This occurs when the CO2 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 CO2 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 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.

* + 1. See “Generic Thermal Zones” (Section 4.9) for set points, loops, control modes, alarms, etc.
    2. See “Generic Ventilation Zones” (Section 4.8) for calculation of zone minimum outdoor airflow.
    3. See Section 4.5 B. 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.
    4. Active endpoints used in the control logic depicted in Figure 4.17.1and Figure 4.17.2 shall vary depending on the mode of the zone group the zone is a part of (see Table 4.17.5).

Table 4.17.5: Airflow Set Points as a Function of Zone Group Mode – Snap-Acting Dual-Duct VAV

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Set Point | Occupied | Cooldown | Setup | Warm-Up | Setback | Unoccupied |
| Cooling Maximum | Vcool-max | Vcool-max | Vcool-max | 0 | 0 | 0 |
| Deadband Minimum | Vmin\* | 0 | 0 | 0 | 0 | 0 |
| Heating Maximum | Vheat-max | 0 | 0 | Vheat-max | Vheat-max | 0 |

* + 1. Control logic is depicted schematically in Figure 4.17.1and Figure 4.17.2 and described in the following subsections.

The engineer must select between ventilation logic options:

• If there are airflow sensors at both inlets to the box, use Section 4.17 E. 1 and delete Section 4.17 E. 2.

• If there is a single airflow sensor at the box discharge, use Section 4.17 E. 2 and delete Section 4.17 E. 1

* + - 1. Temperature and Damper Control with Dual Inlet Airflow Sensors
         1. When the zone state is cooling, the cooling-loop output shall reset the active cold duct airflow set point from the minimum endpoint to cooling maximum endpoint. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at the active cold duct airflow set point. The hot duct damper shall be closed.

If cold-deck supply air temperature from the air handler is greater than room temperature, the active cold duct airflow set point shall be no higher than the minimum endpoint.

* + - * 1. When the zone state is deadband, the active cold duct and hot duct airflow set points shall be their last set points just before entering deadband. In other words, when going from cooling to deadband, the active cold duct airflow set point is equal to the minimum endpoint, and the active hot duct set point is zero. When going from heating to deadband, the active hot duct airflow set point is equal to the minimum endpoint and the active cold duct airflow set point is zero. This results in a snap-action switch in the damper set point as indicated in Figure 4.17.1 and Figure 4.17.2.

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.

* + - * 1. When the zone state is heating, the heating-loop output shall reset the active hot duct airflow set point from the minimum endpoint to the heating maximum endpoint. The hot duct damper shall be modulated by a control loop to maintain the measured heating airflow at the active hot duct airflow set point. The cold duct damper shall be closed.

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

* + - 1. Temperature and Damper Control with a Single Discharge Airflow Sensor
         1. When the zone states is cooling, the cooling-loop output shall reset the active airflow set point from the minimum to cooling maximum endpoint. The cold duct damper shall be modulated by a control loop to maintain the measured discharge airflow at the active cold duct airflow set point. The hot duct damper shall be closed.
         2. When the zone state is deadband, the active airflow set point shall be the minimum endpoint, 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 cold duct damper shall maintain the discharge airflow at the minimum endpoint, and the heating damper shall be closed. When going from heating to deadband, the hot duct damper shall maintain the discharge airflow at the minimum endpoint, and the cold duct damper shall be closed. This results in a snap-action switch in the active damper airflow set point as indicated in Figure 4.17.1 and Figure 4.17.2.
         3. When the zone state is heating, the heating-loop output shall reset active hot duct airflow set point from the minimum endpoint to heating maximum endpoint. The hot duct damper shall be modulated by a control loop to maintain the measured discharge airflow at the active hot duct airflowset point. The cold duct damper shall be closed.

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

When the sequences are complete, only one of Section 4.17 E. 1 and Section 4.17 E. 2 should remain. The other section should be deleted, along with these flag notes.

* + - 1. Backflow Prevention Temperature Control Overrides

The following requirements override the temperature control algorithm, discussed in section 4.17 E. 1. These will shut-off the supply duct when one air handler is shut off (e.g. during morning warm-up, when the hot deck air handler is ON and cold deck air handler is OFF, all cooling dampers will be closed to prevent warm air from circulating through the cold deck air handler).

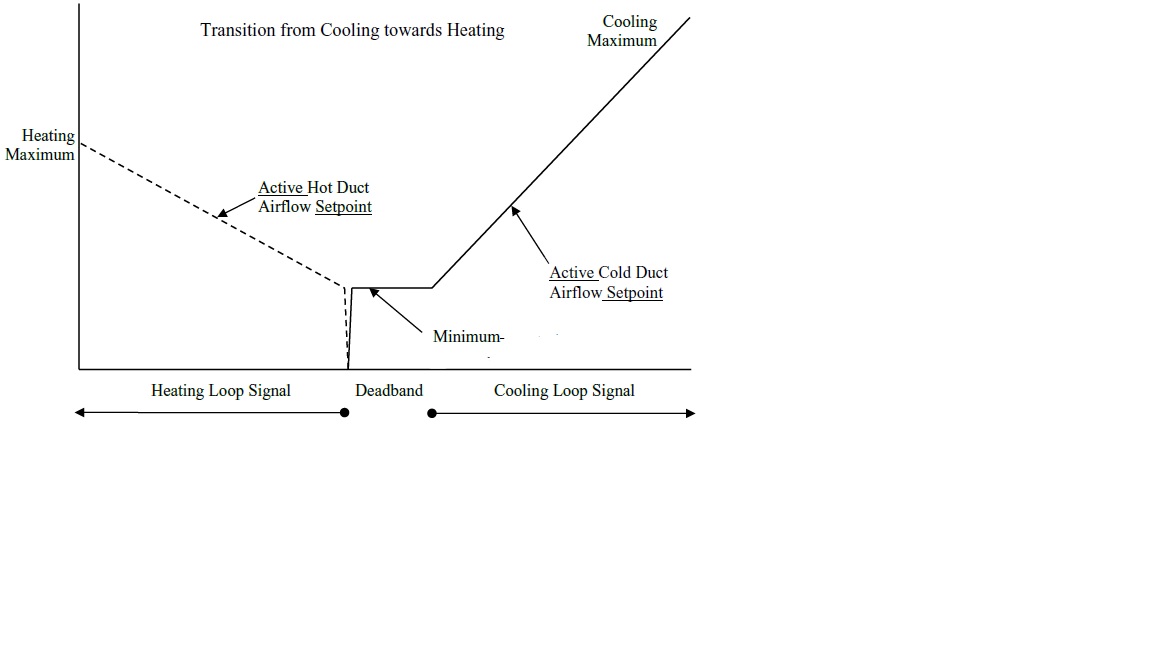


Figure 4.17.1: Control Logic – Transition to Cooling – Snap-Acting Dual-Duct VAV

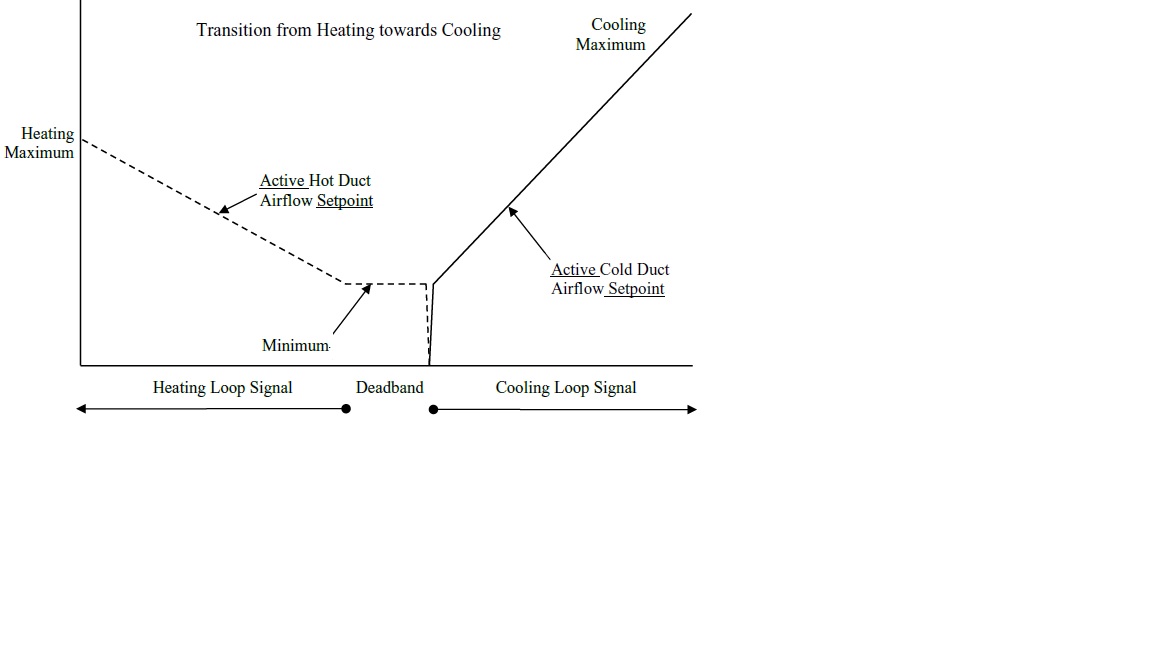


Figure 4.17.2: Control Logic – Transition to Heating – Snap-Acting Dual-Duct VAV

* + 1. Alarms

Table 4.17.6 Alarm List - Dual Duct Terminal Unit

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Level | Definition | Applicable Spec Section |
|  | Window Left Open | 4 | When other than occupied mode and window switch indicates window is open. | 4.9 B. 7. b |
|  | Ceiling Fan Left On | 4 | When other than occupied mode and ceiling fan is proven ON. | 4.9 B. 9. d |
|  | High Zone Temp I | 3 | Zone temperature is 3°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. i |
|  | High Zone Temp II | 2 | Zone temperature is 5°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. ii |
|  | Low Zone Temp I | 3 | Zone temperature is 3°F below heating setpoint for 10 minutes | 4.9 F. 1. b. i |
|  | Low Zone Temp II | 2 | Zone temperature is 5°F below heating setpoint for 10 minutes | 4.9 F. 1. b. ii |
|  | Low CO2, Calibration Needed | 3 | CO2 concentration is less than 300 ppm | 4.9 F. 2. a |
|  | High Vacant CO2, Calibration Needed | 3 | CO2 concentration is above 600 ppm and in unoccupied mode for 2 hours | 4.9 F. 2. a |
|  | High Occupied CO2 | 3 | CO2 concentration is exceeds set point by 10% for more than 10 minutes. | 4.9 F. 2. b |
|  | Zone Low Airflow I | 3 | Measured airflow 70% less than active airflow set point for 5 minutes | 4.17 F. 1. a |
|  | Zone Low Airflow II | 2 | Measured airflow 50% less than active airflow set point for 5 minutes | 4.17 F. 1. b |
|  | Zone Airflow Calibration | 3 | Fan serving zone is off for 10 minutes and measured airflow 10% above active airflow set point. | 4.17 F. 2 |
|  | Zone Leaking Damper | 4 | Damper position is 0%, measured is 10% above active airflow set point for 10 minutes, fan serving zone is proven on. | 4.17 F. 3 |

* + - 1. Low Airflow
         1. If the measured airflow is less than 70% of set point for 10 minutes while set point is greater than zero, generate a Level 4 alarm.
         2. If the measured airflow is less than 50% of set point for 10 minutes while set point is greater than zero, generate a Level 3 alarm.
         3. If a zone has an Importance-Multiplier of 0 (see Section 4.7 N. 2. a. i) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.
      2. Airflow Sensor Calibration. If the fan serving the zone is off and airflow sensor reading is above the larger of 10% of the maximum airflow set point or 50 cfm for 30 minutes, generate a Level 3 alarm.
      3. Leaking Damper. If the damper position is 0%, and airflow sensor reading is above the larger of 10% of the cooling maximum airflow set point or 50 cfm for 10 minutes while the fan serving the damper is proven ON, generate a Level 4 alarm.
    1. Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to:
       1. force zone airflow set point to zero,
       2. force zone airflow set point to Vcool-max,
       3. force zone airflow set point to Vmin,
       4. force zone airflow set point to Vheat-max,
       5. force cooling damper full closed/open,
       6. force heating damper full closed/open, and
       7. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 1.5K, 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 1.8E.

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.

* + 1. System Requests
       1. Cooling SAT Reset Requests
          1. If the zone temperature exceeds the zone’s cooling set point by 5°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 3 requests.
          2. Else if the zone temperature exceeds the zone’s cooling set point by 3°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 2 requests.
          3. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
          4. Else if the cooling loop is less than 95%, send 0 requests.
       2. Cold-Duct Static Pressure Reset Requests
          1. 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.
          2. 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.
          3. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
          4. Else if the damper position is less than 95%, send 0 requests.
       3. Heating SAT Reset Requests
          1. If the zone temperature is below the zone’s heating set point by 5°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 3 requests.
          2. Else if the zone temperature is below the zone’s heating set point by 3°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 2 requests.
          3. Else if the heating loop is greater than 95%, send 1 request until the heating loop is less than 85%.
          4. Else if the heating loop is less than 95%, send 0 requests
       4. Hot-Duct Static Pressure Reset Requests
          1. 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.
          2. 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.
          3. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
          4. Else if the damper position is less than 95%, send 0 requests.
       5. Heating-Fan Requests. Send the heating fan that serves the zone a heating-fan request as follows:
          1. If the heating loop is greater than 15%, send 1 request until the heating loop is less than 1%.
          2. Else if the heating loop is less than 15%, send 0 requests.

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

Table 4.18.1 Dual Duct VAV Terminal Unit – Mixing Inlet Airflow Sensors – Hardware Points List

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Type | Device | Required |
|  | Hot Deck Damper Position | AO | Modulating Actuator | R |
|  | Cold Deck Damper Position | AO | Modulating Actuator | R |
|  | Hot Deck Supply Flow | AI | Differential pressure transducer connected to a flow sensor | R |
|  | Cold Deck Supply Flow | AI | Differential pressure transducer connected to a flow sensor | R |
|  | Zone Temperature | AI | Room Temperature Sensor, typically integrated into the thermostat | R |
|  | Valve Position | AO | Reheat Coil Valve Position | R |
|  | Discharge Air Temp | AI | Discharge Air Temperature | R |
|  | Fan Start/Stop | DO | Parallel Fan Start/Stop | R |
|  | Fan Status | DI | Parallel Fan Status | R |
|  | Local Override | DI | Zone thermostat override | Define |
|  | Occupancy Status | DI or Software | Occupancy Sensor | Define |
|  | Window Open/Closed | DI or Software | Window Switch | Define |
|  | Zone Temperature Adjustment | AI | Zone thermostat setpoint adjustment button or dial | Define |
|  | Zone CO2 Level | AI | Zone CO2 Sensor | Define |
|  | Zone Ceiling Fan Status | DI | Status indicator | Define |

Table 4.18.2 Dual Duct VAV Terminal Unit – Mixing Inlet Airflow Sensors – Software Points List (Excluding Ventilation)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | System OK | SystemOK | Binary | § 4.7 S |  |  | X |  | |
|  | Zone State | ZoneState | - | § 4.9 E |  |  | X |  | |
|  | Parent AHU System Mode |  |  | § 4.21 |  |  | X |  | |
|  | Zone Cooling Setpoint |  | °F | § 4.5 A. 1 | X | X |  |  | |
|  | Zone Heating Setpoint |  | °F | § 4.5 B | X | X |  |  | |
|  | VAV Box Minimum Velocity Pressure Sensor Reading for Accuracy | VPm | in. w.c. | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Velocity | vm | fpm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Flow Application Factor | F | - | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Diameter | D | In | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Area | A | in² | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Controllable Airflow | Vm | cfm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | Zone Maximum Cooling Airflow Set point | Vcool-max | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Minimum Airflow Set point | Vmin | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Active Airflow Set point | Vspt | cfm | § 4.18 E |  |  | X |  | |
|  | Zone Cooling Control Loop |  | - | § 4.18 E. 1. a |  |  | X | 0 = no cooling, 100 = full cooling | |
|  | Cooling Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | Zone Heating Control Loop |  | - | 4.18 E. 1. c |  |  | X | 0 = no heating, 100 = full heating | |
|  | Heating Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | Cold SAT Requests |  | - | § 4.18 H. 1 |  |  | X |  | |
|  | Cold SAT Importance-Multiplier |  | - | § 4.18 H. 1 | X | X |  |  | |
|  | Cold SAT Request-Hours Accumulator |  | hrs | § 4.18 H. 1 |  | X | X | User can reset | |
|  | Cold SAT System Run-Hours Total |  | hrs | § 4.18 H. 1 |  | X | X | User can reset | |
|  | Cold SAT Cumulative % Request-Hours |  | % | § 4.18 H. 1 |  | X | X | User can reset | |
|  | Cold DSP Requests |  | - | § 4.18 H. 2 |  |  | X |  | |
|  | Cold DSP Importance-Multiplier |  | - | § 4.18 H. 2 | X | X |  |  | |
|  | Cold DSP Request-Hours Accumulator |  | hrs | § 4.18 H. 2 |  | X | X | User can reset | |
|  | Cold DSP System Run-Hours Total |  | hrs | § 4.18 H. 2 |  | X | X | User can reset | |
|  | Cold DSP Cumulative % Request-Hours |  | % | § 4.18 H. 2 |  | X | X | User can reset | |
|  | Hot SAT Requests |  | - | § 4.18 H. 3 |  |  | X |  | |
|  | Hot SAT Importance-Multiplier |  | - | § 4.18 H. 3 | X | X |  |  | |
|  | Hot SAT Request-Hours Accumulator |  | hrs | § 4.18 H. 3 |  | X | X | User can reset | |
|  | Hot SAT System Run-Hours Total |  | hrs | § 4.18 H. 3 |  | X | X | User can reset | |
|  | Hot SAT Cumulative % Request-Hours |  | % | § 4.18 H. 3 |  | X | X | User can reset | |
|  | Hot DSP Requests |  | - | § 4.18 H. 4 |  |  | X |  | |
|  | Hot DSP Importance-Multiplier |  | - | § 4.18 H. 4 | X | X |  |  | |
|  | Hot DSP Request-Hours Accumulator |  | hrs | § 4.18 H. 4 |  | X | X | User can reset | |
|  | Hot DSP System Run-Hours Total |  | hrs | § 4.18 H. 4 |  | X | X | User can reset | |
|  | Hot DSP Cumulative % Request-Hours |  | % | § 4.18 H. 4 |  | X | X | User can reset | |
|  | Heating Fan Requests |  | - | § 4.18 H. 5 |  |  | X |  | |
|  | Heating Fan Importance-Multiplier |  | - | § 4.18 H. 5 | X | X |  |  | |
|  | Heating Fan Request-Hours Accumulator |  | hrs | § 4.18 H. 5 |  | X | X | User can reset | |
|  | Heating Fan System Run-Hours Total |  | hrs | § 4.18 H. 5 |  | X | X | User can reset | |
|  | Heating Fan Cumulative % Request-Hours |  | % | § 4.18 H. 5 |  | X | X | User can reset | |
|  | TAV Ratio | TAVratio | - | § 4.8 B |  |  | X |  | |
|  | TAV Zone Lowest Possible Air Flow | Vm | cfm | § 4.8 B | X | X |  |  | |
|  | TAV Total Cycle Time | TCT | min | § 4.8 B | X | X |  |  | |
|  | TAV Open Period | OP | min | § 4.8 B |  |  | X |  | |
|  | TAV Closed Period | CP | min | § 4.8 B |  |  | X |  | |
|  | TAV Setpoint | Vspt\* | cfm | § 4.8 B |  |  | X |  | |
|  | Window-switch Cooling Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Window-switch Heating Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Occupancy Cooling Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Occupancy Heating Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Demand Limited Level 1 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 2 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 3 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limit Exempt |  | - | § 4.9 B. 6 | X | X |  | Yes/No | |
|  | Ceiling Fan Offset |  | - | § 4.9 B. 9 | X | X |  |  | |

Table 4.18.3 Dual Duct VAV Terminal Unit – Mixing Inlet Airflow Sensors – Ventilation Software Points – Title 24

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Zone Occupancy Minimum Ventilation Rate | Vocc-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; 15 cfm/person |
| 2 | Zone Area Minimum Ventilation Rate | Varea-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; by space type |
| 3 | Absolute OA Minimum | Zone-Abs-OA-min | cfm | § 4.8 A. 4. b. i |  |  | X |  |
| 4 | Design OA Minimum | Zone-Des-OA-min | cfm | § 4.8 A. 4. b. ii |  |  | X |  |
| 5 | CO2 Loop Output |  | % | § 4.8 A. 4. d. iii |  |  | X | 0 = no demand 100 = full demand |
| 6 | CO2 Minimum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Varea-min |
| 7 | CO2 Maximum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Vcool-max |
| 8 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  Max CO2 - 200 |
| 9 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  CO2 Setpoint |
| 10 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 4. d. iii |  |  | X | Reset based on CO2 loop |
| 11 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

Table 4.18.4 Dual Duct VAV Terminal Unit – Mixing Inlet Airflow Sensors – Ventilation Software Points – ASHRAE 62.1

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Ventilation, Area Component | Vbz-A | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 2 | Ventilation, People Component | Vbz-P | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 3 | Ventilation, Active Air Distribution Effectiveness | Ez | cfm | § 4.5 A. 1. b |  |  | X | Calculated |
| 4 | Ventilation, Heating Air Distribution Effectiveness | EzH | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 5 | Ventilation, Cooling Air Distribution Effectiveness | EzC | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 6 | Ventilation, Required | Voz | cfm | § 4.8 A |  |  | X | Equals  (Vbz-A + Vbz-P)/Ez |
| 7 | CO2 People Component | Vbz-P\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Reset between 0 and Vbz-P |
| 8 | CO2 Loop Output |  | - | § 4.8 A. 3. f. iv |  |  | X | 0 = no demand 100 = full demand |
| 9 | CO2 Minimum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vbz-A |
| 10 | CO2 Maximum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vcool-max |
| 11 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals  Max CO2 - 200 |
| 12 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals CO2 Setpoint |
| 13 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals  (Vbz-A + Vbz-P\*)/Ez |
| 14 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

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.

* + 1. See “Generic Thermal Zones” (Section 4.9) for set points, loops, control modes, alarms, etc.
    2. See “Generic Ventilation Zones” (Section 4.8) for calculation of zone minimum outdoor airflow.
    3. See Section 4.5 B. 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.
    4. Active endpoints used in the control logic depicted in Figure 4.18.1 shall vary depending on the mode of the zone group the zone is a part of (see Table 4.18.5).

Table 4.18.5: Airflow Set Points as a Function of Zone Group Mode – Mixing Dual Duct VAV with Inlet Airflow Sensor

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Endpoint | Occupied | Cooldown | Setup | Warm-Up | Setback | Unoccupied |
| Cooling Maximum | Vcool-max | Vcool-max | Vcool-max | 0 | 0 | 0 |
| Deadband Minimum | Vmin\* | 0 | 0 | 0 | 0 | 0 |
| Heating Maximum | Vheat-max | 0 | 0 | Vheat-max | Vheat-max | 0 |

* + 1. Control logic is depicted schematically in Figure 4.18.1 and described in the following sections.
       1. Temperature Control
          1. When the zone state is cooling, the cooling loop output shall reset the active cold duct airflow set point from minimum endpoint to the cooling maximum endpoint. The cooling damper shall be modulated by a control loop to maintain the measured cold duct airflow at active cold duct airflow set point.

If cold-duct supply air temperature from the air handler is greater than room temperature, the ctive cold duct airflow set point shall be no higher than the minimum endpoint.

* + - * 1. When the zone state is deadband, the active cold duct airflow set point shall be the minimum endpoint. The cooling damper shall be modulated by a control loop to maintain the measured cooling airflow at the active cold duct air flow set point. The hot duct 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 out-door air economizer.

* + - * 1. When the zone state is heating, the heating-loop output shall reset the active hot duct airflow set point from zero to the heating maximum endpoint. The heating damper shall be modulated by a control loop to maintain the measured hot duct airflow at the active hot duct airflow set point. The cold duct damper shall be controlled to maintain the sum of the measured inlet airflows at the minimum endpoint.

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

* + - 1. Backflow Prevention Temperature Control Overrides

The following requirements override the temperature control algorithm, discussed in section 4.18 E. 1 These will shut-off the supply duct when one air handler is shut off (e.g. during morning warm-up, when the hot deck air handler is ON and cold deck air handler is OFF, all cooling dampers will be closed to prevent warm air from circulating through the cold deck air handler).

* + - * 1. If heating air handler is not proven ON, the heating damper shall be closed.
        2. If cooling air handler is not proven ON, the cooling damper shall be closed.

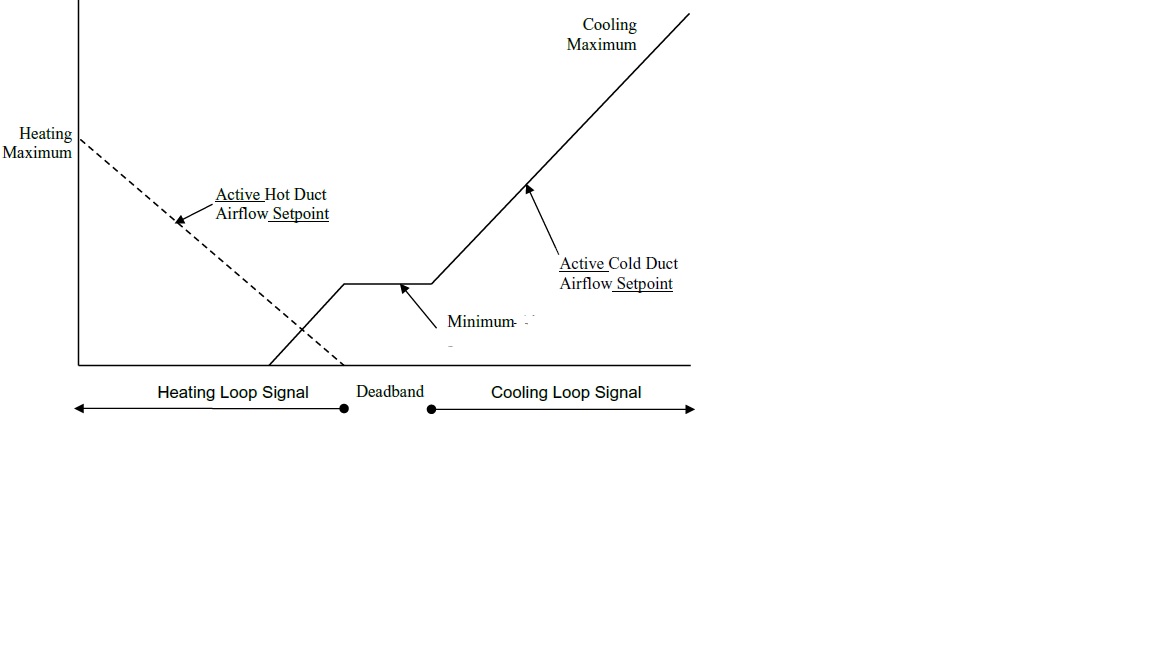


Figure 4.18.1: Control Logic – Mixing Dual-Duct VAV Zone with Inlet Airflow Sensors

* + 1. Alarms

Table 4.18.6 Alarm List - Dual Duct Terminal Unit

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Level | Definition | Applicable Spec Section |
|  | Window Left Open | 4 | When other than occupied mode and window switch indicates window is open. | 4.9 B. 7. b |
|  | Ceiling Fan Left On | 4 | When other than occupied mode and ceiling fan is proven ON. | 4.9 B. 9. d |
|  | High Zone Temp I | 3 | Zone temperature is 3°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. i |
|  | High Zone Temp II | 2 | Zone temperature is 5°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. ii |
|  | Low Zone Temp I | 3 | Zone temperature is 3°F below heating setpoint for 10 minutes | 4.9 F. 1. b. i |
|  | Low Zone Temp II | 2 | Zone temperature is 5°F below heating setpoint for 10 minutes | 4.9 F. 1. b. ii |
|  | Low CO2, Calibration Needed | 3 | CO2 concentration is less than 300 ppm | 4.9 F. 2. a |
|  | High Vacant CO2, Calibration Needed | 3 | CO2 concentration is above 600 ppm and in unoccupied mode for 2 hours | 4.9 F. 2. a |
|  | High Occupied CO2 | 3 | CO2 concentration is exceeds set point by 10% for more than 10 minutes. | 4.9 F. 2. b |
|  | Zone Low Airflow I | 3 | Measured airflow 70% less than active airflow set point for 5 minutes | 4.18 F. 1. a |
|  | Zone Low Airflow II | 2 | Measured airflow 50% less than active airflow set point for 5 minutes | 4.18 F. 1. b |
|  | Zone Airflow Calibration | 3 | Fan serving zone is off for 10 minutes and measured airflow 10% above active airflow set point. | 4.18 F. 2 |
|  | Zone Leaking Damper | 4 | Damper position is 0%, measured is 10% above active airflow set point for 10 minutes, fan serving zone is proven on. | 4.18 F. 3 |

* + - 1. Low Airflow
         1. If the measured airflow is less than 70% of set point for 5 minutes while set point is greater than zero, generate a Level 4 alarm.
         2. If the measured airflow is less than 50% of set point for 5 minutes while set point is greater than zero, generate a Level 3 alarm.
         3. If a zone has an Importance-Multiplier of 0 (see Section 4.7 N. 2. a. i) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.
      2. Airflow Sensor Calibration. If the fan serving the zone is OFF and airflow sensor reading is above the larger of 10% of the maximum airflow set point or 50 cfm for 30 minutes, generate a Level 3 alarm.
      3. Leaking Damper. If the damper position is 0%, and airflow sensor reading is above the larger of 10% of the cooling maximum airflow set point or 50 cfm for 10 minutes while the fan serving the damper is proven ON, generate a Level 4 alarm.
    1. Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to
       1. force zone airflow set point to zero,
       2. force zone airflow set point to Vcool-max,
       3. force zone airflow set point to Vmin,
       4. force zone airflow set point to Vheat-max,
       5. force cooling damper full closed/open,
       6. force heating damper full closed/open, and
       7. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 1.5K, 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 1.8E.

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.

* + 1. System Requests
       1. Cooling SAT Reset Requests
          1. If the zone temperature exceeds the zone’s cooling set point by 5°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 3 requests.
          2. Else if the zone temperature exceeds the zone’s cooling set point by 3°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 2 requests.
          3. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
          4. Else if the cooling loop is less than 95%, send 0 requests.
       2. Cold-Duct Static Pressure Reset Requests
          1. 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.
          2. 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.
          3. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
          4. Else if the damper position is less than 95%, send 0 requests.
       3. Heating SAT Reset Requests
          1. If the zone temperature is below the zone’s heating set point by 5°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 3 requests.
          2. Else if the zone temperature is below the zone’s heating set point by 3°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 2 requests.
          3. Else if the heating loop is greater than 95%, send 1 request until the heating loop is less than 85%.
          4. Else if the heating loop is less than 95%, send 0 requests.
       4. Hot-Duct Static Pressure Reset Requests
          1. 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.
          2. 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.
          3. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
          4. Else if the damper position is less than 95%, send 0 requests.
       5. Heating-Fan Requests. Send the heating fan that serves the zone a heating-fan request as follows:
          1. If the heating loop is greater than 15%, send 1 request until the heating loop is less than 1%.
          2. Else if the heating loop is less than 15%, send 0 requests.

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

Table 4.19.1 Dual Duct VAV Terminal Unit – Mixing Discharge Airflow Sensors – Hardware Points List

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Type | Device | Required |
|  | Hot Deck Damper Position | AO | Modulating Actuator | R |
|  | Cold Deck Damper Position | AO | Modulating Actuator | R |
|  | Discharge Supply Flow | AI | Differential pressure transducer connected to a flow sensor | Define |
|  | Zone Temperature | AI | Room Temperature Sensor, typically integrated into the thermostat | R |
|  | Valve Position | AO | Reheat Coil Valve Position | R |
|  | Discharge Air Temp | AI | Discharge Air Temperature | R |
|  | Fan Start/Stop | DO | Parallel Fan Start/Stop | R |
|  | Fan Status | DI | Parallel Fan Status | R |
|  | Local Override | DI | Zone thermostat override | Define |
|  | Occupancy Status | DI or Software | Occupancy Sensor | Define |
|  | Window Open/Closed | DI or Software | Window Switch | Define |
|  | Zone Temperature Adjustment | AI | Zone thermostat setpoint adjustment button or dial | Define |
|  | Zone CO2 Level | AI | Zone CO2 Sensor | Define |
|  | Zone Ceiling Fan Status | DI | Status indicator | Define |

Table 4.19.2 Dual Duct VAV Terminal Unit – Mixing Discharge Airflow Sensors – Software Points List (Excluding Ventilation)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | System OK | SystemOK | Binary | § 4.7 S |  |  | X |  | |
|  | Zone State | ZoneState | - | § 4.9 E |  |  | X |  | |
|  | Parent AHU System Mode |  |  | § 4.21 |  |  | X |  | |
|  | Zone Cooling Setpoint |  | °F | § 4.5 A. 1 | X | X |  |  | |
|  | Zone Heating Setpoint |  | °F | § 4.5 B | X | X |  |  | |
|  | VAV Box Minimum Velocity Pressure Sensor Reading for Accuracy | VPm | in. w.c. | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Velocity | vm | fpm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Flow Application Factor | F | - | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Diameter | D | In | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Area | A | in² | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Controllable Airflow | Vm | cfm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | Zone Maximum Cooling Airflow Set point | Vcool-max | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Minimum Airflow Set point | Vmin | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Active Airflow Set point | Vspt | cfm | § 4.19 E |  |  | X |  | |
|  | Zone Cooling Control Loop |  | - | § 4.19 E. 1. a |  |  | X | 0 = no cooling, 100 = full cooling | |
|  | Cooling Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | Zone Heating Control Loop |  | - | §4.19 E. 1. c |  |  | X | 0 = no heating, 100 = full heating | |
|  | Heating Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | Cold DSP Requests |  | - | § 4.19 H. 2 |  |  | X |  | |
|  | Cold DSP Importance-Multiplier |  | - | § 4.19 H. 2 | X | X |  |  | |
|  | Cold DSP Request-Hours Accumulator |  | hrs | § 4.19 H. 2 |  | X | X | User can reset | |
|  | Cold DSP System Run-Hours Total |  | hrs | § 4.19 H. 2 |  | X | X | User can reset | |
|  | Cold DSP Cumulative % Request-Hours |  | % | § 4.19 H. 2 |  | X | X | User can reset | |
|  | Hot DSP Requests |  | - | § 4.19 H. 4 |  |  | X |  | |
|  | Hot DSP Importance-Multiplier |  | - | § 4.19 H. 4 | X | X |  |  | |
|  | Hot DSP Request-Hours Accumulator |  | hrs | § 4.19 H. 4 |  | X | X | User can reset | |
|  | Hot DSP System Run-Hours Total |  | hrs | § 4.19 H. 4 |  | X | X | User can reset | |
|  | Hot DSP Cumulative % Request-Hours |  | % | § 4.19 H. 4 |  | X | X | User can reset | |
|  | Cold SAT Requests |  | - | § 4.19 H. 1 |  |  | X |  | |
|  | Cold SAT Importance-Multiplier |  | - | § 4.19 H. 1 | X | X |  |  | |
|  | Cold SAT Request-Hours Accumulator |  | hrs | § 4.19 H. 1 |  | X | X | User can reset | |
|  | Cold SAT System Run-Hours Total |  | hrs | § 4.19 H. 1 |  | X | X | User can reset | |
|  | Cold SAT Cumulative % Request-Hours |  | % | § 4.19 H. 1 |  | X | X | User can reset | |
|  | Hot SAT Requests |  | - | § 4.19 H. 3 |  |  | X |  | |
|  | Hot SAT Importance-Multiplier |  | - | § 4.19 H. 3 | X | X |  |  | |
|  | Hot SAT Request-Hours Accumulator |  | hrs | § 4.19 H. 3 |  | X | X | User can reset | |
|  | Hot SAT System Run-Hours Total |  | hrs | § 4.19 H. 3 |  | X | X | User can reset | |
|  | Hot SAT Cumulative % Request-Hours |  | % | § 4.19 H. 3 |  | X | X | User can reset | |
|  | Heating Fan Requests |  | - | § 4.19 H. 5 |  |  | X |  | |
|  | Heating Fan Importance-Multiplier |  | - | § 4.19 H. 5 | X | X |  |  | |
|  | Heating Fan Request-Hours Accumulator |  | hrs | § 4.19 H. 5 |  | X | X | User can reset | |
|  | Heating Fan System Run-Hours Total |  | hrs | § 4.19 H. 5 |  | X | X | User can reset | |
|  | Heating Fan Cumulative % Request-Hours |  | % | § 4.19 H. 5 |  | X | X | User can reset | |
|  | TAV Ratio | TAVratio | - | § 4.8 B |  |  | X |  | |
|  | TAV Zone Lowest Possible Air Flow | Vm | cfm | § 4.8 B | X | X |  |  | |
|  | TAV Total Cycle Time | TCT | min | § 4.8 B | X | X |  |  | |
|  | TAV Open Period | OP | min | § 4.8 B |  |  | X |  | |
|  | TAV Closed Period | CP | min | § 4.8 B |  |  | X |  | |
|  | TAV Setpoint | Vspt\* | cfm | § 4.8 B |  |  | X |  | |
|  | Window-switch Cooling Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Window-switch Heating Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Occupancy Cooling Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Occupancy Heating Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Demand Limited Level 1 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 2 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 3 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limit Exempt |  | - | § 4.9 B. 6 | X | X |  | Yes/No | |
|  | Ceiling Fan Offset |  | - | § 4.9 B. 9 | X | X |  |  | |

Table 4.19.3 Dual Duct VAV Terminal Unit – Mixing Discharge Airflow Sensors – Ventilation Software Points – Title 24

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Zone Occupancy Minimum Ventilation Rate | Vocc-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; 15 cfm/person |
| 2 | Zone Area Minimum Ventilation Rate | Varea-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; by space type |
| 3 | Absolute OA Minimum | Zone-Abs-OA-min | cfm | § 4.8 A. 4. b. i |  |  | X |  |
| 4 | Design OA Minimum | Zone-Des-OA-min | cfm | § 4.8 A. 4. b. ii |  |  | X |  |
| 5 | CO2 Loop Output |  | % | § 4.8 A. 4. d. iii |  |  | X | 0 = no demand 100 = full demand |
| 6 | CO2 Minimum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Varea-min |
| 7 | CO2 Maximum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Vcool-max |
| 8 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  Max CO2 - 200 |
| 9 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  CO2 Setpoint |
| 10 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 4. d. iii |  |  | X | Reset based on CO2 loop |
| 11 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

Table 4.19.4 Dual Duct VAV Terminal Unit – Mixing Discharge Airflow Sensors – Ventilation Software Points – ASHRAE 62.1

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Ventilation, Area Component | Vbz-A | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 2 | Ventilation, People Component | Vbz-P | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 3 | Ventilation, Active Air Distribution Effectiveness | Ez | cfm | § 4.5 A. 1. b |  |  | X | Calculated |
| 4 | Ventilation, Heating Air Distribution Effectiveness | EzH | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 5 | Ventilation, Cooling Air Distribution Effectiveness | EzC | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 6 | Ventilation, Required | Voz | cfm | § 4.8 A |  |  | X | Equals  (Vbz-A + Vbz-P)/Ez |
| 7 | CO2 People Component | Vbz-P\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Reset between 0 and Vbz-P |
| 8 | CO2 Loop Output |  | - | § 4.8 A. 3. f. iv |  |  | X | 0 = no demand 100 = full demand |
| 9 | CO2 Minimum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vbz-A |
| 10 | CO2 Maximum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vcool-max |
| 11 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals  Max CO2 - 200 |
| 12 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals CO2 Setpoint |
| 13 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals  (Vbz-A + Vbz-P\*)/Ez |
| 14 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

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 air-flow 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.

* + 1. See “Generic Thermal Zones” (Section 4.9) for set points, loops, control modes, alarms, etc.
    2. See “Generic Ventilation Zones” (Section 4.8) for calculation of zone minimum outdoor airflow.
    3. See Section 4.5 B. 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.
    4. Active endpoints used in the control logic depicted in Figure 4.19.1 shall vary depending on the mode of the zone group the zone is a part of (see Table 4.19.5).

Table 4.19.5: Airflow Set Points as a Function of Zone Group Mode – Mixing Dual Duct VAV with Discharge Airflow Sensor

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Endpoint | Occupied | Cooldown | Setup | Warm-Up | Setback | Unoccupied |
| Cooling Maximum | Vcool-max | Vcool-max | Vcool-max | 0 | 0 | 0 |
| Deadband Minimum | Vmin\* | 0 | 0 | 0 | 0 | 0 |
| Heating Maximum | Vheat-max | 0 | 0 | Vheat-max | Vheat-max | 0 |

* + 1. Control logic is depicted schematically in Figure 4.19.1 and described in the following subsections.
       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).

* + - * 1. When the zone state is cooling, the cooling-loop output shall reset the active cold duct airflow set point from minimum endpoint to the cooling maximum endpoint. The cold duct damper shall be modulated by a control loop to maintain the measured cold duct airflow at the active cold duct airflow set point.

If cold-deck supply air temperature from the air handler is greater than room temperature, the active cold duct airflow set point shall be no higher than the minimum endpoint.

* + - * 1. When the zone state is deadband, the active cold duct airflow set point shall be the minimum endpoint. The cold duct damper shall be modulated by a control loop to maintain the measured cold duct airflow at the active cold duct airflow set point. The hot duct 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 out-door air economizer.

* + - * 1. When the zone state is heating, the heating loop output shall be mapped to the hot duct damper position. The cold duct damper is modulated to maintain measured discharge airflow at the minimum endpoint.

If hotduct supply air temperature from the air handler is less than room temperature, the hot duct damper shall be closed.

Maximum hot duct airflow shall be limited by a reverse-acting P-only loop whose set point is the heating maximum endpoint and whose output is maximum hot duct damper position ranging from 0% to 100%.

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

* + - 1. Backflow Prevention Temperature Control Overrides

The following requirements override the temperature control algorithm, discussed in section 4.19 E. 1. These will shut-off the supply duct when one air handler is shut off (e.g. during morning warm-up, when the hot deck air handler is ON and cold deck air handler is OFF, all cooling dampers will be closed to prevent warm air from circulating through the cold deck air handler).

* + - * 1. If heating air handler is not proven ON, the heating damper shall be closed.
        2. If cooling air handler is not proven ON, the cooling damper shall be closed.

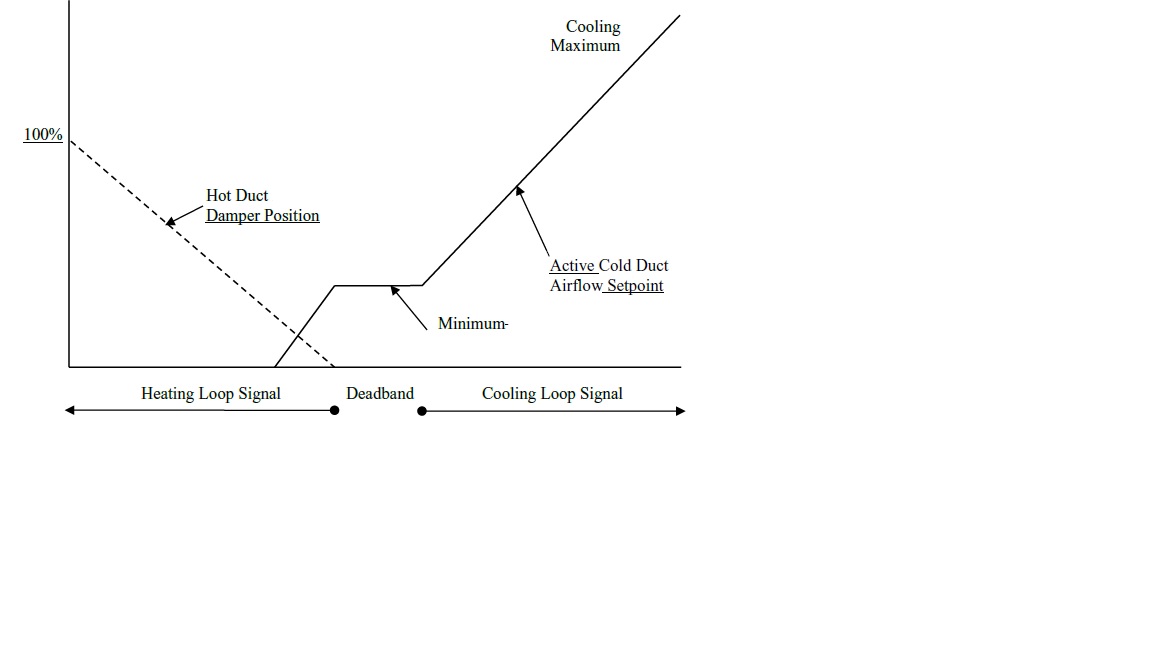


Figure 4.19.1: Control Logic – Mixing Dual Duct VAV with Discharge Airflow Sensor

* + 1. Alarms

Table 4.19.6 Alarm List - Dual Duct Terminal Unit

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Level | Definition | Applicable Spec Section |
|  | Window Left Open | 4 | When other than occupied mode and window switch indicates window is open. | 4.9 B. 7. b |
|  | Ceiling Fan Left On | 4 | When other than occupied mode and ceiling fan is proven ON. | 4.9 B. 9. d |
|  | High Zone Temp I | 3 | Zone temperature is 3°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. i |
|  | High Zone Temp II | 2 | Zone temperature is 5°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. ii |
|  | Low Zone Temp I | 3 | Zone temperature is 3°F below heating setpoint for 10 minutes | 4.9 F. 1. b. i |
|  | Low Zone Temp II | 2 | Zone temperature is 5°F below heating setpoint for 10 minutes | 4.9 F. 1. b. ii |
|  | Low CO2, Calibration Needed | 3 | CO2 concentration is less than 300 ppm | 4.9 F. 2. a |
|  | High Vacant CO2, Calibration Needed | 3 | CO2 concentration is above 600 ppm and in unoccupied mode for 2 hours | 4.9 F. 2. a |
|  | High Occupied CO2 | 3 | CO2 concentration is exceeds set point by 10% for more than 10 minutes. | 4.9 F. 2. b |
|  | Zone Low Airflow I | 3 | Measured airflow 70% less than active airflow set point for 5 minutes | 4.19 F. 1. a |
|  | Zone Low Airflow II | 2 | Measured airflow 50% less than active airflow set point for 5 minutes | 4.19 F. 1. b |
|  | Zone Airflow Calibration | 3 | Fan serving zone is off for 10 minutes and measured airflow 10% above active airflow set point. | 4.19 F. 2 |
|  | Zone Leaking Damper | 4 | Damper position is 0%, measured is 10% above active airflow set point for 10 minutes, fan serving zone is proven on. | 4.19 F. 3 |

* + - 1. Low Airflow
         1. If the measured airflow is less than 70% of set point for 5 minutes while set point is greater than zero, generate a Level 4 alarm.
         2. If the measured airflow is less than 50% of set point for 5 minutes while set point is greater than zero, generate a Level 3 alarm.
         3. If a zone has an Importance-Multiplier of 0 (see Section 4.7 N. 2. a. i) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.
      2. Airflow Sensor Calibration. If the fan serving the zone is OFF, and airflow sensor reading is above the larger of 10% of the maximum airflow set point or 50 cfm for 30 minutes, generate a Level 3 alarm.
      3. Leaking Damper. If the damper position is 0%, and airflow sensor reading is above the larger of 10% of the cooling maximum airflow set point or 50 cfm for 10 minutes while the fan serving the damper is proven ON, generate a Level 4 alarm.
    1. Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to
       1. force zone airflow set point to zero,
       2. force zone airflow set point to Vcool-max,
       3. force zone airflow set point to Vmin,
       4. force zone airflow set point to Vheat-max,
       5. force cooling damper full closed/open,
       6. force heating damper full closed/open, and
       7. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 1.5K, 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 1.8E.

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.

* + 1. System Requests
       1. Cooling SAT Reset Requests
          1. If the zone temperature exceeds the zone’s cooling set point by 5°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 3 requests.
          2. Else if the zone temperature exceeds the zone’s cooling set point by 3°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 2 requests.
          3. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
          4. Else if the cooling loop is less than 95%, send 0 requests.
       2. Cold-Duct Static Pressure Reset Requests
          1. 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.
          2. 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.
          3. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
          4. Else if the damper position is less than 95%, send 0 requests.
       3. Heating SAT Reset Requests
          1. If the zone temperature is below the zone’s heating set point by 5°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 3 requests.
          2. Else if the zone temperature is below the zone’s heating set point by 3°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 2 requests.
          3. Else if the heating loop is greater than 95%, send 1 request until the heating loop is less than 85%.
          4. Else if the heating loop is less than 95%, send 0 requests.
       4. Hot-Duct Static Pressure Reset Requests
          1. If the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
          2. Else if the damper position is less than 95%, send 0 requests.
       5. Heating-Fan Requests
          1. If the heating loop is greater than 15%, send 1 request until the heating loop is less than 1%
          2. Else if the heating loop is less than 15%, send 0 requests.

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

Table 4.20.1 Dual Duct VAV Terminal Unit – Cold-Duct Minimum Control – Hardware Points List

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Type | Device | Required |
|  | Hot Deck Damper Position | AO | Modulating Actuator | R |
|  | Cold Deck Damper Position | AO | Modulating Actuator | R |
|  | Hot Deck Supply Flow | AI | Differential pressure transducer connected to a flow sensor | R |
|  | Cold Deck Supply Flow | AI | Differential pressure transducer connected to a flow sensor | R |
|  | Zone Temperature | AI | Room Temperature Sensor, typically integrated into the thermostat | R |
|  | Valve Position | AO | Reheat Coil Valve Position | R |
|  | Discharge Air Temp | AI | Discharge Air Temperature | R |
|  | Fan Start/Stop | DO | Parallel Fan Start/Stop | R |
|  | Fan Status | DI | Parallel Fan Status | R |
|  | Local Override | DI | Zone thermostat override | Define |
|  | Occupancy Status | DI or Software | Occupancy Sensor | Define |
|  | Window Open/Closed | DI or Software | Window Switch | Define |
|  | Zone Temperature Adjustment | AI | Zone thermostat setpoint adjustment button or dial | Define |
|  | Zone CO2 Level | AI | Zone CO2 Sensor | Define |
|  | Zone Ceiling Fan Status | DI | Status indicator | Define |

Table 4.20.2 Dual Duct VAV Terminal Unit – Cold-Duct Minimum Control – Software Points List (Excluding Ventilation)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | System OK | SystemOK | Binary | § 4.7 S |  |  | X |  | |
|  | Zone State | ZoneState | - | § 4.9 E |  |  | X |  | |
|  | Parent AHU System Mode |  |  | § 4.21 |  |  | X |  | |
|  | Zone Cooling Setpoint |  | °F | § 4.5 A. 1 | X | X |  |  | |
|  | Zone Heating Setpoint |  | °F | § 4.5 B | X | X |  |  | |
|  | VAV Box Minimum Velocity Pressure Sensor Reading for Accuracy | VPm | in. w.c. | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Velocity | vm | fpm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Flow Application Factor | F | - | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Diameter | D | In | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Nominal Duct Area | A | in² | § 4.7 O. 5. c. i | X | X |  |  | |
|  | VAV Box Minimum Controllable Airflow | Vm | cfm | § 4.7 O. 5. c. i | X | X |  |  | |
|  | Zone Maximum Cooling Airflow Set point | Vcool-max | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Minimum Airflow Set point | Vmin | cfm | § 4.5 A. 1. b | X | X |  |  | |
|  | Zone Active Airflow Set point | Vspt | cfm | § 4.20 E |  |  | X |  | |
|  | Zone Cooling Control Loop |  | - | § 4.20 E. 1. a |  |  | X | 0 = no cooling, 100 = full cooling | |
|  | Cooling Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Cooling Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | Zone Heating Control Loop |  | - | § 4.20 E. 1. c |  |  | X | 0 = no heating, 100 = full heating | |
|  | Heating Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Heating Derivative Gain |  | - | § 4.7 H | X | X |  | Ideally, not used | |
|  | Cold DSP Requests |  | - | § 4.20 H. 2 |  |  | X |  | |
|  | Cold DSP Importance-Multiplier |  | - | § 4.20 H. 2 | X | X |  |  | |
|  | Cold DSP Request-Hours Accumulator |  | hrs | § 4.20 H. 2 |  | X | X | User can reset | |
|  | Cold DSP System Run-Hours Total |  | hrs | § 4.20 H. 2 |  | X | X | User can reset | |
|  | Cold DSP Cumulative % Request-Hours |  | % | § 4.20 H. 2 |  | X | X | User can reset | |
|  | Hot DSP Requests |  | - | § 4.20 H. 4 |  |  | X |  | |
|  | Hot DSP Importance-Multiplier |  | - | § 4.20 H. 4 | X | X |  |  | |
|  | Hot DSP Request-Hours Accumulator |  | hrs | § 4.20 H. 4 |  | X | X | User can reset | |
|  | Hot DSP System Run-Hours Total |  | hrs | § 4.20 H. 4 |  | X | X | User can reset | |
|  | Hot DSP Cumulative % Request-Hours |  | % | § 4.20 H. 4 |  | X | X | User can reset | |
|  | Cold SAT Requests |  | - | § 4.20 H. 1 |  |  | X |  | |
|  | Cold SAT Importance-Multiplier |  | - | § 4.20 H. 1 | X | X |  |  | |
|  | Cold SAT Request-Hours Accumulator |  | hrs | § 4.20 H. 1 |  | X | X | User can reset | |
|  | Cold SAT System Run-Hours Total |  | hrs | § 4.20 H. 1 |  | X | X | User can reset | |
|  | Cold SAT Cumulative % Request-Hours |  | % | § 4.20 H. 1 |  | X | X | User can reset | |
|  | Hot SAT Requests |  | - | § 4.20 H. 3 |  |  | X |  | |
|  | Hot SAT Importance-Multiplier |  | - | § 4.20 H. 3 | X | X |  |  | |
|  | Hot SAT Request-Hours Accumulator |  | hrs | § 4.20 H. 3 |  | X | X | User can reset | |
|  | Hot SAT System Run-Hours Total |  | hrs | § 4.20 H. 3 |  | X | X | User can reset | |
|  | Hot SAT Cumulative % Request-Hours |  | % | § 4.20 H. 3 |  | X | X | User can reset | |
|  | Heating Fan Requests |  | - | § 4.20 H. 5 |  |  | X |  | |
|  | Heating Fan Importance-Multiplier |  | - | § 4.20 H. 5 | X | X |  |  | |
|  | Heating Fan Request-Hours Accumulator |  | hrs | § 4.20 H. 5 |  | X | X | User can reset | |
|  | Heating Fan System Run-Hours Total |  | hrs | § 4.20 H. 5 |  | X | X | User can reset | |
|  | Heating Fan Cumulative % Request-Hours |  | % | § 4.20 H. 5 |  | X | X | User can reset | |
|  | TAV Ratio | TAVratio | - | § 4.8 B |  |  | X |  | |
|  | TAV Zone Lowest Possible Air Flow | Vm | cfm | § 4.8 B | X | X |  |  | |
|  | TAV Total Cycle Time | TCT | min | § 4.8 B | X | X |  |  | |
|  | TAV Open Period | OP | min | § 4.8 B |  |  | X |  | |
|  | TAV Closed Period | CP | min | § 4.8 B |  |  | X |  | |
|  | TAV Setpoint | Vspt\* | cfm | § 4.8 B |  |  | X |  | |
|  | Window-switch Cooling Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Window-switch Heating Setback |  | °F | § 4.9 B. 7. a | X | X |  |  | |
|  | Occupancy Cooling Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Occupancy Heating Setback |  | °F | § 4.9 B. 8 | X | X |  |  | |
|  | Demand Limited Level 1 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 2 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limited Level 3 |  | - | § 4.9 B. 6 |  |  | X | Status, Indicate Heating or Cooling | |
|  | Demand Limit Exempt |  | - | § 4.9 B. 6 | X | X |  | Yes/No | |
|  | Ceiling Fan Offset |  | - | § 4.9 B. 9 | X | X |  |  | |

Table 4.20.3 Dual Duct VAV Terminal Unit – Cold-Duct Minimum Control – Ventilation Software Points – Title 24

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Zone Occupancy Minimum Ventilation Rate | Vocc-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; 15 cfm/person |
| 2 | Zone Area Minimum Ventilation Rate | Varea-min | cfm | § 4.5 A. 1. b | X | X |  | See CA Title 24; by space type |
| 3 | Absolute OA Minimum | Zone-Abs-OA-min | cfm | § 4.8 A. 4. b. i |  |  | X |  |
| 4 | Design OA Minimum | Zone-Des-OA-min | cfm | § 4.8 A. 4. b. ii |  |  | X |  |
| 5 | CO2 Loop Output |  | % | § 4.8 A. 4. d. iii |  |  | X | 0 = no demand 100 = full demand |
| 6 | CO2 Minimum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Varea-min |
| 7 | CO2 Maximum |  | cfm | § 4.8 A. 4. d. iii |  |  | X | Equals Vcool-max |
| 8 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  Max CO2 - 200 |
| 9 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 4. d. iii |  |  | X | Equals  CO2 Setpoint |
| 10 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 4. d. iii |  |  | X | Reset based on CO2 loop |
| 11 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

Table 4.20.4 Dual Duct VAV Terminal Unit – Cold-Duct Minimum Control – Ventilation Software Points – ASHRAE 62.1

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | Notes |
| Manually Defined | User  Adjustable | Software Calculated |
| 1 | Ventilation, Area Component | Vbz-A | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 2 | Ventilation, People Component | Vbz-P | cfm | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Space Type |
| 3 | Ventilation, Active Air Distribution Effectiveness | Ez | cfm | § 4.5 A. 1. b |  |  | X | Calculated |
| 4 | Ventilation, Heating Air Distribution Effectiveness | EzH | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 5 | Ventilation, Cooling Air Distribution Effectiveness | EzC | - | § 4.5 A. 1. b | X | X |  | See ASHRAE 62.1, by Application |
| 6 | Ventilation, Required | Voz | cfm | § 4.8 A |  |  | X | Equals  (Vbz-A + Vbz-P)/Ez |
| 7 | CO2 People Component | Vbz-P\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Reset between 0 and Vbz-P |
| 8 | CO2 Loop Output |  | - | § 4.8 A. 3. f. iv |  |  | X | 0 = no demand 100 = full demand |
| 9 | CO2 Minimum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vbz-A |
| 10 | CO2 Maximum |  | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals Vcool-max |
| 11 | CO2 Minimum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals  Max CO2 - 200 |
| 12 | CO2 Maximum Concentration |  | ppm | § 4.8 A. 3. f. iv |  |  | X | Equals CO2 Setpoint |
| 13 | CO2 Ventilation Minimum | Vmin\* | cfm | § 4.8 A. 3. f. iv |  |  | X | Equals  (Vbz-A + Vbz-P\*)/Ez |
| 14 | CO2 Setpoint |  | ppm | § 4.5 A. 3 | X | X |  |  |

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.

* + 1. See “Generic Thermal Zones” (Section 4.9) for set points, loops, control modes, alarms, etc.
    2. See “Generic Ventilation Zones” (Section 4.8) for calculation of zone minimum outdoor airflow.
    3. See Section 4.5 B. 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.
    4. Active endpoints used in the control logic depicted in Figure 4.20.1 shall vary depending on the mode of the zone group the zone is a part of (see Table 4.20.5).

Table 4.20.5: Airflow Set Points as a Function of Zone Group Mode – Mixing Dual Duct VAV with Cold-Duct Minimum Airflow

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Endpoint | Occupied | Cooldown | Setup | Warm-Up | Setback | Unoccupied |
| Cooling Maximum | Vcool-max | Vcool-max | Vcool-max | 0 | 0 | 0 |
| Deadband Minimum | Vmin\* | 0 | 0 | 0 | 0 | 0 |
| Heating Maximum | Vheat-max | 0 | 0 | Vheat-max | Vheat-max | 0 |

* + 1. Control logic is depicted schematically in Figure 4.20.1 and described in the following subsections.
       1. Temperature and Damper Control
          1. When the zone state is cooling, the cooling loop output shall reset the cold duct airflow set point from the minimum endpoint to cooling maximum endpoint. The cold duct damper shall be modulated by a control loop to maintain the measured cold duct airflow at set point. The hot duct damper shall be closed.

If cold-duct supply air temperature from air handler is greater than room temperature, the active cold duct airflow set point shall be no higher than the minimum endpoint.

* + - * 1. When the zone state is deadband, the active cold duct airflow set point shall be the minimum endpoint. The cold duct damper shall be modulated by a control loop to maintain the measured cold duct airflow at the active cold duct airflow set point. The hot duct damper shall be closed.
        2. When the zone state is heating:

The heating loop output shall reset the active hot duct set point from zero to heating maximum endpoint. The hot duct damper shall be modulated by a control loop to maintain the measured hot duct airflow at the active hot duct airflow set point.

The active cold duct airflow set point shall be the minimum endpoint. The cold duct damper shall be modulated by a control loop to maintain the measured cold duct airflow at the active cold duct airflow set point.

If hotduct supply air temperature from the air handler is less than room temperature, the hot duct damper shall be closed.

* + - 1. Backflow Prevention Temperature Control Overrides

The following requirements override the temperature control algorithm, discussed in section 4.20 E. 1. These will shut-off the supply duct when one air handler is shut off (e.g. during morning warm-up, when the hot deck air handler is ON and cold deck air handler is OFF, all cooling dampers will be closed to prevent warm air from circulating through the cold deck air handler).

* + - * 1. If heating air handler is not proven ON, the heating damper shall be closed.
        2. If cooling air handler is not proven ON, the cooling damper shall be closed.

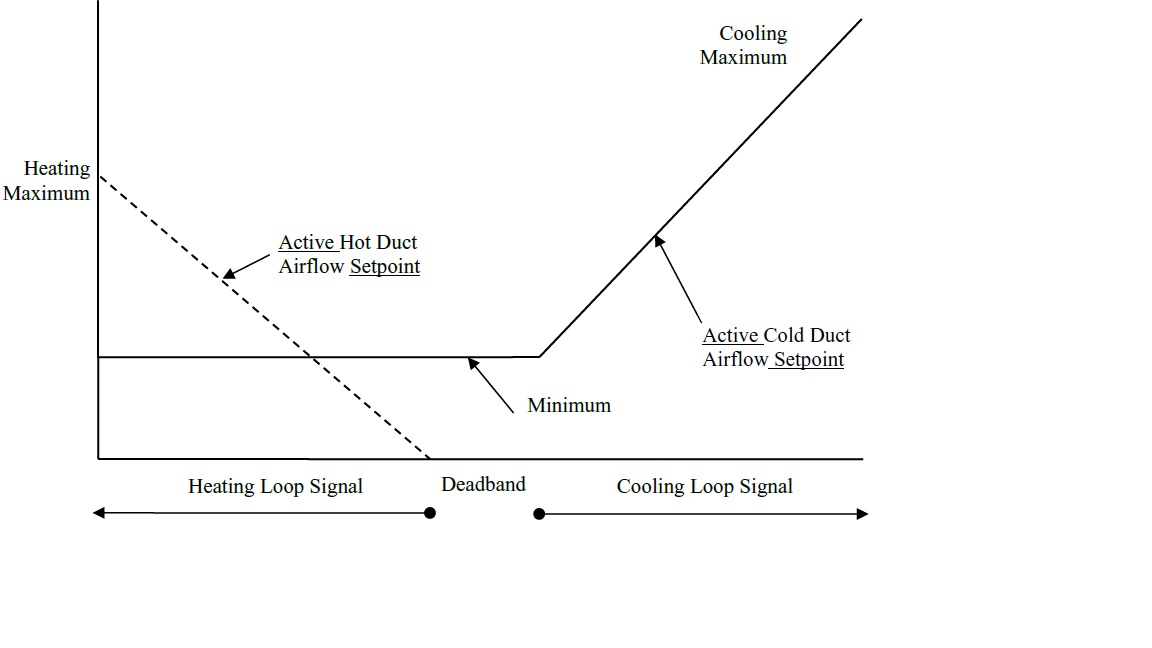


Figure 4.20.1: Control Logic – Mixing Dual Duct VAV with Cold-Duct Minimum Airflow

* + 1. Alarms

Table 4.20.6 Alarm List - Dual Duct Terminal Unit

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Level | Definition | Applicable Spec Section |
|  | Window Left Open | 4 | When other than occupied mode and window switch indicates window is open. | 4.9 B. 7. b |
|  | Ceiling Fan Left On | 4 | When other than occupied mode and ceiling fan is proven ON. | 4.9 B. 9. d |
|  | High Zone Temp I | 3 | Zone temperature is 3°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. i |
|  | High Zone Temp II | 2 | Zone temperature is 5°F above cooling setpoint for 10 minutes | 4.9 F. 1. a. ii |
|  | Low Zone Temp I | 3 | Zone temperature is 3°F below heating setpoint for 10 minutes | 4.9 F. 1. b. i |
|  | Low Zone Temp II | 2 | Zone temperature is 5°F below heating setpoint for 10 minutes | 4.9 F. 1. b. ii |
|  | Low CO2, Calibration Needed | 3 | CO2 concentration is less than 300 ppm | 4.9 F. 2. a |
|  | High Vacant CO2, Calibration Needed | 3 | CO2 concentration is above 600 ppm and in unoccupied mode for 2 hours | 4.9 F. 2. a |
|  | High Occupied CO2 | 3 | CO2 concentration is exceeds set point by 10% for more than 10 minutes. | 4.9 F. 2. b |
|  | Zone Low Airflow I | 3 | Measured airflow 70% less than active airflow set point for 5 minutes | 4.20 F. 1. a |
|  | Zone Low Airflow II | 2 | Measured airflow 50% less than active airflow set point for 5 minutes | 4.20 F. 1. b |
|  | Zone Airflow Calibration | 3 | Fan serving zone is off for 10 minutes and measured airflow 10% above active airflow set point. | 4.20 F. 2 |
|  | Zone Leaking Damper | 4 | Damper position is 0%, measured is 10% above active airflow set point for 10 minutes, fan serving zone is proven on. | 4.20 F. 3 |

* + - 1. Low Airflow
         1. If the measured airflow is less than 70% of set point for 10 minutes while set point is greater than zero, generate a Level 4 alarm.
         2. If the measured airflow is less than 50% of set point for 10 minutes while set point is greater than zero, generate a Level 3 alarm.
         3. If a zone has an Importance-Multiplier of 0 (see Section 4.7 N. 2. a. i) for its static pressure reset T&R control loop, low airflow alarms shall be suppressed for that zone.
      2. Airflow Sensor Calibration. If the fan serving the zone is off and airflow sensor reading is above the larger of 10% of the maximum airflow set point or 50 cfm for 30 minutes, generate a Level 3 alarm.
      3. Leaking Damper. If the damper position is 0%, and airflow sensor reading is above the larer of 10% of the cooling maximum airflow set point or 50 cfm for 10 minutes while the fan serving the damper is proven ON, generate a Level 4 alarm.
    1. Testing/Commissioning Overrides. Provide software switches that interlock to a system level point to
       1. force zone airflow set point to zero,
       2. force zone airflow set point to Vcool-max,
       3. force zone airflow set point to Vmin,
       4. force zone airflow set point to Vheat-max,
       5. force cooling damper full closed/open,
       6. force heating damper full closed/open, and
       7. reset request-hours accumulator point to zero (provide one point for each reset type listed in the next section).

Per Section 1.5K, 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 1.8E.

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.

* + 1. System Requests
       1. Cooling SAT Reset Requests
          1. If the zone temperature exceeds the zone’s cooling set point by 5°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 3 requests.
          2. Else if the zone temperature exceeds the zone’s cooling set point by 3°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 2 requests.
          3. Else if the cooling loop is greater than 95%, send 1 request until the cooling loop is less than 85%.
          4. Else if the cooling loop is less than 95%, send 0 requests.
       2. Cold-Duct Static Pressure Reset Requests
          1. 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.
          2. 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.
          3. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
          4. Else if the damper position is less than 95%, send 0 requests.
       3. Heating SAT Reset Requests
          1. If the zone temperature is below the zone’s heating set point by 5°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 3 requests.
          2. Else if the zone temperature is below the zone’s heating set point by 3°F for 2 minutes and after suppression period due to set point change per Section 4.7 S, send 2 requests.
          3. Else if the heating loop is greater than 95%, send 1 request until the heating loop is less than 85%.
          4. Else if the heating loop is less than 95%, send 0 requests.
       4. Hot-Duct Static Pressure Reset Requests
          1. If the measured airflow is less than 50% of set point while set point is greater than zero for 1 minute, send 3 requests.
          2. 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.
          3. Else if the damper position is greater than 95%, send 1 request until the damper position is less than 85%.
          4. Else if the damper position is less than 95%, send 0 requests.
       5. Heating-Fan Requests. Send the heating fan that serves the zone a heating-fan request as follows:
          1. If the heating loop is greater than 15%, send 1 request until the heating loop is less than 1%.
          2. Else if the heating loop is less than 15%, send 0 requests.

## Air-Handling Unit System Modes

* + 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):

Reference mode definitions in Section: 4.10 Zone Groups.

Although only the last mode is titled “Unoccupied Mode”, all modes except 1: Occupied, are modes without regular occupancy.

* + - 1. Occupied mode
      2. Cooldown mode
      3. Setup mode
      4. Warm-up mode
      5. Setback mode
      6. Freeze protection setback mode
      7. Unoccupied mode

## 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.

Table 4.22.1 Multiple Zone VAV Air-Handling Unit – Hardware Points List

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Type | Device | Required |
|  | Exhaust Air Damper | AO |  | Define |
|  | Return Air Damper | AO |  | R |
|  | Econ OA Damper | AO |  | R |
|  | Min OA Damper | AO |  | R |
|  | Outdoor Air Temp | AI |  | R |
|  | Mixed Air Temp | AI |  | R |
|  | Return Air Temp | AI |  | R |
|  | Supply Air Temp | AI |  | R |
|  | Outside Air Flow | AI |  | R |
|  | Return Air Flow | AI |  | R |
|  | Supply Air Flow | AI |  | R |
|  | Supply Fan High Static | DI |  | R |
|  | Return Fan High Static | DI |  | R |
|  | Return Fan High Static | DI |  | R |
|  | Duct Static Pressure | AI |  | R |
|  | Building Static Pressure | AI |  | R |
|  | Supply Fan VFD - Status | DI |  | R |
|  | Supply Fan VFD - Start | DO |  | R |
|  | Supply Fan VFD - Speed | AO |  | R |
|  | Return Fan VFD - Status | DI |  | Define |
|  | Return Fan VFD - Start | DO |  | Define |
|  | Return Fan VFD - Speed | AO |  | Define |
|  | Exhaust Fan VFD - Status | DI |  | Define |
|  | Exhaust Fan VFD - Start | DO |  | Define |
|  | Exhaust Fan VFD - Speed | AO |  | Define |
|  | Filter Differential Pressure | AI |  | R |
|  | Hot Water Coil Valve Position | AO |  | R |
|  | Hot Water Coil DAT | AI |  | R |
|  | Chilled Water Coil Valve Position | AO |  | R |

Table 4.22.2 Multiple Zone VAV Air-Handling Unit – Software Points List (Excluding Ventilation)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Cooling SAT Maximum | Max\_ClgSAT |  | § 4.5 D. 1. a | X | X |  |  | |
|  | Cooling SAT Minimum | Min\_ClgSAT |  | § 4.5 D. 1. b | X | X |  |  | |
|  | Cooling SAT OAT Max | OAT\_Max |  | § 4.5 D. 1. c | X | X |  |  | |
|  | Cooling SAT OAT Min | OAT\_Min |  | § 4.5 D. 1. d | X | X |  |  | |
|  | Duct Design Maximum Static Pressure | Max\_DSP |  | § 4.6 A. 1 | X | X |  | Field Measured | |
|  | Supply Fan – Minimum Speed |  |  | § 4.6 A. 2. a. i | X | X |  | Field Measured | |
|  | Return Fan – Minimum Speed |  |  | § 4.6 A. 2. a. ii | X | X |  | Remove if not present, Field Measured | |
|  | Relief Fan – Minimum Speed |  |  | § 4.6 A. 2. a. iii | X | X |  | Remove if not present, Field Measured | |
|  | Return Fan Discharge Static Pressure Setpoint, Minimum | RFDSPmin |  | § 4.6 A. 4. a | X | X |  | Field Measured, Remove if not used | |
|  | Return Fan Discharge Static Pressure Setpoint, Maximum | RFDSPmax |  | § 4.6 A. 4. b | X | X |  | Field Measured, Remove if not used | |
|  | Supply vs. Return Airflow Differential | S-R-DIFF |  | 4.6 A. 5. a | X | X |  | Field Measured, Remove if not used | |
|  | System Mode |  |  | § 4.21 A |  |  | X |  | |
|  | Totalized Airflow from VAVs | Vps |  | § 4.22 A. 1. c |  |  | X |  | |
|  | Duct Static Pressure Setpoint | DSP\_SP | in. w.c. | § 4.22 A. 2. a |  |  | X |  | |
|  | DSP SP Loop |  |  | § 4.22 A. 2. a |  |  | X |  | |
|  | DSP SP Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | DSP SP Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | DSP SP Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | DSP Minimum Setpoint | DSP\_SPmin | in. w.c. | Table 4.22.9 | X | X |  |  | |
|  | DSP Maximum Setpoint | DSP\_SPmax | in. w.c. | Table 4.22.9 |  |  | X | Equals Max\_DSP | |
|  | DSP Delay Timer | DSP\_Td | min. | Table 4.22.9 | X | X |  |  | |
|  | DSP Time Step | DSP\_T | min. | Table 4.22.9 | X | X |  |  | |
|  | DSP Ignored Requests Threshold | DSP\_I | - | Table 4.22.9 | X | X |  |  | |
|  | DSP Totalized Requests from VAVs | DSP\_R | - | Table 4.22.9 | X | X |  |  | |
|  | DSP Trim Amount | DSP\_SPtrim | in. w.c. | Table 4.22.9 | X | X |  |  | |
|  | DSP Respond Amount | DSP\_SPres | in. w.c. | Table 4.22.9 | X | X |  |  | |
|  | DSP Maximum Response | DSP\_SPres-max | in. w.c. | Table 4.22.9 | X | X |  |  | |
|  | Supply Air Temperature Setpoint | SAT\_SP | °F | § 4.22 B. 2 |  |  | X |  | |
|  | SAT SP Loop |  |  | § 4.22 B. 2 |  |  | X |  | |
|  | SAT SP Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | SAT SP Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | SAT SP Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | SAT Minimum Setpoint | SAT\_SPmin | °F | Table 4.22.10 | X | X |  |  | |
|  | SAT Maximum Setpoint | SAT\_SPmax | °F | Table 4.22.10 |  |  | X | Equals Max\_DSP | |
|  | SAT Delay Timer | SAT\_Td | min. | Table 4.22.10 | X | X |  |  | |
|  | SAT Time Step | SAT\_T | min. | Table 4.22.10 | X | X |  |  | |
|  | SAT Ignored Requests Threshold | SAT\_I | - | Table 4.22.10 | X | X |  |  | |
|  | SAT Totalized Requests from VAVs | SAT\_R | - | Table 4.22.10 | X | X |  |  | |
|  | SAT Trim Amount | SAT\_SPtrim | °F | Table 4.22.10 | X | X |  |  | |
|  | SAT Respond Amount | SAT\_SPres | °F | Table 4.22.10 | X | X |  |  | |
|  | SAT Maximum Response | SAT\_SPres-max | °F | Table 4.22.10 | X | X |  |  | |
|  | SAT Setback/Warm-up Setpoint |  | °F | § 4.22 B. 2. d | X | X |  |  | |
|  | Return Air Damper Position SP | MaxRA-P | % | § 4.22 D. 4 |  |  | X |  | |
|  | Return Air Damper Position Loop |  |  | § 4.22 D. 4 |  |  | X |  | |
|  | Return Air Damper Position Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Return Air Damper Position Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Return Air Damper Position Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | Freeze Protection Stage 1 Enabled Setpoint |  | °F | § 4.22 K. 1 | X | X |  |  | |
|  | Freeze Protection Stage 1 Enabled Timer |  | min. | § 4.22 K. 1 | X | X |  |  | |
|  | Freeze Protection SAT Setpoint Min |  | °F | § 4.22 K. 1 | X | X |  |  | |
|  | Freeze Protection Stage 1 Disabled Setpoint |  | °F | § 4.22 K. 1 | X | X |  |  | |
|  | Freeze Protection Stage 1 Disabled Timer |  | min. | § 4.22 K. 1 | X | X |  |  | |
|  | Freeze Protection Stage 2 Setpoint |  | °F | § 4.22 K. 2 | X | X |  |  | |
|  | Freeze Protection Stage 2 Timer |  | min. | § 4.22 K. 2 | X | X |  |  | |
|  | Freeze Protection Stage 2 Duration |  | min. | § 4.22 K. 2 | X | X |  |  | |
|  | Freeze Protection Stage 3 Setpoint |  | °F | § 4.22 K. 30 | X | X |  |  | |
|  | Freeze Protection Stage 3 Timer |  | min. | § 4.22 K. 3 | X | X |  |  | |
|  | Freeze Protection Stage 3 SAT Setpoint |  | °F | § 4.22 K. 3 | X | X |  |  | |
|  | Chilled Water Reset Requests |  |  | § 4.22 O. 1 |  |  | X |  | |
|  | Chilled Water Plant Requests |  |  | § 4.22 O. 2 |  |  | X |  | |
|  | Hot Water Reset Requests |  |  | § 4.22 O. 3 |  |  | X |  | |
|  | Hot Water Plant Requests |  |  | § 4.22 O. 4 |  |  | X |  | |

Table 4.22.3 Multiple Zone VAV Air-Handling Unit – ASHRAE 62.1/90.1 Ventilation Software Points

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Design Ventilation, Uncorrected | DesVou | cfm | 4.5 D. 2. a. i | X | X |  | Include zone diversity | |
|  | Design Total Ventilation | DesVot | cfm | 4.5 D. 2. a. ii | X | X |  | Adjusted DesVou for ventilation efficiency | |
|  | Economizer High Limit |  | °F | 4.5 H. 1 | X | X |  |  | |
|  | Design Minimum OA Damper DP to Provide Min Outdoor Air Flow | DesMinDP | in w.c. | 4.6 A. 3. a. i | X | X |  | Field Measured | |
|  | Minimum OA Damper Minimum Position | MinOA-P | % | § 4.22 D | X | X |  |  | |
|  | Maximum RA Damper Position | MaxRA-P | % | § 4.22 D | X | X |  |  | |
|  | Occupied Uncorrected Outdoor Air Rate | Vou | cfm | § 4.22 C. 1. c. i |  |  | X |  | |
|  | Totalized Primary Airflow Rate | Vpz | cfm | § 4.22 C. 1. d |  |  | X |  | |
|  | Occupied Primary Airflow Fraction | Zpz | % | § 4.22 C. 1. e |  |  | X | For each zone | |
|  | Maximum Primary Airflow Fraction | Zp | % | § 4.22 C. 1. f |  |  | X |  | |
|  | System Ventilation Efficiency | Ev | - | § 4.22 C. 1. g |  |  | X |  | |
|  | Minimum Outside Airflow Setpoint | MinOAs | cfm | § 4.22 C. 1. h |  |  | X |  | |
|  | Min OA Flow SP Loop |  |  | § 4.22 D. 1. c |  |  | X |  | |
|  | Min OA Flow Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA Flow Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA Flow Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | Minimum Outdoor Air DP Setpoint | MinDPsp | in. w.c. | § 4.22 D. 1. c |  |  | X |  | |
|  | Min OA DP SP Loop |  |  | § 4.22 D. 1. c |  |  | X |  | |
|  | Min OA DP Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA DP Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA DP Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |

Table 4.22.4 Multiple Zone VAV Air-Handling Unit – Title 24 Ventilation Software Points

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Minimum Ventilation when Variable Ventilation Spaces are Unpopulated | AbsMinOA | cfm | 4.5 D. 2. b. i | X | X |  |  | |
|  | Design Minimum Outdoor Airflow at Design Population | DesMinOA | cfm | 4.5 D. 2. b. ii | X | X |  |  | |
|  | Economizer High Limit |  | °F | 4.5 H. 1 | X | X |  |  | |
|  | Minimum OA Damper DP to Provide Minimum Ventilation when Spaces are Unpopulated | AbsMinDP | in w.c. | 4.6 A. 3. b. i | X | X |  |  | |
|  | Minimum OA Damper DP to Provided Minimum Ventilation when at Design Population | DesMinDP | in w.c. | 4.6 A. 3. b. ii | X | X |  |  | |
|  | Current Absolute Minimum Ventilation Rate | AbsMinOA\* | cfm | 4.22 C. 2. c. i |  |  | X |  | |
|  | Current Design Minimum Ventilation Rate | DesMinOA\* | cfm | 4.22 C. 2. c. i |  |  | X |  | |
|  | Current Absolute Minimum Ventilation Rate | AbsDPsp\* | in. w.c. | 4.22 D. 2. d |  |  | X |  | |
|  | Current Design Minimum Ventilation Rate | DesDPsp\* | in. w.c. | 4.22 D. 2. d |  |  | X |  | |
|  | Minimum Outside Air DP Setpoint | MinDPsp | in. w.c. | 4.22 D. 2. e |  |  | X |  | |
|  | Min OA DP SP Loop |  |  | § 4.22 D. 2. e |  |  | X |  | |
|  | Min OA DP Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA DP Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA DP Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | Minimum Outside Airflow Setpoint | MinOAsp | cfm | 4.22 D. 2. f |  |  | X |  | |
|  | Min OA Flow SP Loop |  |  | § 4.22 D. 2. f |  |  | X |  | |
|  | Min OA Flow Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA Flow Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA Flow Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | Highest Zone CO2 control-loop signal | MaxZnCO2 | - | 4.22 D. 2. e |  |  | X |  | |
|  | Zone with Highest CO2 control-loop |  | - | 4.22 D. 2. g |  |  | X |  | |

Table 4.22.5 Multiple Zone VAV Air-Handling Unit – Relief Damper Control without Relief Fans

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Building Static Pressure Setpoint |  | in. w.c. | § 4.22 G. 2 | X | X |  |  | |
|  | Building SP Setpoint Loop |  | - | § 4.22 G. 2 |  |  | X |  | |
|  | Building SP Setpoint Proportional Gain |  | - | § 4.7 H | X | X |  | No integral or derivative gain required. | |

Table 4.22.6 Multiple Zone VAV Air-Handling Unit – Relief Damper Control with Relief Fans

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Building Static Pressure Setpoint |  | in. w.c. | § 4.22 H. 4 | X | X |  |  | |
|  | Building SP Setpoint Loop |  | - | § 4.22 H. 4 |  |  | X |  | |
|  | Building SP Setpoint Proportional Gain |  | - | § 4.7 H | X | X |  | No integral or derivative gain required. | |
|  | Relief Fan Stage-Up Step |  | % | § 4.22 H. 5. b | X | X |  |  | |
|  | Relief Fan Stage-Up Interval |  | min. | § 4.22 H. 5. b | X | X |  |  | |
|  | Relief Fan Stage-Down Interval |  | min. | § 4.22 H. 5. c | X | X |  |  | |

Table 4.22.7 Multiple Zone VAV Air-Handling Unit – Relief Damper Control with Return Fan, Direct Pressure Control, and Actuated Relief Dampers

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Building Static Pressure Setpoint |  | in. w.c. | § 4.22 H. 4 | X | X |  |  | |
|  | Building SP Setpoint Loop |  | - | § 4.22 H. 4 |  |  | X |  | |
|  | Building SP Setpoint Proportional Gain |  | - | § 4.7 H | X | X |  | No integral or derivative gain required. | |
|  | Return Fan DP Setpoint |  |  | § 4.22 I. 2 |  |  | X |  | |
|  | Return Fan DP Control-Loop |  |  | § 4.22 I. 2 |  |  | X |  | |
|  | Return Fan DP Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Return Fan DP Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Return Fan DP Derivative Gain |  |  | § 4.7 H | X | X |  |  | |

Table 4.22.8 Multiple Zone VAV Air-Handling Unit – Relief Damper Control with Return Fan, Airflow Tracking, and Actuated Relief Dampers

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Return Fan Airflow Setpoint |  | cfm | § 0 |  |  | X |  | |
|  | Return Fan Airflow Control-Loop |  | - | § 0 |  |  | X |  | |
|  | Return Fan Airflow Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Return Fan Airflow Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Return Fan Airflow Derivative Gain |  | - | § 4.7 H | X | X |  |  | |

* + 1. Supply Fan Control
       1. Supply Fan Start/Stop
          1. Supply fan shall run when system is in the cooldown mode, setup mode, or occupied mode.
          2. If there are any VAV-reheat boxes on perimeter zone, 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 air flow monitoring station (AFMS).

* + - * 1. 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.

* + - 1. Static Pressure Set-Point Reset
         1. Static pressure set point. Set point shall be reset using T&R logic (see Section 4.7 N) using the parameters shown in Table 4.22.9. The T&R reset parameters in Table 4.22.9 are suggested as a starting point; they will most likely require adjustment during the commissioning/tuning phase.

Table 4.22.9: Trim & Response Variables – Multi-Zone VAV Static Pressure Reset

|  |  |  |
| --- | --- | --- |
| Variable | Definition | Sample Values |
| Device | Associated Device | Supply Fan |
| SP0 | Initial T&R set point | 0.5 in. of water |
| SPmin | Minimum allowed T&R set point | 0.1 in. of water |
| SPmax | Maximum allowed T&R set point | Max\_DSP (~1.5 iwc) |
| Td | Delay timer | 20 minutes |
| T | Time step | 5 minutes |
| I | Number of ignored requests | 2 |
| R | Number of requests from downstream devices | (sum) |
| SPtrim | T&R set point trim amount (devices are satisfied) | -0.05 in. of water |
| SPres | T&R set point response amount (devices are unsatisfied) | +0.06 in. of water |
| SPrex-max | Max T&R set point response amount per time step | +0.13 in. of water |

* + - 1. Static Pressure Control
         1. 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.

* + 1. Supply Air Temperature Control
       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.
       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., 65°F – 55°F]) to minimize fan energy if

• there is a 24/7 chiller plant that is running anyway;

• reheat is minimized, as in a VAV dual-fan dual-duct system, 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.

* + - * 1. See Section 4.5 D. 1 for Min\_ClgSAT, Max\_ClgSAT, OAT\_Min, and OAT\_Max set points.

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.

T-max shall be reset using T&R logic (see Section 4.7 N) between Min\_ClgSAT and Max\_ClgSAT.

The parameters shown in Table 4.22.10 are suggested as a starting place, but they will require adjustment during the commissioning/tuning phase.

* + - * 1. The net result of this SAT reset strategy is depicted in the Figure 4.22.1 for Min\_ClgSAT = 55°F, Max\_ClgSAT = 65°F, OAT\_Max = 70°F, and OAT\_Min = 60°F.
        2. During cooldown mode, set point shall be Min\_ClgSAT.
        3. During warm-up and setback modes, set point shall be 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.

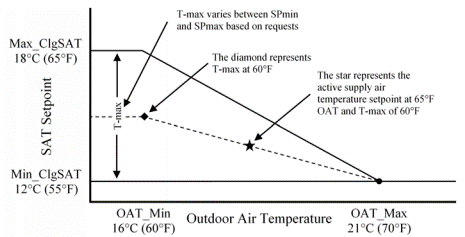


Figure 4.22.1: Example Supply Air Temperature Reset Diagram

Table 4.22.10: Trim & Response Variables – Multi-Zone VAV Supply Air Temperature Reset

|  |  |  |
| --- | --- | --- |
| Variable | Definition | Sample Values |
| Device | Associated Device | Cooling Coil |
| SP0 | Initial T&R set point | SPmax (65°F) |
| SPmin | Minimum allowed T&R set point | Min\_ClgSAT (57 °F) |
| SPmax | Maximum allowed T&R set point | Max\_ClgSAT (65 °F) |
| Td | Delay timer | 20 minutes |
| T | Time step | 5 minutes |
| I | Number of ignored requests | 2 |
| R | Number of requests from downstream devices | (sum) |
| SPtrim | T&R set point trim amount (devices are satisfied) | +0.2°F |
| SPres | T&R set point response amount (devices are unsatisfied) | -0.3°F |
| SPrex-max | Max T&R set point response amount per time step | -1.0°F |

* + - 1. 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 4.22.1.
         1. For units with return fans

Return air damper maximum position MaxRA-P is modulated to control minimum outdoor air volume

* + - * 1. For units with reflief dampers or relief fans

Economizer damper minimum position MinOA-P and/or return air damper maximum position MaxRA-P are modulated to control minimum outdoor air volume.

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 (ii) and delete subsection (iii).

• If there is a single common damper, keep subsection (iii) and delete subsection (ii).

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

Delete this flag note after selection has been made.

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 4.22 D and 4.22 E).

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 4.22 E. 4) Economizer damper maximum position MaxOA-P is limited during minimum outdoor air control (e.g. economizer lockout due to high OAT).

* + - * 1. The points of transition along the x-axis shown and described in Figure 4.22.1 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 4.22.1 to provide stable control. Damper control depends on the type of building pressure control system.

For AHUs with relief fans, outdoor air and return air dampers are sequenced rather than complementary (as per traditional sequences) to reduce fan power at part loads. For AHUs with return fans and airflow tracking control, the SAT control loop makes the economizer outdoor air damper open fully whenever the AHU is on, while the return air damper modulates to maintain supply air temperature as shown below. Relief/exhaust damper position tracks inversely with the return damper position.

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.

Note that the economizer damper will close (if there is a separate minimum outdoor air damper) or modulate to minimum position (if there is a single outdoor air damper) whenever minimum outdoor air control is active. See logic for Minimum Outdoor Air Control below.

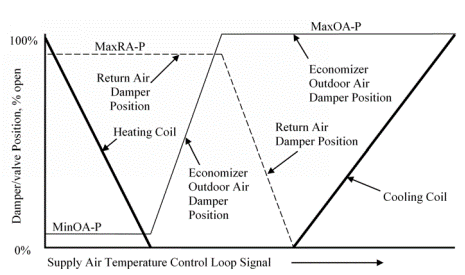


Figure 4.22.2 Supply Air Temperature Loop Mapping with Relief Damper or Relief Fan

The figure above does not illustrate the outdoor air damper position (MaxOA-P) going to minimum at the economizer lockout temperature. That occurrence is only based on the outside air temperature (dry-bulb); the SAT cooling loop does not depend on when that occurs.

Economizer high limit lockout setpoint is defined in Section 4.5D.3 Economizer High Limit.

Economizer lockout sequences are defined in Section 4.5 H. 1.

For AHUs with return fans and direct building pressure controls, the SAT control loop makes the economizer outdoor air damper open fully whenever the AHU is on, while the return air damper modulates to maintain supply air temperature as shown below. Relief/exhaust damper position tracks inversely with the return damper position.

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.

Note that the economizer damper will close (if there is a separate minimum outdoor air damper) or modulate to minimum position (if there is a single outdoor air damper) whenever minimum outdoor air control is active. See logic for Minimum Outdoor Air Control below.

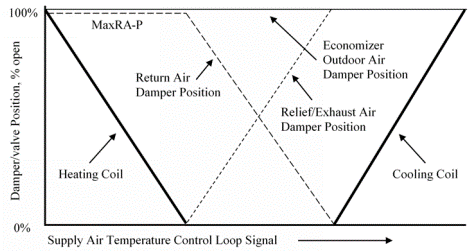


Figure 4.22.3 Supply Air Temperature Loop Mapping with Return Fan Control with Airflow Tracking

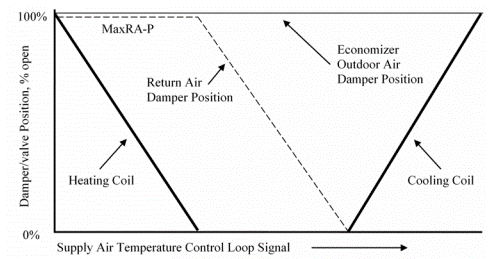


Figure 4.22.4 Supply Air Temperature Loop Mapping with Return Fan Control with Direct Building Pressure Controls

* + 1. 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 4.22 C. 1 and delete Section 4.22 C. 2.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.22 C. 2 and delete Section 4.22 C. 1

* + - 1. Outdoor Airflow Set Point for ASHRAE Standard 62.1-2016 Ventilation CO2 DCV at the system level is not yet implemented for Standard 62.1 compliance, pending the results of RP-1747.
         1. See Section 4.8 A. 3. f for zone outdoor air requirement Voz.
         2. See Section 4.5 D. 2. a 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.

* + - * 1. Outdoor air absolute minimum and design minimum set points are recalculated continuously based on the adjusted ventilation rates Vbz-A\* and Vbz-P\* of the zones being served, determined in accordance with Section 4.8 A.3.

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 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.

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.



* + - * 1. 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.
        2. For each zone in occupied mode, calculate the zone primary outdoor air fraction Zpz:

Zpz = 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.

* + - * 1. Calculate the maximum zone outdoor air fraction Zp:

Zp = max(Zpz)

* + - * 1. Calculate the current system ventilation efficiency Ev:

Ev = 1 + (Vou/Vps) – Zp

* + - * 1. 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:

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.22 C. 2 and delete Section 4.22 C. 1.

• If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep 4.22 C. 1 and delete Section 4.22 C. 2.

* + - 1. Outdoor Airflow Set Point for California Title 24 Ventilation
         1. See Section 4.8 A. 4. bfor zone outdoor air rates Zone-Abs-OA-min and Zone-Des-OA-min.
         2. See Section 4.5 D. 2. b for set points AbsMinOA and DesMinOA.
         3. Effective outdoor air absolute minimum and design minimum set points are recalculated continuously based on the mode of the zones being served.

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.

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 4.22 C. 1 or Section 4.22 C. 2 should remain. The other sub-section 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 air-flow measurement station (AFMS)?

Control logic selections should be made as follows:

• For AHUs with separate dedicated dampers and OA measurement by ΔP, use Section 4.22 D and delete Sections 4.22 E and 4.22 F.

• For AHUs with separate dedicated dampers and OA measurement by AFMS, use Section 4.22 E and delete Sections 4.22 D and 4.22 F.

• For AHUs with a single common damper and OA measurement by AFMS, use Section 4.22 F and delete Sections 4.22 D and 4.22 E.

• 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.

* + 1. Minimum Outdoor Air Control with a Separate Minimum Outdoor Air Damper and Differential Pressure Control

The engineer must select between ventilation logic options:

• If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 4.22 D. 1 and delete Section 4.22 D. 2.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.22 D. 2 and delete Section 4.22 D. 1.

* + - 1. DP Set Point for ASHRAE Standard 62.1 Ventilation
         1. See Section 4.6 A. 5 for design OA DP set points.
         2. See Section 4.22 C. 1. c for calculation of current outdoor air set point MinOAsp.
         3. The minimum outdoor air DP set point MinDPsp shall be calculated as

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.22 D. 2 and delete Section 4.22 D. 1.

• If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 4.22 D. 1 and delete Section 4.22 D. 2.

* + - 1. DP set point for California Title 24 Ventilation
         1. See Section 4.6 A. 5 for design OA DP set points.
         2. See Section 4.22 C. 2. c for calculation of current set points AbsMinOA\* and DesMinOA\*.
         3. See zone CO2 control logic under terminal unit sequences.
         4. The active minimum DP set points AbsDPsp\* and DesD-Psp\* shall be determined by the following equations:

This equation prevents excess outdoor air from being sup-plied during periods of partial occupancy.

* + - * 1. The minimum outdoor air DP set point MinDPsp shall be reset based on the highest zone CO2 control-loop signal from AbsDPsp\* at 50% signal to DesDPsp\* at 100% signal.
        2. The minimum outdoor air set point MinOAsp shall be reset based on the highest zone CO2 control-loop signal from AbsMinOA\* at 50% signal to DesMinOA\* at 100% signal.

The requirement below was added to provide a quick way to check which zone is driving the minimum outdoor air DP set point.

* + - * 1. The control system shall identify the zone that corresponds to the maximum CO2 loop by the zone name or terminal unit number.

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

When the sequences are complete, only one of Section 4.22 D. 1 and Section 4.22 D. 2 should remain. The other section should be deleted along with these flag notes.

* + - 1. 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.
      2. Outdoor Air and Return Air Dampers
         1. For units with return fans

Minimum outdoor air control is enabled when return damper position exceeds MRA-P because it cannot be assumed that the combination of the minimum and the economizer outdoor air dampers are providing sufficient outdoor air under these conditions. The 20% threshold can be increased to ensure minimum outdoor airflow will be maintained but at the expense of fan energy. This threshold could be determined empirically during TAB work as well.

When the supply air fan is proven on and the system is in occupied mode and MinDPsp is greater than zero, the system shall calculate MRA-P. The value of MRA-P shall scale from 95% when supply fan speed is at 100% design speed proportionally down to 20% when the fan is at minimum speed. When MRA-P is not being calculated for any reason, it shall be set to 100%.

Minimum outdoor air control shall be enabled when the unit is in Occupied Mode and either of the following conditions are true for 10 minutes:

The economizer high limit conditions are exceeded.

When the minimum outdoor air damper is open and the return air damper position is greater than MRA-P.

When minimum outdoor air control is enabled, the normal sequencing of economizer outdoor air and return air dampers shall be suspended per the following sequence:

Fully open return air damper; and

Wait 15 seconds, then close the economizer outdoor air damper; and

Wait 3 minutes, then release return air damper position for control by the SAT control loop in Section 4.22 B. Economizer outdoor air damper remains closed.

The maximum return air damper position endpoint MaxRA-P shall be modulated from 100% to 0% to maintain DP across the minimum outdoor air damper at set point MinDPsp.

Minimum outdoor air control shall be disabled when the unit is no longer in Occupied Mode, or both of the following conditions are true for 10 minutes:

The economizer high limit conditions in Section 4.5 E. 2 are not exceeded.

The minimum outdoor air damper is closed or the return air damper position is 10% below MRA-P.

When minimum outdoor air control is disabled:

Economizer outdoor air damper shall be fully opened.

MaxRA-P shall be set to 100%.

Economizer and return air damper positions shall be controlled by the SAT control loop.

* + - * 1. For units with relief dampers or relief fans

Minimum outdoor air control is enabled when economizer damper position is less than MOA-P because it cannot be assumed that the combination of the minimum and the economizer outdoor air dampers are providing sufficient outdoor air under these conditions.

Minimum outdoor air control is disabled when return damper position is less than MRA-P, because the economizer damper has been closed to enable an accurate airflow measurement through the minimum outdoor air damper. The 20% and 80% thresholds can be increased/decreased to ensure minimum outdoor airflow will be maintained but at the expense of fan energy. This threshold could be determined empirically during TAB work as well.

When the supply air fan is proven on and the system is in occupied mode and MinDPsp is greater than zero, the system shall calculate MOA-P. The value of MOA-P shall scale from 5% when supply-fan speed is at 100% design speed proportionally up to 80% when the fan is at minimum speed. When MOA-P is not being calculated for any reason, it shall be set to 0%.

When the supply air fan is proven on and the system is in occupied mode and MinDPsp is greater than zero, the system shall calculate MRA-P. The value of MRA-P shall scale from 95% when supply fan speed is at 100% design speed proportionally down to 20% when the fan is at minimum speed. When MRA-P is not being calculated for any reason, it shall be set to 100%.

Minimum outdoor air control shall be enabled when the unit is in Occupied Mode and either of the following conditions are true for 10 minutes:

The economizer high limit conditions in Section 4.5 E. 2 are exceeded.

When the minimum outdoor air damper is open and the economizer outdoor air damper position is less than MOA-P.

When minimum outdoor air control is enabled, the normal sequencing of economizer outdoor air and return air dampers per Section 4.22 B shall be suspended per the following sequence:

Fully open return air damper; and

Wait 15 seconds, then close the economizer outdoor air damper; and

Wait 3 minutes, then release return air damper position for control by the SAT control loop in Section 4.22 B Economizer outdoor air damper remains closed.

The maximum return air damper position endpoint MaxRA-P shall be modulated from 100% to 0% to maintain DP across the minimum outdoor air damper at set point MinDPsp.

Minimum outdoor air control shall be disabled when the unit is no longer in Occupied Mode, or both of the following conditions are true for 10 minutes:

The economizer high limit conditions are not exceeded.

The minimum outdoor air damper is closed or the return air damper position is 10% below MRA-P.

When minimum outdoor air control is disabled:

MaxRA-P shall be set to 100%.

b. Economizer and return air damper positions shall be controlled by the SAT control loop

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 air-flow measurement station (AFMS)?

Control logic selections should be made as follows:

• For AHUs with separate dedicated dampers and OA measurement by AFMS, use Section 4.22 E and delete Sections 4.22 D and 4.22 F.

• For AHUs with separate dedicated dampers and OA measurement by ΔP, use Section 4.22 D and delete Sections 4.22 E and 4.22 F.

• For AHUs with a single common damper and OA measurement by AFMS, use Section 4.22 F and delete Sections 4.22 D and 4.22 E.

• 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.

* + 1. Minimum Outdoor Air Control with a Separate Minimum Outdoor Air Damper 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 4.22 E. 1

and delete Section 4.22 E. 2.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.22 E. 2 and delete Section 4.22 E. 1.

* + - 1. Outdoor Airflow Set Point for ASHRAE Standard 62.1-2016 Ventilation
         1. See Section 4.22 C. 1. h for calculation of current outdoor air set point MinOAsp.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.22 E. 2 and delete Section 4.22 E. 1.

• If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 4.22 E. 1 and delete Section 4.22 E. 2.

* + - 1. Outdoor Airflow Set Point for California Title 24 Ventilation
         1. See Section 4.22 C. 2. c for calculation of current set points AbsMinOA\* and DesMinOA\*.
         2. See zone CO2 control logic under terminal unit sequences.
         3. See Section 4.22 D. 2. f for MinOAsp control logic.

This concludes the section where the ventilation logic option is selected. When the sequences are complete, only one of Section 4.22 E. 1 and Section 4.22 E. 2 should remain. The other section should be deleted along with these flag notes.

* + - 1. Open minimum outdoor air damper when the supply fan is proven ON, the AHU is in Occupied Mode and MinOAsp is greater than zero. Minimum outdoor air damper shall be closed otherwise.
      2. Outdoor Air and Return Air Dampers
         1. For units with return air fans

Minimum outdoor air control is enabled when return damper position exceeds MRA-P because it cannot be assumed that the combination of the minimum and the economizer outdoor air dampers are providing sufficient outdoor air under these conditions. The 20% threshold can be increased to ensure minimum outdoor airflow will be maintained but at the expense of fan energy. This threshold could be determined empirically during TAB work as well.

When the supply air fan is proven on and the system is in occupied mode and MinOAsp is greater than zero, the system shall calculate MRA-P. The value of MRA-P shall scale from 95% when supply fan speed is at 100% design speed proportionally down to 20% when the fan is at minimum speed. When MRA-P is not being calculated for any reason, it shall be set to 100%.

Minimum outdoor air control shall be enabled when the unit is in Occupied Mode and either of the following conditions are true for 10 minutes:

The economizer high limit conditions are exceeded.

When the minimum outdoor air damper is open and the return air damper position is greater than MRA-P.

When minimum outdoor air control is enabled, the normal sequencing of economizer outdoor air and return air dampers per Section 4.22 B shall be suspended per the following sequence:

Fully open return air damper; and

Wait 15 seconds, then close the economizer outdoor air damper; and

Wait 3 minutes, then release return air damper position for control by the SAT control loop in Section 4.22 B. Economizer outdoor air damper remains closed.

The maximum return air damper position endpoint MaxRA-P shall be modulated from 100% to 0% to maintain airflow across the minimum outdoor air damper at set point MinOAsp.

Minimum outdoor air control shall be disabled when the unit is no longer in

Occupied Mode, or both of the following conditions are true for 10 minutes:

The economizer high limit conditions in Section 4.5 E. 2 are not exceeded.

The minimum outdoor air damper is closed or the return air damper position is 10% below MRA-P.

When minimum outdoor air control is disabled:

Economizer outdoor air damper shall be fully opened.

MaxRA-P shall be set to 100%.

Economizer and return air damper positions shall be controlled by the SAT control loop per Section 4.22 B.

* + - * 1. For units with relief dampers or relief fans

Minimum outdoor air control is enabled when economizer damper position is less than MOA-P because it cannot be assumed that the combination of the minimum and the economizer outdoor air dampers are providing sufficient outdoor air under these conditions.

Minimum outdoor air control is disabled when return damper position is less than MRA-P, because the economizer damper has been closed to enable an accurate airflow measurement through the minimum outdoor air damper.

The 20% and 80% thresholds can be increased/decreased to ensure minimum outdoor airflow will be maintained but at the expense of fan energy. This threshold could be determined empirically during TAB work as well.

When the supply air fan is proven on and the system is in occupied mode and MinOAsp is greater than zero, the system shall calculate MOA-P. The value of MOA-P shall scale from 5% when supply-fan speed is at 100% design speed proportionally up to 80% when the fan is at minimum speed. When MOA-P is not being calculated for any reason, it shall be set to 0%.

When the supply air fan is proven on and the system is in occupied mode and MinOAsp is greater than zero, the system shall calculate MRA-P. The value of MRA-P shall scale from 95% when supply fan speed is at 100% design speed proportionally down to 20% when the fan is at minimum speed. When MRA-P is not being calculated for any reason, it shall be set to 100%.

Minimum outdoor air control shall be enabled when the unit is in Occupied Mode and either of the following conditions are true for 10 minutes:

The economizer high limit conditions in Section 4.5 E. 2 are exceeded.

When the minimum outdoor air damper is open and the economizer outdoor air damper position is less than MOA-P.

When minimum outdoor air control is enabled, the normal sequencing of economizer outdoor air and return air dampers per Section 4.22 B shall be suspended per the following sequence:

Fully open return air damper; and

Wait 15 seconds, then close the economizer outdoor air damper; and

Wait 3 minutes, then release return air damper position for control by the SAT control loop in 4.22 B. Economizer outdoor air damper remains closed.

The maximum return air damper position endpoint MaxRA-P shall be modulated from 100% to 0% to maintain airflow across the minimum outdoor air damper at set point MinOAsp.

Minimum outdoor air control shall be disabled when the unit is no longer in Occupied Mode, or both of the following conditions are true for 10 minutes:

The economizer high limit conditions in Section 4.5 E. 2 are not exceeded.

The minimum outdoor air damper is closed or the return air damper position is 10% below MRA-P.

When minimum outdoor air control is disabled:

MaxRA-P shall be set to 100%.

Economizer and return air damper positions shall be controlled by the SAT control loop per Section 4.22 B.

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 air-flow 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 4.22 F and delete Sections 4.22 D and 4.22 E.

• For AHUs with separate dedicated dampers and OA measurement by ΔP, use Section 4.22 D and delete Sections 4.22 E and 4.22 F

• For AHUs with separate dedicated dampers and OA measurement by AFMS, use Section 4.22 E and delete Sections 4.22 D and 4.22 F.

• 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.

* + 1. 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 4.22 F. 1 and delete Section 4.22 F. 2.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.22 F. 2 and delete Section 4.22 F. 1.

* + - 1. Outdoor Airflow Set Point for ASHRAE Standard 62.1-2016 Ventilation
         1. a. See Section 4.22 C. 1 for calculation of current outdoor air set point MinOAsp.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.22 F. 2 and delete Section 4.22 F. 1.

• If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 4.22 F. 1 and delete Section 4.22 F. 2.

* + - 1. Outdoor Airflow Set Point for California Title 24 Ventilation
         1. See Section 4.22 C. 2. c for calculation of current set points AbsMinOA\* and DesMinOA\*.
         2. See zone CO2 control logic under terminal unit sequences.
         3. See Section 4.22 D. 2. f for MinOAsp control logic.

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

When the sequences are complete, only one of Section 4.22 F. 1 and Section 4.22 F. 2 should remain. The other section should be deleted along with these flag notes.

* + - 1. Minimum Outdoor Air Control Loop
         1. 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.
         2. For units with return fans:

The following logic limits the return damper position to ensure that minimum outdoor air is maintained at all times, while the actual return damper position is modulated by the SAT control loop.

The outdoor airflow rate shall be maintained at the minimum outdoor damper outdoor airflow setpoint MinOAsp by a direct-acting control loop whose output is mapped to the return air damper maximum position endpoint MaxRA-P.

The following logic directly controls the return damper position to ensure that exactly the minimum outdoor air – and no more – is provided when economizer lockout conditions are exceeded. When economizer lockout no longer applies, return damper control reverts to the SAT control loop.

While the unit is in Occupied Mode, if the economizer high limit conditions are exceeded for 10 minutes, outdoor air shall be controlled to the minimum outdoor airflow. When this occurs, the normal sequencing of the return air damper by the SAT control loop is suspended, and the return air damper position shall be modulated directly to maintain measured airflow at MinOAsp (i.e. return damper position shall equal MaxRA-P). The economizer damper shall remain open.

If the economizer high limit conditions in Section 4.5 E. 2 are not exceeded for 10 minutes, or the unit is no longer in Occupied Mode, release return damper to control by the SAT control loop (i.e. return damper position is limited by MaxRA-P endpoint, but is not directly controlled to equal MaxRA-P).

* + - * 1. For units with relief dampers or relief fans:

The following logic limits the return and economizer damper positions to ensure that minimum outdoor air is maintained at all times, while the actual damper positions are modulated by the SAT control loop.

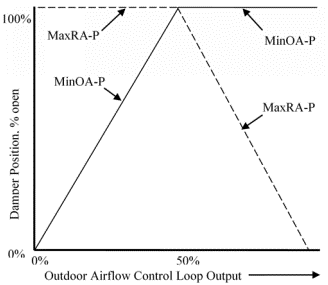
The outdoor airflow rate shall be maintained at the minimum outdoor air set point MinOAsp by a reverse-acting control loop whose output is mapped to economizer damper minimum position MinOA-P and return air damper maximum position MaxRA-P as indicated in Figure 4.22.5.

Figure 4.22.5: Minimum Outdoor Airflow Control Loop Mapping with a Single Damper

While the unit is in Occupied Mode, if the economizer high limit conditions are exceeded for 10 minutes, outdoor air shall be controlled to the minimum outdoor airflow. When this occurs, the normal sequencing of the return air damper by the SAT control loop is suspended:

Fully open return air damper

Wait 15 seconds, then set MaxOA-P equal to MinOA-P

Wait 3 minutes, then modulate return air damper to maintain measured airflow at MinOAsp (i.e. return damper position shall equal MaxRA-P).

If the economizer high limit conditions in Section 4.5 E. 2 are not exceeded for 10 minutes, or the unit is no longer in Occupied Mode, set MaxOA-P = 100% and release return damper to control by the SAT control loop (i.e. return damper position is limited by MaxRA-P endpoint, but is not directly controlled to equal MaxRA-P).

This concludes the section where the minimum outdoor air control logic is selected.

When the sequences are complete, only one of Section 4.22 D, 4.22 E, and 4.22 F should remain. The other two sections should be deleted along with these flag notes.

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 4.22 H and delete sections 4.22 G, 4.22 I, and 4.22 J.

• For AHUs using actuated relief dampers without a fan, use Section 4.22 G and delete sections 4.22 H, 4.22 I, and 4.22 J.

• For AHUs using a return fan with direct building pressure control, use Section 4.22 I and delete Sections 4.22 G, 4.22 H, and 4.22 J.

• For AHUs using a return fan with airflow tracking control, use section use Section 4.22 J and delete sections 4.22 G, 4.22 H, and 4.22 I.

• For AHUs using non-actuated barometric relief only, delete all four Sections 4.22 G, 4.22 H, 4.22 I, and 4.22 J.

A building pressure sensor is required for options in Sections 4.22 G, 4.22 H, 4.22 I.

* + 1. Control of Actuated Relief Dampers without Fans
       1. Relief dampers shall be enabled when the associated supply fan is proven ON, and disabled otherwise.
       2. When enabled, use a P-only control loop to modulate relief dampers to maintain 0.05 in. of water building static pressure. Close damper when disabled.
    2. Relief-Fan Control

A pressure zone is defined as an enclosed area with interconnected return paths. The appropriate boundaries for pressure zones, establishing which relief fans run together and which building pressure sensors are used, will need to be determined by the engineer based on building geometry.

Relief fans are enabled and disabled with their associated supply fans, but all relief fans that are running and serve a run at the same speed. All operating relief fans that serve a pressure zone 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. For example, if two AHUs share a pressure zone, their relief fans should be controlled together as one system while both AHUs are operating.

This prevents relief fans from fighting each other, which can lead to flow reversal or unstable fan speed control and 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.

* + - 1. All operating relief fans that serve a pressure zone shall be grouped and controlled as if they were one system, running at the same speed when enabled and using the same control loop, even if they are associated with different AHUs.
      2. A relief fan shall be enabled when its associated supply fan is proven ON, and shall be disabled otherwise.
      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.
         1. Where multiple building pressure sensors are used, each shall be time-averaged and the highest of the averaged values for sensors within a pressure zone shall be used for control.
      4. A P-only control loop for each pressure zone shall maintain the building pressure at a set point of 0.05 in. of water with an out-put ranging from 0% to 100%. The loop shall be enabled when any supply fan within pressure zone is proven ON. The loop is disabled with output set to zero otherwise.

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 running at minimum speed.

For best results, fan speed minimums should be set as low as possible.

* + - 1. 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.

In some installations, the relief fan inlet plenum may also be the return plenum to the AHU mixed air plenum, in which case, the pressure in this plenum may be drawn negative relative to the outdoors by the supply air fan drawing return air from this plenum. This can occur when the return path has a fairly high pressure drop. If the engineer is concerned that this may occur, Stage 0 and references to it should be deleted.

* + - * 1. 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.
        2. 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%.

For systems where relief fans share a common relief fan inlet plenum: 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.

For systems where relief fans do not share a common relief fan inlet plenum: When staging from Stage 0 (no relief fans) to Stage 1 (one relief fan), the discharge dampers of all nonoperating relief fans shall remain open when the associated supply fan is proven ON.

* + - * 1. 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).
      1. For fans in a Level 2 alarm and status is OFF, discharge damper shall be closed when stage is above Stage 0.
    1. Return-Fan Control—Direct Building Pressure
       1. Return fan operates whenever the associated supply fan is proven ON and shall be off otherwise.
       2. Return fans shall be controlled to maintain return-fan discharge static pressure at set point (Section 4.22 I. 4).
       3. Building static pressure shall be time aver-aged with a sliding 5-minute window and 15 seconds sampling rate (to dampen fluctuations). The averaged value shall be that displayed and used for control.
          1. Where multiple building pressure sensors are used, the highest of the averaged values for sensors within a pressure zone shall be 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.

* + - 1. A single P-only control loop for each pressure zone shall modulate to maintain the building pressure at a setpoint of 0.05 in. of water with an output ranging from 0% to 100%. The loop shall be enabled when the supply and return fans for any unit within the pressure zone are proven ON and the minimum outdoor air damper is open. The exhaust dampers shall be closed with loop output set to zero otherwise. All exhaust damper and return fan static pressure setpoints for units in an associated pressure zone shall be sequenced based on building pressure control loop output signal.

A pressure zone is defined as an enclosed area with interconnected return air paths. All operating relief dampers and return fans that serve a pressure zone shall be controlled as if they were one system, using the same control loop, even if they are associated with different AHUs. The appropriate boundaries for pressure zones, establishing which return fans run together, will need to be determined by the engineer based on building geometry.

* + - * 1. From 0% to 50%, the building pressure control loop shall modulate the exhaust dampers from 0% to 100% open.
        2. 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 4.6 A. 4 for RFDSPmin and RFDSPmax.

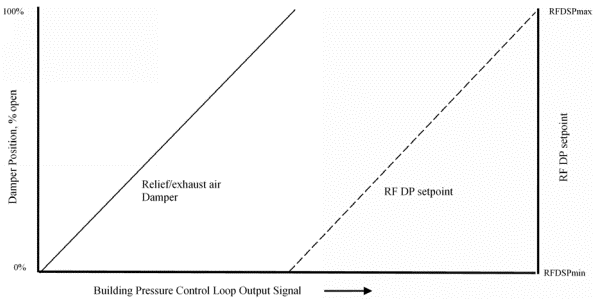


Figure 4.22.6 Exhaust Damper Position and Return Fan DP Reset Loop Mapping

* + 1. Return-Fan Control— Airflow Tracking
       1. Return fan operates whenever associated supply fan is proven ON.
       2. The active differential airflow setpoint S-R-DIFF\* shall e S-R-DIFF for the entire system (see Section 4.8 A 3.5) adjusted by the sum of the area component of the breathing zone outdoor airflow rate of the zones in the Zone Groups that are in the occupied mode relative to that in all zones served by the system.

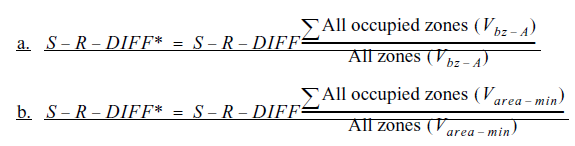
The equations below will result in S-R-DIFF set to zero if no zones are in occupied mode, e.g., during warm-up, cooldown, setback, and setup modes.

If the project is to comply with California Title 24 ventilation requirements, keep (b) and

delete (a).

If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep

(a) and delete (b).



* + - 1. Return-fan speed shall be controlled to maintain return airflow equal to supply airflow less differential S-R-DIFF\*. Where multiple air handling units share a common return fan (i.e. dual fan dual duct), return fan speed shall be controlled to maintain return airflow equal to total supply airflow of all associated units less differential S-R-DIFF\*.
      2. Supply fan airflow shall be limited by a reverse-acting P-only loop whose set point is (Vrf-max + S-R-DIFF\*) and whose output is maximum supply fan speed ranging from 0% to 100%.
      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 4.22 B. 3.

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 4.22 G, 4.22 H, 4.22 I, and 4.22 J 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.

* + 1. 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).

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 4.22 K but maintain the alarms. Delete this flag note when sequences are complete.

* + - 1. If the supply air temperature drops below 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 42°F. Disable this function when supply air temperature rises above 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.

* + - 1. If the supply air temperature drops below 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 4.22 K. 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 42°F]), after which one of three possibilities will occur:

a. If it is warm enough that the SAT rises above 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 38°F and 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.

* + - 1. Upon signal from the freeze-stat (if installed), or if supply air temperature drops below 38F) for 15 minutes or below 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 80°F, and set a Level 2 alarm indicating the unit is shut down by freeze protection.
         1. 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 work-station. (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 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.

* + 1. Alarms

Table 4.22.11 Alarm List – Multiple-Zone VAV Air-Handling Unit

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Level | Definition | Applicable Spec Section |
|  | Freeze Protection Stage 2 | 3 | When Freeze Protection Stage 2 Occurs | 4.22 K. 2 |
|  | Freeze Protection Stage 3 | 2 | When Freeze Protection Stage 3 Occurs | 4.22 K. 3 |
|  | Maintenance Interval | 4 | Accumulated maintenance run hours >1500 hours | 4.22 L. 1 |
|  | Fan Remains Off | 2 | Fan commanded ON, fan status OFF | 4.22 L. 2. a |
|  | Fan Remains On | 4 | Fan commanded OFF, fan status ON | 4.22 L. 2. b |
|  | High Filter Pressure Drop | 4 | See spec section, based on current speed and design high-limit. | 4.22 L. 3 |
|  | High Building Pressure | 3 | Building pressure greater than 0.10 in of w.c. | 4.22 L. 4 |
|  | Low Building Pressure | 4 | Building pressure less than 0.0 in. w.c. | 4.22 L. 5 |

* + - 1. Maintenance interval alarm when fan has operated for more than 1500 hours: Level 4. Reset interval count when alarm is acknowledged.
      2. Fan alarm is indicated by the status being different from the command for a period of 15 seconds.
         1. a. Commanded ON, status OFF: Level 2
         2. b. Commanded OFF, status ON: Level 4
      3. Filter pressure drop exceeds the larger of the alarm limit or 0.05 in. of water for 10 minutes when the airflow (expressed as a percentage of the design airflow of design speed if total airflow is not known) exceeds 20%: Level 4. The alarm limit shall vary with total airflow (if available; use fan speed if total airflow is not known) as follows:

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.

* + - 1. High building pressure (more than 0.10 in. of water): Level 3.
      2. 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.

* + 1. 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.

* + - 1. AFDD conditions are evaluated continuously and separately for each operating AHU.
      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 4.22.12 and Figure 4.22.7

Table 4.22.12 Multi-zone 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, < 100% |
| #3 Mechanical + economizer cooling | = 0 | > 0 | = 100% |
| #4 Mechanical cooling, minimum OA | = 0 | > 0 | = min |
| #5 Unknown or dehumidification | No other OS Applies | | |

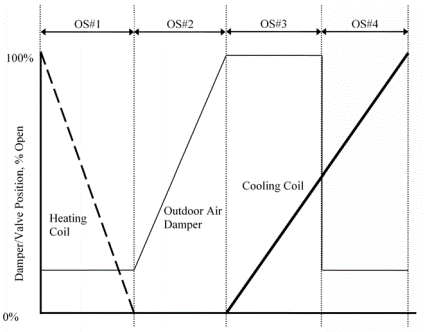


Figure 4.22.7: VAV AHU Operating States

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 4.22.12) represent normal operation during which a fault may nevertheless occur if so determined by the fault condition tests in Section 0.

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.

* + - 1. 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.

* + - * 1. SAT = supply air temperature
        2. MAT = mixed air temperature
        3. RAT = return air temperature
        4. OAT = outdoor air temperature
        5. DSP = duct static pressure
        6. SATSP = supply air temperature set point
        7. DSPSP = duct static pressure set point
        8. HC = heating-coil valve position command; 0% ≤ HC ≤ 100%
        9. CC = cooling-coil valve position command; 0% ≤ CC ≤ 100%
        10. FS = fan speed command; 0% ≤ FS ≤ 100%
        11. CCET = cooling-coil entering temperature (Depending on the AHU configuration, this could be the MAT or a separate sensor for this specific purpose.)
        12. CCLT = cooling-coil leaving temperature (Depending on the AHU configuration, this could be the SAT or a separate sensor for this specific purpose.)
        13. HCET = heating-coil entering temperature (Depending on the AHU configuration, this could be the MAT or a separate sensor for this specific purpose.)
        14. HCLT = heating-coil leaving temperature (Depending on the AHU configuration, this could be the SAT or a separate sensor for this specific purpose.)
      1. The following values must be continuously calculated by the AFDD routines for each AHU:
         1. 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.

SATavg = rolling average of supply air temperature

MATavg = rolling average of mixed air temperature

RATavg = rolling average of return air temperature

OATavg = rolling average of outdoor air temperature

DSPavg = rolling average of duct static pressure

CCETavg = rolling average of cooling-coil entering temperature

CCLTavg = rolling average of cooling-coil leaving temperature

HCETavg = rolling average of heating-coil entering temperature

HCLTavg = rolling average of heating-coil leaving temperature

* + - * 1. %OA = actual outdoor air fraction as a percentage = (MAT – RAT)/(OAT – RAT), or per airflow measurement station if available.
        2. %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.
        3. OS = number of changes in operating state during the previous 60 minutes (moving window)
      1. The internal variables shown in Table 4.22.13 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 4.22 M. 12.

Table 4.22.13 Multi-zone VAV AHU Internal Variables

|  |  |  |
| --- | --- | --- |
| Variable Name | Description | Default Value |
| ΔTSF | Temperature rise across supply fan | 1°F |
| ΔTmin | Minimum difference between OAT and RAT to evaluate economizer error conditions (FC#6) | 10°F |
| εSAT | Temperature error threshold for SAT sensor | 2°F |
| εRAT | Temperature error threshold for RAT sensor | 2°F |
| εMAT | Temperature error threshold for MAT sensor | 5°F |
| εOAT | Temperature error threshold for OAT sensor | 2°F if local to unit;  5°F if global sensor |
| εF | Airflow error threshold | 30% |
| εVFDSPD | VFD Speed Error Threshold | 5% |
| εDSP | DSP error threshold | 0.1 inch of water |
| εCCET | Cooling coil entering temperature sensor error; Either equals εMAT **OR** dedicated sensor error | Varies; see description |
| εCCLT | Cooling coil leaving temperature sensor error; Either equals εSAT **OR** dedicated sensor error |
| εHCET | Heating coil entering temperature sensor error; Either equals εMAT **OR** dedicated sensor error |
| εHCLT | Heating coil leaving temperature sensor error; Either equals εSAT **OR** dedicated sensor error |
| ΔOSmax | Maximum number of changes in Operating State during the previous 60 minutes (rolling/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 |

* + - 1. Table 4.22.1 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 4.22.1 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.

Omit FC-2, FC-3, FC-5, FC-8, FC-10, FC-12 if no MAT sensor is used

Table 4.22.1: Multi-zone VAV AHU Fault Conditions

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Fault Condition | Description | Equation(s) | Possible Diagnosis | Applicable Operating States | | | | | |
| 1 | 2 | 3 | 4 | 5 |
| Heating | Economizer Free Cooling | Economizer + Mech. Cooling | Mechanical Cooling | Unknown/ Dehumidifying |
| 1 | Duct static pressure too low with fan at full speed | **AND** | * Problem with VFD * Mechanical problem with fan * Fan undersized * SAT set point too high (too much zone demand) | X | X | X | X | X |
| 2 | MAT too low, should be between OAT & RAT |  | * RAT sensor error * MAT sensor error * OAT sensor error | X | X | X | X | X |
| 3 | MAT too high, should be between OAT & RAT |  | * RAT sensor error * MAT sensor error * OAT sensor error | X | X | X | X | X |
| 4 | Too many changes in operating state |  | * Unstable control due to poorly tuned loop or mechanical problem | X | X | X | X | X |
| 5 | SAT too low; should be higher than MAT |  | * 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 | X |  |  |  |  |
| 6 | OA fraction too low or too high; should equal %OAmin | **AND** | * RAT sensor error * MAT sensor error * OAT sensor error * Leaking or stuck economizer damper or actuator | X | X | X | X |  |
| 7 | SAT too low in full heating | **AND** | * 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 | X |  |  |  |  |
| 8 | SAT and MAT should be approximately equal when Free-Cooling |  | * SAT sensor error * MAT sensor error * Cooling-coil valve leaking or stuck open * Heating-coil valve leaking or stuck open |  | X |  |  |  |
| 9 | OAT too high for free cooling without additional mechanical cooling |  | * SAT sensor error * OAT sensor error * Cooling-coil valve leaking or stuck open |  | X |  |  |  |
| 10 | OAT and MAT should be approximately equal |  | * MAT sensor error * OAT sensor error * Leaking or stuck economizer damper or actuator |  |  | X |  |  |
| 11 | OAT too low for 100% OA cooling |  | * SAT sensor error * OAT sensor error * Heating-coil valve leaking or stuck open * Leaking or stuck economizer damper or actuator |  |  | X |  |  |
| 12 | SAT too high; should be less than MAT |  | * SAT sensor error * MAT sensor error * Cooling-coil valve stuck closed or actuator failure * Fouled or undersized cooling coil * CHW temperature too high or CHW unavailable * DX cooling unavailable * Gas or electric heat stuck ON * Heating-coil valve leaking or stuck open |  |  | X | X |  |
| 13 | SAT too high in full cooling | **AND** | * 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 |  |  | X | X |  |
| 14 | Temperature drop across inactive cooling coil | \*Omit the term if the fan is not located between the CCET and CCLT sensors. | * CCET sensor error * CCLT sensor error * Cooling-coil valve stuck open or leaking * DX cooling stuck on | X | X |  |  |  |
| 15 | Temperature rise across inactive heating coil | \*Omit the term if the fan is not located between the HCET and HCLT sensors. | * HCET sensor error * HCLT sensor error * Heating-coil valve stuck open or leaking. |  | X | X | X |  |
| Footnotes:  Variables that appear in this table are defined in Section 4.25 D. 2 and 4.25 D. 3.  Internal variables shall be programmed for each air handler, as defined in 4.25 D. 4. | | | | | | | | |

* + - 1. 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:
         1. In OS#1 (heating), the following fault conditions shall be evaluated:

FC#1: DSP too low with fan at full speed

FC#2: MAT too low; should be between RAT and OAT

FC#3: MAT too high; should be between RAT and OAT

FC#4: Too many changes in OS

FC#5: SAT too low; should be higher than MAT

FC#6: OA fraction too low or too high; should equal %OAmin

FC#7: SAT too low in full heating

FC#14: Temperature drop across inactive cooling coil

* + - * 1. In OS#2 (modulating economizer), the following fault conditions shall be evaluated:

FC#1: DSP too low with fan at full speed

FC#2: MAT too low; should be between RAT and OAT

FC#3: MAT too high; should be between RAT and OAT

FC#4: Too many changes in OS

FC#8: SAT and MAT should be approximately equal

FC#9: OAT too high for free cooling without mechanical cooling

FC#14: Temperature drop across inactive cooling coil

FC#15: Temperature rise across inactive heating coil

* + - * 1. In OS#3 (mechanical + 100% economizer cooling), the following fault conditions shall be evaluated:

FC#1: DSP too low with fan at full speed

FC#2: MAT too low; should be between RAT and OAT

FC#3: MAT too high; should be between RAT and OAT

FC#4: Too many changes in OS

FC#10: OAT and MAT should be approximately equal

FC#11: OAT too low for 100% OA

FC#12: SAT too high; should be less than MAT

FC#13: SAT too high in full cooling

FC#15: Temperature rise across inactive heating coil

* + - * 1. In OS#4 (mechanical Cooling, minimum OA), the following fault conditions shall be evaluated:

FC#1: DSP too low with fan at full speed

FC#2: MAT too low; should be between RAT and OAT

FC#3: MAT too high; should be between RAT and OAT

FC#4: Too many changes in OS

FC#6: OA fraction too low or too high; should equal %OAmin

FC#12: SAT too high; should be less than MAT

FC#13: SAT too high in full cooling

FC#15: Temperature rise across inactive heating coil

* + - * 1. In OS#5 (other), the following fault conditions shall be evaluated:

FC#1: DSP too low with fan at full speed

FC#2: MAT too low; should be between RAT and OAT

FC#3: MAT too high; should be between RAT and OAT

FC#4: Too many changes in OS

* + - 1. For each air handler, the operator shall be able to suppress the alarm for any fault condition.
      2. Evaluation of fault conditions shall be sus-pended under the following conditions:
         1. When AHU is not operating
         2. For a period of ModeDelay minutes following a change in mode (e.g., from warm-up to occupied) of any zone group served by the AHU
      3. Fault conditions that are not applicable to the current OS shall not be evaluated.
      4. A fault condition that evaluates as TRUE must do so continuously for AlarmDelay minutes before it is reported to the operator.
      5. 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.
      6. 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 0.
    1. Testing/Commissioning Overrides. Provide software switches that interlock to a CHW and hot-water plant level to
       - 1. force HW valve full open if there is a hot-water coil,
         2. force HW valve full closed if there is a hot-water coil,
         3. force CHW valve full open, and
         4. force CHW valve full closed.

Per Section 4.7 K, 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 4.10 E.

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.

* + 1. Plant Requests
       1. Chilled-Water Reset Requests
          1. If the supply air temperature exceeds the supply air temperature set point by 5°F for 2 minutes, send 3 requests.
          2. Else if the supply air temperature exceeds the supply air temperature set point by 3°F for 2 minutes, send 2 requests.
          3. 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.
       2. Chiller Plant Requests. Send the chiller plant that serves the system a chiller plant request as follows:
          1. If the CHW valve position is greater than 95%, send 1 request until the CHW valve position is less than 10%.
          2. Else if the CHW valve position is less than 95%, send 0 requests.
       3. If There Is a Hot-Water Coil, Hot-Water Reset Requests
          1. If the supply air temperature is 30°F less than set point for 5 minutes, send 3 requests.
          2. Else if the supply air temperature is 15°F less than set point for 5 minutes, send 2 requests.
          3. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
          4. Else if the HW valve position is less than 95%, send 0 requests.
       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:
          1. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.
          2. Else if the HW valve position is less than 95%, send 0 requests.

## Dual-Fan Dual-Duct Cooling-Only Ventilating Air-Handling Unit

This section describes a cooling-only air handler servicing the cold duct of a dual-duct air handling distribution system. The cooling-only air handler is responsible for ventilating the zones.

Table 4.23.1 Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit – Hardware Points List

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Type | Device | Required |
|  | Exhaust Air Damper | AO |  | Define |
|  | Return Air Damper | AO |  | R |
|  | Econ OA Damper | AO |  | R |
|  | Min OA Damper | AO |  | R |
|  | Outdoor Air Temp | AI |  | R |
|  | Mixed Air Temp | AI |  | R |
|  | Return Air Temp | AI |  | R |
|  | Supply Air Temp | AI |  | R |
|  | Outside Air Flow | AI |  | R |
|  | Return Air Flow | AI |  | R |
|  | Supply Air Flow | AI |  | R |
|  | Supply Fan High Static | DI |  | R |
|  | Return Fan High Static | DI |  | R |
|  | Return Fan High Static | DI |  | R |
|  | Duct Static Pressure | AI |  | R |
|  | Building Static Pressure | AI |  | R |
|  | Supply Fan VFD - Status | DI |  | R |
|  | Supply Fan VFD - Start | DO |  | R |
|  | Supply Fan VFD - Speed | AO |  | R |
|  | Return Fan VFD - Status | DI |  | Define |
|  | Return Fan VFD - Start | DO |  | Define |
|  | Return Fan VFD - Speed | AO |  | Define |
|  | Exhaust Fan VFD - Status | DI |  | Define |
|  | Exhaust Fan VFD - Start | DO |  | Define |
|  | Exhaust Fan VFD - Speed | AO |  | Define |
|  | Filter Differential Pressure | AI |  | R |
|  | Hot Water Coil Valve Position | AO |  | R |
|  | Hot Water Coil DAT | AI |  | R |
|  | Chilled Water Coil Valve Position | AO |  | R |

Table 4.23.2 Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit – Software Points List (Excluding Ventilation)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Cooling SAT Maximum | Max\_ClgSAT |  | § 4.5 E. 1. a | X | X |  |  | |
|  | Cooling SAT Minimum | Min\_ClgSAT |  | § 4.5 E. 1. b | X | X |  |  | |
|  | Cooling SAT OAT Max | OAT\_Max |  | § 4.5 E. 1. c | X | X |  |  | |
|  | Cooling SAT OAT Min | OAT\_Min |  | § 4.5 E. 1. d | X | X |  |  | |
|  | Duct Design Maximum Static Pressure | Max\_DSP |  | § 4.6 A. 1 | X | X |  | Field Measured | |
|  | Supply Fan – Minimum Speed |  |  | § 4.6 A. 2. a. i | X | X |  | Field Measured | |
|  | Return Fan – Minimum Speed |  |  | § 4.6 A. 2. a. ii | X | X |  | Remove if not present, Field Measured | |
|  | Relief Fan – Minimum Speed |  |  | § 4.6 A. 2. a. iii | X | X |  | Remove if not present, Field Measured | |
|  | Return Fan Discharge Static Pressure Setpoint, Minimum | RFDSPmin |  | § 4.6 A. 4. a | X | X |  | Field Measured, Remove if not used | |
|  | Return Fan Discharge Static Pressure Setpoint, Maximum | RFDSPmax |  | § 4.6 A. 4. b | X | X |  | Field Measured, Remove if not used | |
|  | Supply vs. Return Airflow Differential | S-R-DIFF |  | 4.6 A. 5. a | X | X |  | Field Measured, Remove if not used | |
|  | System Mode |  |  | § 4.21 A |  |  | X |  | |
|  | Totalized Airflow from VAVs | Vps |  | § 4.23 A. 1. c |  |  | X |  | |
|  | Duct Static Pressure Setpoint | DSP\_SP | in. w.c. | § 4.23 A. 1. a |  |  | X |  | |
|  | DSP SP Loop |  |  | § 4.23 A. 1. a |  |  | X |  | |
|  | DSP SP Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | DSP SP Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | DSP SP Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | DSP Minimum Setpoint | DSP\_SPmin | in. w.c. | Table 4.23.9 | X | X |  |  | |
|  | DSP Maximum Setpoint | DSP\_SPmax | in. w.c. | Table 4.23.9 |  |  | X | Equals Max\_DSP | |
|  | DSP Delay Timer | DSP\_Td | min. | Table 4.23.9 | X | X |  |  | |
|  | DSP Time Step | DSP\_T | min. | Table 4.23.9 | X | X |  |  | |
|  | DSP Ignored Requests Threshold | DSP\_I | - | Table 4.23.9 | X | X |  |  | |
|  | DSP Totalized Requests from VAVs | DSP\_R | - | Table 4.23.9 | X | X |  |  | |
|  | DSP Trim Amount | DSP\_SPtrim | in. w.c. | Table 4.23.9 | X | X |  |  | |
|  | DSP Respond Amount | DSP\_SPres | in. w.c. | Table 4.23.9 | X | X |  |  | |
|  | DSP Maximum Response | DSP\_SPres-max | in. w.c. | Table 4.23.9 | X | X |  |  | |
|  | Supply Air Temperature Setpoint | SAT\_SP | °F | § 4.23 B. 2 |  |  | X |  | |
|  | SAT SP Loop |  |  | § 4.23 B. 2 |  |  | X |  | |
|  | SAT SP Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | SAT SP Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | SAT SP Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | SAT Minimum Setpoint | SAT\_SPmin | °F | Table 4.23.10 | X | X |  |  | |
|  | SAT Maximum Setpoint | SAT\_SPmax | °F | Table 4.23.10 |  |  | X | Equals Max\_DSP | |
|  | SAT Delay Timer | SAT\_Td | min. | Table 4.23.10 | X | X |  |  | |
|  | SAT Time Step | SAT\_T | min. | Table 4.23.10 | X | X |  |  | |
|  | SAT Ignored Requests Threshold | SAT\_I | - | Table 4.23.10 | X | X |  |  | |
|  | SAT Totalized Requests from VAVs | SAT\_R | - | Table 4.23.10 | X | X |  |  | |
|  | SAT Trim Amount | SAT\_SPtrim | °F | Table 4.23.10 | X | X |  |  | |
|  | SAT Respond Amount | SAT\_SPres | °F | Table 4.23.10 | X | X |  |  | |
|  | SAT Maximum Response | SAT\_SPres-max | °F | Table 4.23.10 | X | X |  |  | |
|  | SAT Setback/Warm-up Setpoint |  | °F | § 4.23 B. 2. d | X | X |  |  | |
|  | Return Air Damper Position SP | MaxRA-P | % | § **Error! Reference source not found.** |  |  | X |  | |
|  | Return Air Damper Position Loop |  |  | § **Error! Reference source not found.** |  |  | X |  | |
|  | Return Air Damper Position Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Return Air Damper Position Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Return Air Damper Position Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | Freeze Protection Stage 1 Enabled Setpoint |  | °F | § 4.23 L. 1 | X | X |  |  | |
|  | Freeze Protection Stage 1 Enabled Timer |  | min. | § 4.23 L. 1 | X | X |  |  | |
|  | Freeze Protection SAT Setpoint Min |  | °F | § 4.23 L. 1 | X | X |  |  | |
|  | Freeze Protection Stage 1 Disabled Setpoint |  | °F | § 4.23 L. 1 | X | X |  |  | |
|  | Freeze Protection Stage 1 Disabled Timer |  | min. | § 4.23 L. 1 | X | X |  |  | |
|  | Freeze Protection Stage 2 Setpoint |  | °F | § 4.23 L. 2 | X | X |  |  | |
|  | Freeze Protection Stage 2 Timer |  | min. | § 4.23 L. 2 | X | X |  |  | |
|  | Freeze Protection Stage 2 Duration |  | min. | § 4.23 L. 2 | X | X |  |  | |
|  | Freeze Protection Stage 3 Setpoint |  | °F | § 4.23 L. 3 | X | X |  |  | |
|  | Freeze Protection Stage 3 Timer |  | min. | § 4.23 L. 3 | X | X |  |  | |
|  | Freeze Protection Stage 3 SAT Setpoint |  | °F | § 4.23 L. 3 | X | X |  |  | |
|  | Chilled Water Reset Requests |  |  | § 4.23 P. 1 |  |  | X |  | |
|  | Chilled Water Plant Requests |  |  | § 4.23 P. 2 |  |  | X |  | |
|  | Hot Water Reset Requests |  |  | § 4.23 P. 3 |  |  | X |  | |
|  | Hot Water Plant Requests |  |  | § 4.23 P. 4 |  |  | X |  | |

Table 4.23.3 Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit – ASHRAE 62.1/90.1 Ventilation Software Points

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Design Ventilation, Uncorrected | DesVou | cfm | 4.5 D. 2. a. i | X | X |  | Include zone diversity | |
|  | Design Total Ventilation | DesVot | cfm | 4.5 D. 2. a. ii | X | X |  | Adjusted DesVou for ventilation efficiency | |
|  | Economizer High Limit |  | °F | 4.5 H. 1 | X | X |  |  | |
|  | Design Minimum OA Damper DP to Provide Min Outdoor Air Flow | DesMinDP | in w.c. | 4.6 A. 3. a. i | X | X |  | Field Measured | |
|  | Minimum OA Damper Minimum Position | MinOA-P | % | § 4.23 D | X | X |  |  | |
|  | Maximum RA Damper Position | MaxRA-P | % | § 4.23 D | X | X |  |  | |
|  | Occupied Uncorrected Outdoor Air Rate | Vou | cfm | § 4.23 C. 1. c. i |  |  | X |  | |
|  | Totalized Primary Airflow Rate | Vpz | cfm | § 4.23 C. 1. d |  |  | X |  | |
|  | Occupied Primary Airflow Fraction | Zpz | % | § 4.23 C. 1. e |  |  | X | For each zone | |
|  | Maximum Primary Airflow Fraction | Zp | % | § 4.23 C. 1. f |  |  | X |  | |
|  | System Ventilation Efficiency | Ev | - | § 4.23 C. 1. g |  |  | X |  | |
|  | Minimum Outside Airflow Setpoint | MinOAs | cfm | § 4.23 C. 1. h |  |  | X |  | |
|  | Min OA Flow SP Loop |  |  | § 4.23 D. 1. c |  |  | X |  | |
|  | Min OA Flow Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA Flow Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA Flow Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | Minimum Outdoor Air DP Setpoint | MinDPsp | in. w.c. | § 4.23 D. 1. c |  |  | X |  | |
|  | Min OA DP SP Loop |  |  | § 4.23 D. 1. c |  |  | X |  | |
|  | Min OA DP Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA DP Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA DP Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |

Table 4.23.4 Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit – Title 24 Ventilation Software Points

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Minimum Ventilation when Variable Ventilation Spaces are Unpopulated | AbsMinOA | cfm | § 4.5 D. 2. b. i | X | X |  |  | |
|  | Design Minimum Outdoor Airflow at Design Population | DesMinOA | cfm | § 4.5 D. 2. b. ii | X | X |  |  | |
|  | Economizer High Limit |  | °F | § 4.5 H. 1 | X | X |  |  | |
|  | Minimum OA Damper DP to Provide Minimum Ventilation when Spaces are Unpopulated | AbsMinDP | in w.c. | § 4.6 A. 3. b. i | X | X |  |  | |
|  | Minimum OA Damper DP to Provided Minimum Ventilation when at Design Population | DesMinDP | in w.c. | § 4.6 A. 3. b. ii | X | X |  |  | |
|  | Current Absolute Minimum Ventilation Rate | AbsMinOA\* | cfm | § 4.23 C. 2. c. i |  |  | X |  | |
|  | Current Design Minimum Ventilation Rate | DesMinOA\* | cfm | § 4.23 C. 2. c. i |  |  | X |  | |
|  | Current Absolute Minimum Ventilation Rate | AbsDPsp\* | in. w.c. | § 4.23 D. 2. d |  |  | X |  | |
|  | Current Design Minimum Ventilation Rate | DesDPsp\* | in. w.c. | § 4.23 D. 2. d |  |  | X |  | |
|  | Minimum Outside Air DP Setpoint | MinDPsp | in. w.c. | § 4.23 D. 2. e |  |  | X |  | |
|  | Min OA DP SP Loop |  |  | § 4.23 D. 2. e |  |  | X |  | |
|  | Min OA DP Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA DP Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA DP Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | Minimum Outside Airflow Setpoint | MinOAsp | cfm | § 4.23 D. 2. f |  |  | X |  | |
|  | Min OA Flow SP Loop |  |  | § 4.23 D. 2. f |  |  | X |  | |
|  | Min OA Flow Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA Flow Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA Flow Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | Highest Zone CO2 control-loop signal | MaxZnCO2 | - | § 4.23 D. 2. e |  |  | X |  | |
|  | Zone with Highest CO2 control-loop |  | - | § 4.23 D. 2. g |  |  | X |  | |

Table 4.23.5 Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit – Relief Damper Control without Relief Fans

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Building Static Pressure Setpoint |  | in. w.c. | § 4.23 H. 2 | X | X |  |  | |
|  | Building SP Setpoint Loop |  | - | § 4.23 H. 2 |  |  | X |  | |
|  | Building SP Setpoint Proportional Gain |  | - | § 4.7 H | X | X |  | No integral or derivative gain required. | |

Table 4.23.6 Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit – Relief Damper Control with Relief Fans

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Building Static Pressure Setpoint |  | in. w.c. | § 4.23 I. 4 | X | X |  |  | |
|  | Building SP Setpoint Loop |  | - | § 4.23 I. 4 |  |  | X |  | |
|  | Building SP Setpoint Proportional Gain |  | - | § 4.7 H | X | X |  | No integral or derivative gain required. | |
|  | Relief Fan Stage-Up Step |  | % | § 4.22 H. 5. b | X | X |  |  | |
|  | Relief Fan Stage-Up Interval |  | min. | § 4.23 I. 5. b | X | X |  |  | |
|  | Relief Fan Stage-Down Interval |  | min. | § 4.23 I. 5. c | X | X |  |  | |

Table 4.23.7 Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit – Relief Damper Control with Return Fan, Direct Pressure Control, and Actuated Relief Dampers

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Building Static Pressure Setpoint |  | in. w.c. | § 4.23 J. 4 | X | X |  |  | |
|  | Building SP Setpoint Loop |  | - | § 4.23 J. 4 |  |  | X |  | |
|  | Building SP Setpoint Proportional Gain |  | - | § 4.7 H | X | X |  | No integral or derivative gain required. | |
|  | Return Fan DP Setpoint |  |  | § 4.23 J. 2 |  |  | X |  | |
|  | Return Fan DP Control-Loop |  |  | § 4.23 J. 2 |  |  | X |  | |
|  | Return Fan DP Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Return Fan DP Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Return Fan DP Derivative Gain |  |  | § 4.7 H | X | X |  |  | |

Table 4.23.8 Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit – Relief Damper Control with Return Fan, Airflow Tracking, and Actuated Relief Dampers

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Return Fan Airflow Setpoint |  | cfm | § 4.23 K. 2 |  |  | X |  | |
|  | Return Fan Airflow Control-Loop |  | - | § 4.23 K. 2 |  |  | X |  | |
|  | Return Fan Airflow Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Return Fan Airflow Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Return Fan Airflow Derivative Gain |  | - | § 4.7 H | X | X |  |  | |

* + 1. Supply Fan Control
       1. Supply Fan Start/Stop
          1. Supply fan shall run when system is in the cooldown mode, setup mode, or occupied mode.
          2. If there are any VAV-reheat boxes on perimeter zone, 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 air flow monitoring station (AFMS).

* + - * 1. 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.

* + - 1. Static Pressure Set-Point Reset
         1. Static pressure set point. Set point shall be reset using T&R logic (see Section 4.7 N) using the parameters shown in Table 4.23.9. The T&R reset parameters in Table 4.23.9 are suggested as a starting point; they will most likely require adjustment during the commissioning/tuning phase.

Table 4.23.9: Trim & Response Variables – Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit Static Pressure Reset

|  |  |  |
| --- | --- | --- |
| Variable | Definition | Sample Values |
| Device | Associated Device | Supply Fan |
| SP0 | Initial T&R set point | 0.5 in. of water |
| SPmin | Minimum allowed T&R set point | 0.1 in. of water |
| SPmax | Maximum allowed T&R set point | Max\_DSP (~1.5 iwc) |
| Td | Delay timer | 20 minutes |
| T | Time step | 5 minutes |
| I | Number of ignored requests | 2 |
| R | Number of requests from downstream devices | (sum) |
| SPtrim | T&R set point trim amount (devices are satisfied) | -0.05 in. of water |
| SPres | T&R set point response amount (devices are unsatisfied) | +0.06 in. of water |
| SPrex-max | Max T&R set point response amount per time step | +0.13 in. of water |

* + - 1. Static Pressure Control
         1. 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.

* + 1. Supply Air Temperature Control
       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.
       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., 65°F – 55°F]) to minimize fan energy if

• there is a 24/7 chiller plant that is running anyway;

• reheat is minimized, as in a VAV dual-fan dual-duct system, 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.

* + - * 1. See Section 4.5 D. 1 for Min\_ClgSAT, Max\_ClgSAT, OAT\_Min, and OAT\_Max set points.

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.

T-max shall be reset using T&R logic (see Section 4.7 N) between Min\_ClgSAT and Max\_ClgSAT.

The parameters shown in Table 4.22.10 are suggested as a starting place, but they will require adjustment during the commissioning/tuning phase.

* + - * 1. The net result of this SAT reset strategy is depicted in the Figure 4.22.1 for Min\_ClgSAT = 55°F, Max\_ClgSAT = 65°F, OAT\_Max = 70°F, and OAT\_Min = 60°F.
        2. During cooldown mode, set point shall be Min\_ClgSAT.
        3. During warm-up and setback modes, set point shall be 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.

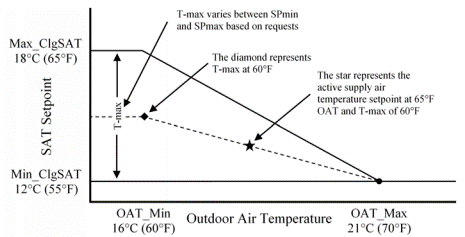


Figure 4.23.1: Example Supply Air Temperature Reset Diagram

Table 4.23.10: Trim & Response Variables – Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit Supply Air Temperature Reset

|  |  |  |
| --- | --- | --- |
| Variable | Definition | Sample Values |
| Device | Associated Device | Cooling Coil |
| SP0 | Initial T&R set point | SPmax (65°F) |
| SPmin | Minimum allowed T&R set point | Min\_ClgSAT (57 °F) |
| SPmax | Maximum allowed T&R set point | Max\_ClgSAT (65 °F) |
| Td | Delay timer | 20 minutes |
| T | Time step | 5 minutes |
| I | Number of ignored requests | 2 |
| R | Number of requests from downstream devices | (sum) |
| SPtrim | T&R set point trim amount (devices are satisfied) | +0.2°F |
| SPres | T&R set point response amount (devices are unsatisfied) | -0.3°F |
| SPrex-max | Max T&R set point response amount per time step | -1.0°F |

* + - 1. 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 4.23.1.
         1. Economizer damper maximum position MaxOA-P is limited for economizer high-limit lockout (see Section 4.5 H. 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 out-door air AFMS. It is not a valid choice if minimum out-door air control is being done by DP (i.e., if is being used).

Delete this flag note after selection has been made.

* + - * 1. 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 4.23 D and 4.23 E).
        2. 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 4.23 E. 4).
        3. The points of transition along the x-axis shown and described in Figure 4.23.1 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 4.23.1 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 4.23.2) Outdoor air and return air dampers are sequenced rather than complementary (as per traditional sequences) to reduce fan power at part loads.

2. Return-fan control with airflow tracking (Figure 4.23.3)

3. Return-fan control with direct building pressure controls (Figure 4.23.4)

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.

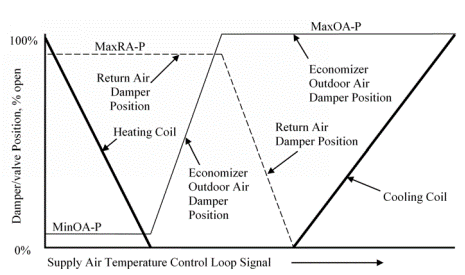


Figure 4.23.2 Supply Air Temperature Loop Mapping with Relief Damper or Relief Fan

The figure above does not illustrate the outdoor air damper position (MaxOA-P) going to minimum at the economizer lockout temperature. That occurrence is only based on the outside air temperature (dry-bulb); the SAT cooling loop does not depend on when that occurs.

Economizer high limit lockout setpoint is defined in Section 4.5 D. 3 Economizer High Limit.

Economizer lockout sequences are defined in Section 4.5 H. 1.

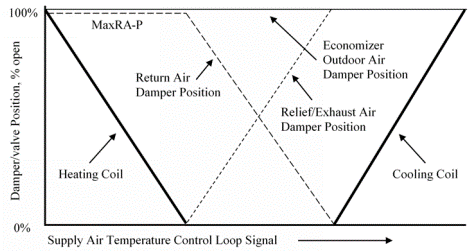


Figure 4.23.3 Supply Air Temperature Loop Mapping with Return Fan Control with Airflow Tracking

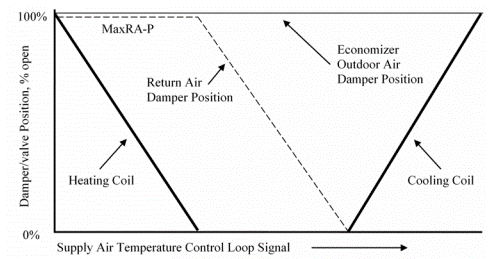


Figure 4.23.4 Supply Air Temperature Loop Mapping with Return Fan Control with Direct Building Pressure Controls

* + 1. 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 4.23 C. 1 and delete Section 4.23 C. 2.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.23 C. 2 and delete Section 4.23 C. 1.

* + - 1. Outdoor Airflow Set Point for ASHRAE Standard 62.1-2016 Ventilation CO2 DCV at the system level is not yet implemented for Standard 62.1 compliance, pending the results of RP-1747.
         1. See Section 4.8 A. 3. f for zone outdoor air requirement Voz.
         2. See Section 4.5 D. 2. a 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.

* + - * 1. 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 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.

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.

* + - * 1. 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.
        2. For each zone in occupied mode, calculate the zone primary outdoor air fraction Zpz:

Zpz = 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.

* + - * 1. Calculate the maximum zone outdoor air fraction Zp:

Zp = max(Zpz)

* + - * 1. Calculate the current system ventilation efficiency Ev:

Ev = 1 + (Vou/Vps) – Zp

* + - * 1. 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:

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.23 C. 2 and delete Section 4.23 C. 1.

• If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep 4.23 C. 1 and delete Section 4.23 C. 2.

* + - 1. Outdoor Airflow Set Point for California Title 24 Ventilation
         1. See Section 4.8 A. 4. bfor zone outdoor air rates Zone-Abs-OA-min and Zone-Des-OA-min.
         2. See Section 4.5 D. 2. b for set points AbsMinOA and DesMinOA.
         3. Effective outdoor air absolute minimum and design minimum set points are recalculated continuously based on the mode of the zones being served.

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.

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 4.23 C. 1 or Section 4.23 C. 2 should remain. The other sub-section 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 air-flow measurement station (AFMS)?

Control logic selections should be made as follows:

• For AHUs with separate dedicated dampers and OA measurement by ΔP, use Section 4.23 D and delete Sections 4.22 E and 4.23 F.

• For AHUs with separate dedicated dampers and OA measurement by AFMS, use Section 4.22 E and delete Sections 4.23 D and 4.23 F.

• For AHUs with a single common damper and OA measurement by AFMS, use Section 4.23 F and delete Sections 4.23 D and 4.23 E.

• 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.

* + 1. Minimum Outdoor Air Control with a Separate Minimum Outdoor Air Damper and Differential Pressure Control

The engineer must select between ventilation logic options:

• If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 4.22 D. 1 and delete Section 4.22 D. 2.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.22 D. 2 and delete Section 4.22 D. 1.

* + - 1. DP Set Point for ASHRAE Standard 62.1 Ventilation
         1. See Section 4.6 A. 5 for design OA DP set points.
         2. See Section 4.22 C. 1. c for calculation of current outdoor air set point MinOAsp.
         3. The minimum outdoor air DP set point MinDPsp shall be calculated as

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.22 D. 2 and delete Section 4.22 D. 1.

• If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 4.22 D. 1 and delete Section 4.22 D. 2.

* + - 1. DP set point for California Title 24 Ventilation
         1. See Section 4.6 A. 5 for design OA DP set points.
         2. See Section 4.22 C. 2. c for calculation of current set points AbsMinOA\* and DesMinOA\*.
         3. See zone CO2 control logic under terminal unit sequences.
         4. The active minimum DP set points AbsDPsp\* and DesD-Psp\* shall be determined by the following equations:

This equation prevents excess outdoor air from being sup-plied during periods of partial occupancy.

* + - * 1. The minimum outdoor air DP set point MinDPsp shall be reset based on the highest zone CO2 control-loop signal from AbsDPsp\* at 50% signal to DesDPsp\* at 100% signal.
        2. The minimum outdoor air set point MinOAsp shall be reset based on the highest zone CO2 control-loop signal from AbsMinOA\* at 50% signal to DesMinOA\* at 100% signal.

The requirement below was added to provide a quick way to check which zone is driving the minimum outdoor air DP set point.

* + - * 1. The control system shall identify the zone that corresponds to the maximum CO2 loop by the zone name or terminal unit number.

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

When the sequences are complete, only one of Section 4.22 D. 1 and Section 4.22 D. 2 should remain. The other section should be deleted along with these flag notes.

* + - 1. 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.
      2. Outdoor Air and Return Air Dampers
         1. For units with return fans

Minimum outdoor air control is enabled when return damper position exceeds MRA-P because it cannot be assumed that the combination of the minimum and the economizer outdoor air dampers are providing sufficient outdoor air under these conditions. The 20% threshold can be increased to ensure minimum outdoor airflow will be maintained but at the expense of fan energy. This threshold could be determined empirically during TAB work as well.

When the supply air fan is proven on and the system is in occupied mode and MinDPsp is greater than zero, the system shall calculate MRA-P. The value of MRA-P shall scale from 95% when supply fan speed is at 100% design speed proportionally down to 20% when the fan is at minimum speed. When MRA-P is not being calculated for any reason, it shall be set to 100%.

Minimum outdoor air control shall be enabled when the unit is in Occupied Mode and either of the following conditions are true for 10 minutes:

The economizer high limit conditions are exceeded.

When the minimum outdoor air damper is open and the return air damper position is greater than MRA-P.

When minimum outdoor air control is enabled, the normal sequencing of economizer outdoor air and return air dampers shall be suspended per the following sequence:

Fully open return air damper; and

Wait 15 seconds, then close the economizer outdoor air damper; and

Wait 3 minutes, then release return air damper position for control by the SAT control loop in Section 4.23 B. Economizer outdoor air damper remains closed.

The maximum return air damper position endpoint MaxRA-P shall be modulated from 100% to 0% to maintain DP across the minimum outdoor air damper at set point MinDPsp.

Minimum outdoor air control shall be disabled when the unit is no longer in Occupied Mode, or both of the following conditions are true for 10 minutes:

The economizer high limit conditions in 4.5 E. 2 are not exceeded.

The minimum outdoor air damper is closed or the return air damper position is 10% below MRA-P.

When minimum outdoor air control is disabled:

Economizer outdoor air damper shall be fully opened.

MaxRA-P shall be set to 100%.

Economizer and return air damper positions shall be controlled by the SAT control loop.

* + - * 1. For units with relief dampers or relief fans

Minimum outdoor air control is enabled when economizer damper position is less than MOA-P because it cannot be assumed that the combination of the minimum and the economizer outdoor air dampers are providing sufficient outdoor air under these conditions.

Minimum outdoor air control is disabled when return damper position is less than MRA-P, because the economizer damper has been closed to enable an accurate airflow measurement through the minimum outdoor air damper. The 20% and 80% thresholds can be increased/decreased to ensure minimum outdoor airflow will be maintained but at the expense of fan energy. This threshold could be determined empirically during TAB work as well.

When the supply air fan is proven on and the system is in occupied mode and MinDPsp is greater than zero, the system shall calculate MOA-P. The value of MOA-P shall scale from 5% when supply-fan speed is at 100% design speed proportionally up to 80% when the fan is at minimum speed. When MOA-P is not being calculated for any reason, it shall be set to 0%.

When the supply air fan is proven on and the system is in occupied mode and MinDPsp is greater than zero, the system shall calculate MRA-P. The value of MRA-P shall scale from 95% when supply fan speed is at 100% design speed proportionally down to 20% when the fan is at minimum speed. When MRA-P is not being calculated for any reason, it shall be set to 100%.

Minimum outdoor air control shall be enabled when the unit is in Occupied Mode and either of the following conditions are true for 10 minutes:

The economizer high limit conditions in Section 4.5 E. 2 are exceeded.

When the minimum outdoor air damper is open and the economizer outdoor air damper position is less than MOA-P.

When minimum outdoor air control is enabled, the normal sequencing of economizer outdoor air and return air dampers per Section 4.23 B shall be suspended per the following sequence:

Fully open return air damper; and

Wait 15 seconds, then close the economizer outdoor air damper; and

Wait 3 minutes, then release return air damper position for control by the SAT control loop in Section 4.23 B. Economizer outdoor air damper remains closed.

The maximum return air damper position endpoint MaxRA-P shall be modulated from 100% to 0% to maintain DP across the minimum outdoor air damper at set point MinDPsp.

Minimum outdoor air control shall be disabled when the unit is no longer in Occupied Mode, or both of the following conditions are true for 10 minutes:

The economizer high limit conditions are not exceeded.

The minimum outdoor air damper is closed or the return air damper position is 10% below MRA-P.

When minimum outdoor air control is disabled:

MaxRA-P shall be set to 100%.

b. Economizer and return air damper positions shall be controlled by the SAT control loop

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 air-flow measurement station (AFMS)?

Control logic selections should be made as follows:

• For AHUs with separate dedicated dampers and OA measurement by ΔP, use Section 4.23 D and delete Sections 4.22 E and 4.23 F.

• For AHUs with separate dedicated dampers and OA measurement by AFMS, use Section 4.22 E and delete Sections 4.23 D and 4.23 F.

• For AHUs with a single common damper and OA measurement by AFMS, use Section 4.23 F and delete Sections 4.23 D and 4.23 E.

• 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.

* + 1. Minimum Outdoor Air Control with a Separate Minimum Outdoor Air Damper 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 4.22 E. 1

and delete Section 4.22 E. 2.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.22 E. 2 and delete Section 4.22 E. 1.

* + - 1. Outdoor Airflow Set Point for ASHRAE Standard 62.1-2016 Ventilation
         1. See Section 4.22 C. 1. h for calculation of current outdoor air set point MinOAsp.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.22 E. 2 and delete Section 4.22 E. 1.

• If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 4.22 E. 1 and delete Section 4.22 E. 2.

* + - 1. Outdoor Airflow Set Point for California Title 24 Ventilation
         1. See Section 4.22 C. 2. c for calculation of current set points AbsMinOA\* and DesMinOA\*.
         2. See zone CO2 control logic under terminal unit sequences.
         3. See Section 4.22 D. 2. f for MinOAsp control logic.

This concludes the section where the ventilation logic option is selected. When the sequences are complete, only one of Section 4.22 E. 1 and Section 4.22 E. 2 should remain. The other section should be deleted along with these flag notes.

* + - 1. Minimum Outdoor Air Control Loop
         1. 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.
         2. 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%.
      2. Outdoor Air and Return Air Dampers
         1. For units with return air fans

Minimum outdoor air control is enabled when return damper position exceeds MRA-P because it cannot be assumed that the combination of the minimum and the economizer outdoor air dampers are providing sufficient outdoor air under these conditions. The 20% threshold can be increased to ensure minimum outdoor airflow will be maintained but at the expense of fan energy. This threshold could be determined empirically during TAB work as well.

When the supply air fan is proven on and the system is in occupied mode and MinOAsp is greater than zero, the system shall calculate MRA-P. The value of MRA-P shall scale from 95% when supply fan speed is at 100% design speed proportionally down to 20% when the fan is at minimum speed. When MRA-P is not being calculated for any reason, it shall be set to 100%.

Minimum outdoor air control shall be enabled when the unit is in Occupied Mode and either of the following conditions are true for 10 minutes:

The economizer high limit conditions are exceeded.

When the minimum outdoor air damper is open and the return air damper position is greater than MRA-P.

When minimum outdoor air control is enabled, the normal sequencing of economizer outdoor air and return air dampers per Section 4.23 B shall be suspended per the following sequence:

Fully open return air damper; and

Wait 15 seconds, then close the economizer outdoor air damper; and

Wait 3 minutes, then release return air damper position for control by the SAT control loop in Section 4.23 B. Economizer outdoor air damper remains closed.

The maximum return air damper position endpoint MaxRA-P shall be modulated from 100% to 0% to maintain airflow across the minimum outdoor air damper at set point MinOAsp.

Minimum outdoor air control shall be disabled when the unit is no longer in

Occupied Mode, or both of the following conditions are true for 10 minutes:

The economizer high limit conditions in Section 4.5 E. 2 are not exceeded.

The minimum outdoor air damper is closed or the return air damper position is 10% below MRA-P.

When minimum outdoor air control is disabled:

Economizer outdoor air damper shall be fully opened.

MaxRA-P shall be set to 100%.

Economizer and return air damper positions shall be controlled by the SAT control loop per Section 4.23 B.

* + - * 1. For units with relief dampers or relief fans

Minimum outdoor air control is enabled when economizer damper position is less than MOA-P because it cannot be assumed that the combination of the minimum and the economizer outdoor air dampers are providing sufficient outdoor air under these conditions.

Minimum outdoor air control is disabled when return damper position is less than MRA-P, because the economizer damper has been closed to enable an accurate airflow measurement through the minimum outdoor air damper.

The 20% and 80% thresholds can be increased/decreased to ensure minimum outdoor airflow will be maintained but at the expense of fan energy. This threshold could be determined empirically during TAB work as well.

When the supply air fan is proven on and the system is in occupied mode and MinOAsp is greater than zero, the system shall calculate MOA-P. The value of MOA-P shall scale from 5% when supply-fan speed is at 100% design speed proportionally up to 80% when the fan is at minimum speed. When MOA-P is not being calculated for any reason, it shall be set to 0%.

When the supply air fan is proven on and the system is in occupied mode and MinOAsp is greater than zero, the system shall calculate MRA-P. The value of MRA-P shall scale from 95% when supply fan speed is at 100% design speed proportionally down to 20% when the fan is at minimum speed. When MRA-P is not being calculated for any reason, it shall be set to 100%.

Minimum outdoor air control shall be enabled when the unit is in Occupied Mode and either of the following conditions are true for 10 minutes:

The economizer high limit conditions in Section 4.5 E. 2are exceeded.

When the minimum outdoor air damper is open and the economizer outdoor air damper position is less than MOA-P.

When minimum outdoor air control is enabled, the normal sequencing of economizer outdoor air and return air dampers per Section 4.23 B shall be suspended per the following sequence:

Fully open return air damper; and

Wait 15 seconds, then close the economizer outdoor air damper; and

Wait 3 minutes, then release return air damper position for control by the SAT control loop in Section 4.23 B. Economizer outdoor air damper remains closed.

The maximum return air damper position endpoint MaxRA-P shall be modulated from 100% to 0% to maintain airflow across the minimum outdoor air damper at set point MinOAsp.

Minimum outdoor air control shall be disabled when the unit is no longer in Occupied Mode, or both of the following conditions are true for 10 minutes:

The economizer high limit conditions in Section 4.5 E. 2 are not exceeded.

The minimum outdoor air damper is closed or the return air damper position is 10% below MRA-P.

When minimum outdoor air control is disabled:

MaxRA-P shall be set to 100%.

Economizer and return air damper positions shall be controlled by the SAT control loop per Section 4.23 B.

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 air-flow measurement station (AFMS)?

Control logic selections should be made as follows:

• For AHUs with separate dedicated dampers and OA measurement by ΔP, use Section 4.23 D and delete Sections 4.22 E and 4.23 F.

• For AHUs with separate dedicated dampers and OA measurement by AFMS, use Section 4.22 E and delete Sections 4.23 D and 4.23 F.

• For AHUs with a single common damper and OA measurement by AFMS, use Section 4.23 F and delete Sections 4.23 D and 4.23 E.

• 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.

* + 1. 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 4.22 F. 1 and delete Section 4.22 F. 2.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.22 F. 2 and delete Section 4.22 F. 1.

* + - 1. Outdoor Airflow Set Point for ASHRAE Standard 62.1-2016 Ventilation
         1. a. See Section 4.22 C. 1 for calculation of current outdoor air set point MinOAsp.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.22 F. 2 and delete Section 4.22 F. 1.

• If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 4.22 F. 1 and delete Section 4.22 F. 2.

* + - 1. Outdoor Airflow Set Point for California Title 24 Ventilation
         1. See Section 4.22 C. 2. c for calculation of current set points AbsMinOA\* and DesMinOA\*.
         2. See zone CO2 control logic under terminal unit sequences.
         3. See Section 4.22 D. 2. f for MinOAsp control logic.

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

When the sequences are complete, only one of Section 4.22 F. 1 and Section 4.22 F. 2 should remain. The other section should be deleted along with these flag notes.

* + - 1. Minimum Outdoor Air Control Loop
         1. 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.
         2. For units with return fans:

The following logic limits the return damper position to ensure that minimum outdoor air is maintained at all times, while the actual return damper position is modulated by the SAT control loop.

The outdoor airflow rate shall be maintained at the minimum outdoor damper outdoor airflow setpoint MinOAsp by a direct-acting control loop whose output is mapped to the return air damper maximum position endpoint MaxRA-P.

The following logic directly controls the return damper position to ensure that exactly the minimum outdoor air – and no more – is provided when economizer lockout conditions are exceeded. When economizer lockout no longer applies, return damper control reverts to the SAT control loop.

While the unit is in Occupied Mode, if the economizer high limit conditions are exceeded for 10 minutes, outdoor air shall be controlled to the minimum outdoor airflow. When this occurs, the normal sequencing of the return air damper by the SAT control loop is suspended, and the return air damper position shall be modulated directly to maintain measured airflow at MinOAsp (i.e. return damper position shall equal MaxRA-P). The economizer damper shall remain open.

If the economizer high limit conditions in Section 4.5 E. 2 are not exceeded for 10 minutes, or the unit is no longer in Occupied Mode, release return damper to control by the SAT control loop (i.e. return damper position is limited by MaxRA-P endpoint, but is not directly controlled to equal MaxRA-P).

* + - * 1. For units with relief dampers or relief fans:

The following logic limits the return and economizer damper positions to ensure that minimum outdoor air is maintained at all times, while the actual damper positions are modulated by the SAT control loop.

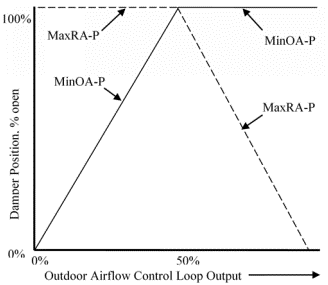
The outdoor airflow rate shall be maintained at the minimum outdoor air set point MinOAsp by a reverse-acting control loop whose output is mapped to economizer damper minimum position MinOA-P and return air damper maximum position MaxRA-P as indicated in Figure 4.23.5.

Figure 4.23.5: Minimum Outdoor Airflow Control Loop Mapping with a Single Damper

While the unit is in Occupied Mode, if the economizer high limit conditions are exceeded for 10 minutes, outdoor air shall be controlled to the minimum outdoor airflow. When this occurs, the normal sequencing of the return air damper by the SAT control loop is suspended:

Fully open return air damper

Wait 15 seconds, then set MaxOA-P equal to MinOA-P

Wait 3 minutes, then modulate return air damper to maintain measured airflow at MinOAsp (i.e. return damper position shall equal MaxRA-P).

If the economizer high limit conditions in Section 4.5 E. 2 are not exceeded for 10 minutes, or the unit is no longer in Occupied Mode, set MaxOA-P = 100% and release return damper to control by the SAT control loop (i.e. return damper position is limited by MaxRA-P endpoint, but is not directly controlled to equal MaxRA-P).

This concludes the section where the minimum outdoor air control logic is selected.

When the sequences are complete, only one of Section 4.23 D, 4.23 E, and 4.23 F should remain. The other two sections should be deleted along with these flag notes.

* + 1. Economizer High-Limit Lockout
       1. The normal sequencing of the economizer dampers in Sections 4.23 B through 4.23 F shall be disabled in accordance with Section 4.7 Q.
       2. When economizer is enabled, MaxOA-P = 100%.
       3. Once the economizer is disabled, it shall not be reenabled within 10 minutes, and vice versa.

Economizer high-limit lockout setpoint is defined in Section 4.5 E. 2.

* + - 1. When the economizer is disabled,
         1. return air damper shall be fully opened;
         2. wait 15 seconds, then set MaxOA-P equal to MinOA-P; and
         3. 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 without a fan, use Section 4.23 H and delete sections 4.23 I, 4.23 J, and 4.23 K.

• For AHUs using actuated relief dampers with relief fan(s), use Section 4.23 I and delete sections 4.23 H, 4.23 J, and 4.23 K.

• For AHUs using a return fan with direct building pressure control, use Section 4.23 J and delete sections 4.23 I, 4.23 H, and 4.23 K.

• For AHUs using a return fan with airflow tracking control, use section use Section 4.23 K and delete sections 4.23 I, 4.23 H, 4.23 J.

• For AHUs using non-actuated barometric relief only, delete all four Sections 4.23 H, 4.23 I, 4.23 J, and 4.23 K.

A building pressure sensor is required for options in Sections 4.23 H, 4.23 I, and 4.23 J.

* + 1. Control of Actuated Relief Dampers without Fans
       1. Relief dampers shall be enabled when the associated supply fan is proven ON, and disabled otherwise.
       2. When enabled, use a P-only control loop to modulate relief dampers to maintain 0.05 in. of water building static pressure. Close damper when disabled.
    2. 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.

* + - 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.
      2. A relief fan shall be enabled when its associated supply fan is proven ON, and shall be disabled otherwise.
      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.
      4. A P-only control loop maintains the building pressure at a set point of 0.05 in. of water with an out-put 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.

* + - 1. 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.
         1. 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.
         2. 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.
         3. 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).
      2. For fans in a Level 2 alarm and status is OFF, discharge damper shall be closed when stage is above Stage 0.
    1. Return-Fan Control—Direct Building Pressure
       1. Return fan operates whenever the associated supply fan is proven ON and shall be off otherwise.
       2. Return fans shall be controlled to maintain return-fan discharge static pressure at set point (Section 4.23 J. 5).
       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.
       4. Building static pressure shall be time aver-aged with a sliding 5-minute window (to dampen fluctuations). 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.

* + - 1. 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 4.23.6, to maintain the building pressure at a set point of 0.05 in. of water.
         1. From 0% to 50%, the building pressure control loop shall modulate the exhaust dampers from 0% to 100% open.
         2. 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 4.6 A. 4 for RFDSPmin and RFDSPmax.

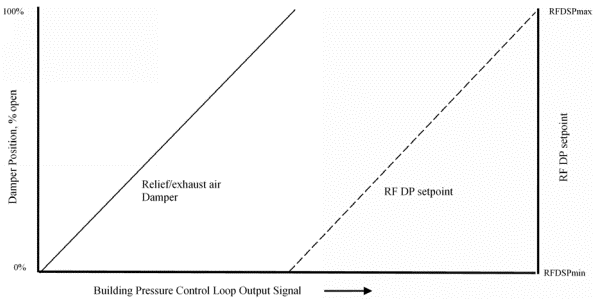


Figure 4.23.6 Exhaust Damper Position and Return Fan DP Reset Loop Mapping

* + 1. Return-Fan Control— Airflow Tracking
       1. Return fan operates whenever associated supply fan is proven ON.
       2. Return-fan speed shall be controlled to maintain return airflow equal to supply airflow less differential S-R-DIFF, as determined per Section 4.6 A. 5.
       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 4.23 B. 3

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 4.23 H, 4.23 I, 4.23 J, or 4.23 K 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.

* + 1. 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).

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 4.23 K but maintain the alarms. Delete this flag note when sequences are complete.

* + - 1. If the supply air temperature drops below 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 42°F. Disable this function when supply air temperature rises above 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.

* + - 1. If the supply air temperature drops below 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 4.23 K. 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 42°F]), after which one of three possibilities will occur:

a. If it is warm enough that the SAT rises above 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 38°F and 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.

* + - 1. Upon signal from the freeze-stat (if installed), or if supply air temperature drops below 38F) for 15 minutes or below 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 80°F, and set a Level 2 alarm indicating the unit is shut down by freeze protection.
         1. 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 work-station. (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 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.

* + 1. Alarms

Table 4.23.11 Alarm List – Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Level | Definition | Applicable Spec Section |
|  | Freeze Protection Stage 2 | 3 | When Freeze Protection Stage 2 Occurs | 4.22 K. 2 |
|  | Freeze Protection Stage 3 | 2 | When Freeze Protection Stage 3 Occurs | 4.22 K. 3 |
|  | Maintenance Interval | 4 | Accumulated maintenance run hours >1500 hours | 4.22 L. 1 |
|  | Fan Remains Off | 2 | Fan commanded ON, fan status OFF | 4.22 L. 2. a |
|  | Fan Remains On | 4 | Fan commanded OFF, fan status ON | 4.22 L. 2. b |
|  | High Filter Pressure Drop | 4 | See spec section, based on current speed and design high-limit. | 4.22 L. 3 |
|  | High Building Pressure | 3 | Building pressure greater than 0.10 in of w.c. | 4.22 L. 4 |
|  | Low Building Pressure | 4 | Building pressure less than 0.0 in. w.c. | 4.22 L. 5 |

* + - 1. Maintenance interval alarm when fan has operated for more than 1500 hours: Level 4. Reset interval count when alarm is acknowledged.
      2. Fan alarm is indicated by the status being different from the command for a period of 15 seconds.
         1. a. Commanded ON, status OFF: Level 2
         2. b. Commanded OFF, status ON: Level 4
      3. Filter pressure drop exceeds alarm limit or 0.05 in. of water for 10 minutes when airflow (expressed as a percentage of design airflow or design speed if total airflow if unknown) exceeds 20%: Level 4. The alarm limit shall vary with total airflow (if available; use fan speed if total airflow is not known) as follows:

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.

* + - 1. High building pressure (more than 0.10 in. of water) for 5 minutes: Level 3.
      2. Low building pressure less than 0.0 in. of water, i.e., negative for 5 minutes: Level 3.

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.

* + 1. 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.

* + - 1. AFDD conditions are evaluated continuously and separately for each operating AHU.
      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 4.23.12 and Figure 4.23.7.

Table 4.23.12 Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit 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, < 100% |
| #3 Mechanical + economizer cooling | = 0 | > 0 | = 100% |
| #4 Mechanical cooling, minimum OA | = 0 | > 0 | = min |
| #5 Unknown or dehumidification | No other OS Applies | | |

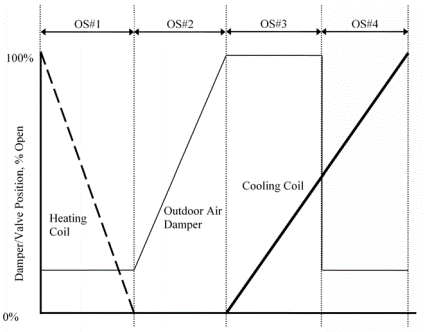


Figure 4.23.7: Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit Operating States

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 4.23.12) represent normal operation during which a fault may nevertheless occur if so determined by the fault condition tests in Section 0.

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.

* + - 1. 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.

* + - * 1. SAT = supply air temperature
        2. MAT = mixed air temperature
        3. RAT = return air temperature
        4. OAT = outdoor air temperature
        5. DSP = duct static pressure
        6. SATSP = supply air temperature set point
        7. DSPSP = duct static pressure set point
        8. HC = heating-coil valve position command; 0% ≤ HC ≤ 100%
        9. CC = cooling-coil valve position command; 0% ≤ CC ≤ 100%
        10. FS = fan speed command; 0% ≤ FS ≤ 100%
        11. CCET = cooling-coil entering temperature (Depending on the AHU configuration, this could be the MAT or a separate sensor for this specific purpose.)
        12. CCLT = cooling-coil leaving temperature (Depending on the AHU configuration, this could be the SAT or a separate sensor for this specific purpose.)
        13. HCET = heating-coil entering temperature (Depending on the AHU configuration, this could be the MAT or a separate sensor for this specific purpose.)
        14. HCLT = heating-coil leaving temperature (Depending on the AHU configuration, this could be the SAT or a separate sensor for this specific purpose.)
      1. The following values must be continuously calculated by the AFDD routines for each AHU:
         1. 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.

SATavg = rolling average of supply air temperature

MATavg = rolling average of mixed air temperature

RATavg = rolling average of return air temperature

OATavg = rolling average of outdoor air temperature

DSPavg = rolling average of duct static pressure

CCETavg = rolling average of cooling-coil entering temperature

CCLTavg = rolling average of cooling-coil leaving temperature

HCETavg = rolling average of heating-coil entering temperature

HCLTavg = rolling average of heating-coil leaving temperature

* + - * 1. %OA = actual outdoor air fraction as a percentage = (MAT – RAT)/(OAT – RAT), or per airflow measurement station if available.
        2. %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.
        3. OS = number of changes in operating state during the previous 60 minutes (moving window)
      1. The internal variables shown in Table 4.23.13 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 4.23 N. 12.

Table 4.23.13 Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit Internal Variables

|  |  |  |
| --- | --- | --- |
| Variable Name | Description | Default Value |
| ΔTSF | Temperature rise across supply fan | 1°F |
| ΔTmin | Minimum difference between OAT and RAT to evaluate economizer error conditions (FC#6) | 10°F |
| εSAT | Temperature error threshold for SAT sensor | 2°F |
| εRAT | Temperature error threshold for RAT sensor | 2°F |
| εMAT | Temperature error threshold for MAT sensor | 5°F |
| εOAT | Temperature error threshold for OAT sensor | 2°F if local to unit;  5°F if global sensor |
| εF | Airflow error threshold | 30% |
| εVFDSPD | VFD Speed Error Threshold | 5% |
| εDSP | DSP error threshold | 0.1 inch of water |
| εCCET | Cooling coil entering temperature sensor error; Either equals εMAT **OR** dedicated sensor error | Varies; see description |
| εCCLT | Cooling coil leaving temperature sensor error; Either equals εSAT **OR** dedicated sensor error |
| εHCET | Heating coil entering temperature sensor error; Either equals εMAT **OR** dedicated sensor error |
| εHCLT | Heating coil leaving temperature sensor error; Either equals εSAT **OR** dedicated sensor error |
| ΔOSmax | Maximum number of changes in Operating State during the previous 60 minutes (rolling/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 |

* + - 1. Table 4.23.14 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.

Table 4.23.14 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.

Omit FC-2, FC-3, FC-5, FC-8, FC-10, FC-12 if no MAT sensor is used

Table 4.23.14: Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit AHU Fault Conditions

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Fault Condition | Description | Equation(s) | Possible Diagnosis | Applicable Operating States | | | | | |
| 1 | 2 | 3 | 4 | 5 |
| Heating | Economizer Free Cooling | Economizer + Mech. Cooling | Mechanical Cooling | Unknown/ Dehumidifying |
| 1 | Duct static pressure too low with fan at full speed | **AND** | * Problem with VFD * Mechanical problem with fan * Fan undersized * SAT set point too high (too much zone demand) | X | X | X | X | X |
| 2 | MAT too low, should be between OAT & RAT |  | * RAT sensor error * MAT sensor error * OAT sensor error | X | X | X | X | X |
| 3 | MAT too high, should be between OAT & RAT |  | * RAT sensor error * MAT sensor error * OAT sensor error | X | X | X | X | X |
| 4 | Too many changes in operating state |  | * Unstable control due to poorly tuned loop or mechanical problem | X | X | X | X | X |
| 5 | SAT too low; should be higher than MAT |  | * 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 | X |  |  |  |  |
| 6 | OA fraction too low or too high; should equal %OAmin | **AND** | * RAT sensor error * MAT sensor error * OAT sensor error * Leaking or stuck economizer damper or actuator | X | X | X | X |  |
| 7 | SAT too low in full heating | **AND** | * 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 | X |  |  |  |  |
| 8 | SAT and MAT should be approximately equal when Free-Cooling |  | * SAT sensor error * MAT sensor error * Cooling-coil valve leaking or stuck open * Heating-coil valve leaking or stuck open |  | X |  |  |  |
| 9 | OAT too high for free cooling without additional mechanical cooling |  | * SAT sensor error * OAT sensor error * Cooling-coil valve leaking or stuck open |  | X |  |  |  |
| 10 | OAT and MAT should be approximately equal |  | * MAT sensor error * OAT sensor error * Leaking or stuck economizer damper or actuator |  |  | X |  |  |
| 11 | OAT too low for 100% OA cooling |  | * SAT sensor error * OAT sensor error * Heating-coil valve leaking or stuck open * Leaking or stuck economizer damper or actuator |  |  | X |  |  |
| 12 | SAT too high; should be less than MAT |  | * SAT sensor error * MAT sensor error * Cooling-coil valve stuck closed or actuator failure * Fouled or undersized cooling coil * CHW temperature too high or CHW unavailable * DX cooling unavailable * Gas or electric heat stuck ON * Heating-coil valve leaking or stuck open |  |  | X | X |  |
| 13 | SAT too high in full cooling | **AND** | * 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 |  |  | X | X |  |
| 14 | Temperature drop across inactive cooling coil | \*Omit the term if the fan is not located between the CCET and CCLT sensors. | * CCET sensor error * CCLT sensor error * Cooling-coil valve stuck open or leaking * DX cooling stuck on | X | X |  |  |  |
| 15 | Temperature rise across inactive heating coil | \*Omit the term if the fan is not located between the HCET and HCLT sensors. | * HCET sensor error * HCLT sensor error * Heating-coil valve stuck open or leaking. |  | X | X | X |  |
| Footnotes:  Variables that appear in this table are defined in Section 4.23 N. 2 and 4.23 N. 3.  Internal variables shall be programmed for each air handler, as defined in 4.23 N. 4. | | | | | | | | |

* + - 1. 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:
         1. In OS#1 (heating), the following fault conditions shall be evaluated:

FC#1: DSP too low with fan at full speed

FC#2: MAT too low; should be between RAT and OAT

FC#3: MAT too high; should be between RAT and OAT

FC#4: Too many changes in OS

FC#5: SAT too low; should be higher than MAT

FC#6: OA fraction too low or too high; should equal %OAmin

FC#7: SAT too low in full heating

FC#14: Temperature drop across inactive cooling coil

* + - * 1. In OS#2 (modulating economizer), the following fault conditions shall be evaluated:

FC#1: DSP too low with fan at full speed

FC#2: MAT too low; should be between RAT and OAT

FC#3: MAT too high; should be between RAT and OAT

FC#4: Too many changes in OS

FC#8: SAT and MAT should be approximately equal

FC#9: OAT too high for free cooling without mechanical cooling

FC#14: Temperature drop across inactive cooling coil

FC#15: Temperature rise across inactive heating coil

* + - * 1. In OS#3 (mechanical + 100% economizer cooling), the following fault conditions shall be evaluated:

FC#1: DSP too low with fan at full speed

FC#2: MAT too low; should be between RAT and OAT

FC#3: MAT too high; should be between RAT and OAT

FC#4: Too many changes in OS

FC#10: OAT and MAT should be approximately equal

FC#11: OAT too low for 100% OA

FC#12: SAT too high; should be less than MAT

FC#13: SAT too high in full cooling

FC#15: Temperature rise across inactive heating coil

* + - * 1. In OS#4 (mechanical Cooling, minimum OA), the following fault conditions shall be evaluated:

FC#1: DSP too low with fan at full speed

FC#2: MAT too low; should be between RAT and OAT

FC#3: MAT too high; should be between RAT and OAT

FC#4: Too many changes in OS

FC#6: OA fraction too low or too high; should equal %OAmin

FC#12: SAT too high; should be less than MAT

FC#13: SAT too high in full cooling

FC#15: Temperature rise across inactive heating coil

* + - * 1. In OS#5 (other), the following fault conditions shall be evaluated:

FC#1: DSP too low with fan at full speed

FC#2: MAT too low; should be between RAT and OAT

FC#3: MAT too high; should be between RAT and OAT

FC#4: Too many changes in OS

* + - 1. For each air handler, the operator shall be able to suppress the alarm for any fault condition.
      2. Evaluation of fault conditions shall be sus-pended under the following conditions:
         1. When AHU is not operating
         2. For a period of ModeDelay minutes following a change in mode (e.g., from warm-up to occupied) of any zone group served by the AHU
      3. Fault conditions that are not applicable to the current OS shall not be evaluated.
      4. A fault condition that evaluates as TRUE must do so continuously for AlarmDelay minutes before it is reported to the operator.
      5. 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.
      6. 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 0.
    1. Testing/Commissioning Overrides. Provide software switches that interlock to a CHW and hot-water plant level to
       - 1. force HW valve full open if there is a hot-water coil,
         2. force HW valve full closed if there is a hot-water coil,
         3. force CHW valve full open, and
         4. force CHW valve full closed.

Per Section 4.7 K, 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 4.10 E.

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.

* + 1. Plant Requests
       1. Chilled-Water Reset Requests
          1. If the supply air temperature exceeds the supply air temperature set point by 5°F for 2 minutes, send 3 requests.
          2. Else if the supply air temperature exceeds the supply air temperature set point by 3°F for 2 minutes, send 2 requests.
          3. 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.
       2. Chiller Plant Requests. Send the chiller plant that serves the system a chiller plant request as follows:
          1. If the CHW valve position is greater than 95%, send 1 request until the CHW valve position is less than 10%.
          2. Else if the CHW valve position is less than 95%, send 0 requests.
       3. If There Is a Hot-Water Coil, Hot-Water Reset Requests
          1. If the supply air temperature is 30°F less than set point for 5 minutes, send 3 requests.
          2. Else if the supply air temperature is 15°F less than set point for 5 minutes, send 2 requests.
          3. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
          4. Else if the HW valve position is less than 95%, send 0 requests.
       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:
          1. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.
          2. Else if the HW valve position is less than 95%, send 0 requests.

## Dual-Fan Dual-Duct Heating-Only Ventilating Air-Handling Unit

This section describes a heating-only air handler servicing the hot duct of a dual-duct air handling distribution system. The heating-only air handler also has an economizer capable of heating the air

Table 4.24.1 Dual-Fan, Dual Duct Heating-Only Ventilating Air Handling Unit – Hardware Points List

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Type | Device | Required |
|  | Exhaust Air Damper | AO |  | Define |
|  | Return Air Damper | AO |  | R |
|  | Econ OA Damper | AO |  | R |
|  | Min OA Damper | AO |  | R |
|  | Outdoor Air Temp | AI |  | R |
|  | Mixed Air Temp | AI |  | R |
|  | Return Air Temp | AI |  | R |
|  | Supply Air Temp | AI |  | R |
|  | Outside Air Flow | AI |  | R |
|  | Return Air Flow | AI |  | R |
|  | Supply Air Flow | AI |  | R |
|  | Supply Fan High Static | DI |  | R |
|  | Return Fan High Static | DI |  | R |
|  | Exhaust Fan High Static | DI |  | R |
|  | Duct Static Pressure | AI |  | R |
|  | Building Static Pressure | AI |  | R |
|  | Hot Deck Supply Fan VFD - Status | DI |  | R |
|  | Hot Deck Supply Fan VFD - Start | DO |  | R |
|  | Hot Deck Supply Fan VFD - Speed | AO |  | R |
|  | Hot Deck Return Fan VFD - Status | DI |  | Define |
|  | Hot Deck Return Fan VFD - Start | DO |  | Define |
|  | Hot Deck Return Fan VFD - Speed | AO |  | Define |
|  | Hot Deck Exhaust Fan VFD - Status | DI |  | Define |
|  | Hot Deck Exhaust Fan VFD - Start | DO |  | Define |
|  | Hot Deck Exhaust Fan VFD - Speed | AO |  | Define |
|  | Filter Differential Pressure | AI |  | R |
|  | Hot Water Coil Valve Position | AO |  | R |

Table 4.24.2 Dual-Fan, Dual Duct Heating-Only Ventilating Air Handling Unit – Software Points List (Excluding Ventilation)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Heating SAT Maximum | Max\_ClgSAT |  | § 4.5 F. 1. a | X | X |  |  | |
|  | Heating SAT Minimum | Min\_ClgSAT |  | § 4.5 F. 1. b | X | X |  |  | |
|  | Heating SAT OAT Max | OAT\_Max |  | § 4.5 F. 1. c | X | X |  |  | |
|  | Heating SAT OAT Min | OAT\_Min |  | § 4.5 F. 1. d | X | X |  |  | |
|  | Duct Design Maximum Static Pressure | Max\_DSP |  | §4.6 B. 1 | X | X |  | Field Measured | |
|  | Supply Fan – Minimum Speed |  |  | § 4.6 B. 2. a. i | X | X |  | Field Measured | |
|  | Return Fan – Minimum Speed |  |  | § 4.6 B. 2. a. ii | X | X |  | Remove if not present, Field Measured | |
|  | Relief Fan – Minimum Speed |  |  | § 4.6 B. 2. a. iii | X | X |  | Remove if not present, Field Measured | |
|  | Return Fan Discharge Static Pressure Setpoint, Minimum | RFDSPmin |  | § 4.6 B. 4. a | X | X |  | Field Measured, Remove if not used | |
|  | Return Fan Discharge Static Pressure Setpoint, Maximum | RFDSPmax |  | § 4.6 B. 4. b | X | X |  | Field Measured, Remove if not used | |
|  | Supply vs. Return Airflow Differential | S-R-DIFF |  | § 4.6 A. 5. a | X | X |  | Field Measured, Remove if not used | |
|  | System Mode |  |  | § 0 |  |  | X |  | |
|  | Totalized Airflow from VAVs | Vps |  | § 4.24 A. 1. c |  |  | X |  | |
|  | Duct Static Pressure Setpoint | DSP\_SP | in. w.c. | § 4.24 A. 2. a |  |  | X |  | |
|  | DSP SP Loop |  |  | § 4.24 A. 2. a |  |  | X |  | |
|  | DSP SP Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | DSP SP Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | DSP SP Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | DSP Minimum Setpoint | DSP\_SPmin | in. w.c. | Table 4.24.9 | X | X |  |  | |
|  | DSP Maximum Setpoint | DSP\_SPmax | in. w.c. | Table 4.24.9 |  |  | X | Equals Max\_DSP | |
|  | DSP Delay Timer | DSP\_Td | min. | Table 4.24.9 | X | X |  |  | |
|  | DSP Time Step | DSP\_T | min. | Table 4.24.9 | X | X |  |  | |
|  | DSP Ignored Requests Threshold | DSP\_I | - | Table 4.24.9 | X | X |  |  | |
|  | DSP Totalized Requests from VAVs | DSP\_R | - | Table 4.24.9 | X | X |  |  | |
|  | DSP Trim Amount | DSP\_SPtrim | in. w.c. | Table 4.24.9 | X | X |  |  | |
|  | DSP Respond Amount | DSP\_SPres | in. w.c. | Table 4.24.9 | X | X |  |  | |
|  | DSP Maximum Response | DSP\_SPres-max | in. w.c. | Table 4.24.9 | X | X |  |  | |
|  | Supply Air Temperature Setpoint | SAT\_SP | °F | § 4.24 B. 2 |  |  | X |  | |
|  | SAT SP Loop |  |  | § 4.24 B. 2 |  |  | X |  | |
|  | SAT SP Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | SAT SP Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | SAT SP Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | SAT Minimum Setpoint | SAT\_SPmin | °F | Table 4.24.10 | X | X |  |  | |
|  | SAT Maximum Setpoint | SAT\_SPmax | °F | Table 4.24.10 |  |  | X | Equals Max\_DSP | |
|  | SAT Delay Timer | SAT\_Td | min. | Table 4.24.10 | X | X |  |  | |
|  | SAT Time Step | SAT\_T | min. | Table 4.24.10 | X | X |  |  | |
|  | SAT Ignored Requests Threshold | SAT\_I | - | Table 4.24.10 | X | X |  |  | |
|  | SAT Totalized Requests from VAVs | SAT\_R | - | Table 4.24.10 | X | X |  |  | |
|  | SAT Trim Amount | SAT\_SPtrim | °F | Table 4.24.10 | X | X |  |  | |
|  | SAT Respond Amount | SAT\_SPres | °F | Table 4.24.10 | X | X |  |  | |
|  | SAT Maximum Response | SAT\_SPres-max | °F | Table 4.24.10 | X | X |  |  | |
|  | SAT Setback/Warm-up Setpoint |  | °F | Table 4.24.10 | X | X |  |  | |
|  | Return Air Damper Position SP | MaxRA-P | % | § **Error! Reference source not found.** |  |  | X |  | |
|  | Return Air Damper Position Loop |  |  | § **Error! Reference source not found.** |  |  | X |  | |
|  | Return Air Damper Position Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Return Air Damper Position Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Return Air Damper Position Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | Hot Water Reset Requests |  |  | § 4.24 O. 1 |  |  | X |  | |
|  | Hot Water Plant Requests |  |  | § 4.24 O. 2 |  |  | X |  | |

Table 4.24.3 Dual-Fan, Dual Duct Heating-Only Ventilating Air Handling Unit – ASHRAE 62.1/90.1 Ventilation Software Points

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Design Ventilation, Uncorrected | DesVou | cfm | § 4.5 D. 2. a. i | X | X |  | Include zone diversity | |
|  | Design Total Ventilation | DesVot | cfm | § 4.5 D. 2. a. ii | X | X |  | Adjusted DesVou for ventilation efficiency | |
|  | Economizer High Limit |  | °F | § 4.5 H. 1 | X | X |  |  | |
|  | Design Minimum OA Damper DP to Provide Min Outdoor Air Flow | DesMinDP | in w.c. | § 4.6 A. 3. a. i | X | X |  | Field Measured | |
|  | Minimum OA Damper Minimum Position | MinOA-P | % | §4.24 D | X | X |  |  | |
|  | Maximum RA Damper Position | MaxRA-P | % | § 4.24 D | X | X |  |  | |
|  | Occupied Uncorrected Outdoor Air Rate | Vou | cfm | § 4.24 C. 1. c |  |  | X |  | |
|  | Totalized Primary Airflow Rate | Vpz | cfm | § 4.24 C. 1. d |  |  | X |  | |
|  | Occupied Primary Airflow Fraction | Zpz | % | § 4.24 C. 1. e |  |  | X | For each zone | |
|  | Maximum Primary Airflow Fraction | Zp | % | § 4.24 C. 1. f |  |  | X |  | |
|  | System Ventilation Efficiency | Ev | - | § 4.24 C. 1. g |  |  | X |  | |
|  | Minimum Outside Airflow Setpoint | MinOAs | cfm | § 4.24 C. 1. h |  |  | X |  | |
|  | Min OA Flow SP Loop |  |  | § 4.24 D. 1. c |  |  | X |  | |
|  | Min OA Flow Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA Flow Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA Flow Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | Minimum Outdoor Air DP Setpoint | MinDPsp | in. w.c. | § 4.24 D. 1. c |  |  | X |  | |
|  | Min OA DP SP Loop |  |  | § 4.24 D. 1. c |  |  | X |  | |
|  | Min OA DP Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA DP Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA DP Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |

Table 4.24.4 Dual-Fan, Dual Duct Heating-Only Ventilating Air Handling Unit – Title 24 Ventilation Software Points

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Minimum Ventilation when Variable Ventilation Spaces are Unpopulated | AbsMinOA | cfm | 4.5 D. 2. b. i | X | X |  |  | |
|  | Design Minimum Outdoor Airflow at Design Population | DesMinOA | cfm | 4.5 D. 2. b. ii | X | X |  |  | |
|  | Economizer High Limit |  | °F | 4.5 H. 1 | X | X |  |  | |
|  | Minimum OA Damper DP to Provide Minimum Ventilation when Spaces are Unpopulated | AbsMinDP | in w.c. | 4.6 A. 3. b. i | X | X |  |  | |
|  | Minimum OA Damper DP to Provided Minimum Ventilation when at Design Population | DesMinDP | in w.c. | 4.6 A. 3. b. ii | X | X |  |  | |
|  | Current Absolute Minimum Ventilation Rate | AbsMinOA\* | cfm | § 4.24 C. 2. c. i |  |  | X |  | |
|  | Current Design Minimum Ventilation Rate | DesMinOA\* | cfm | § 4.24 C. 2. c. i |  |  | X |  | |
|  | Current Absolute Minimum Ventilation Rate Setpoint | AbsDPsp\* | in. w.c. | § 4.24 D. 2. d |  |  | X |  | |
|  | Current Design Minimum Ventilation Rate Setpoint | DesDPsp\* | in. w.c. | § 4.24 D. 2. d |  |  | X |  | |
|  | Minimum Outside Air DP Setpoint | MinDPsp | in. w.c. | § 4.24 D. 2. e |  |  | X |  | |
|  | Min OA DP SP Loop |  |  | § 4.22 D. 2. e |  |  | X |  | |
|  | Min OA DP Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA DP Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA DP Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | Minimum Outside Airflow Setpoint | MinOAsp | cfm | § 4.24 D. 2. f |  |  | X |  | |
|  | Min OA Flow SP Loop |  |  | § 4.24 D. 2. f |  |  | X |  | |
|  | Min OA Flow Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA Flow Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Min OA Flow Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | Highest Zone CO2 control-loop signal | MaxZnCO2 | - | § 4.24 D. 2. e |  |  | X |  | |
|  | Zone with Highest CO2 control-loop |  | - | § 4.24 D. 2. g |  |  | X |  | |

Table 4.24.5 Dual-Fan, Dual Duct Heating-Only Ventilating Air Handling Unit – Relief Damper Control without Relief Fans

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Building Static Pressure Setpoint |  | in. w.c. | § 4.24 H. 2 | X | X |  |  | |
|  | Building SP Setpoint Loop |  | - | § 4.24 H. 2 |  |  | X |  | |
|  | Building SP Setpoint Proportional Gain |  | - | § 4.7 H | X | X |  | No integral or derivative gain required. | |

Table 4.24.6 Dual-Fan, Dual Duct Heating-Only Ventilating Air Handling Unit – Relief Damper Control with Relief Fans

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Building Static Pressure Setpoint |  | in. w.c. | § 4.24 I. 4 | X | X |  |  | |
|  | Building SP Setpoint Loop |  | - | § 4.24 I. 4 |  |  | X |  | |
|  | Building SP Setpoint Proportional Gain |  | - | § 4.7 H | X | X |  | No integral or derivative gain required. | |
|  | Relief Fan Stage-Up Step |  | % | § 4.24 I. 5. b | X | X |  |  | |
|  | Relief Fan Stage-Up Interval |  | min. | § 4.24 I. 5. b | X | X |  |  | |
|  | Relief Fan Stage-Down Interval |  | min. | § 4.24 I. 5. c | X | X |  |  | |

Table 4.24.7 Dual-Fan, Dual Duct Heating-Only Ventilating Air Handling Unit – Relief Damper Control with Return Fan, Direct Pressure Control, and Actuated Relief Dampers

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Building Static Pressure Setpoint |  | in. w.c. | § 4.24 J. 4 | X | X |  |  | |
|  | Building SP Setpoint Loop |  | - | § 4.24 J. 4 |  |  | X |  | |
|  | Building SP Setpoint Proportional Gain |  | - | § 4.7 H | X | X |  | No integral or derivative gain required. | |
|  | Return Fan DP Setpoint |  |  | § 4.24 J. 2 |  |  | X |  | |
|  | Return Fan DP Control-Loop |  |  | § 4.24 J. 2 |  |  | X |  | |
|  | Return Fan DP Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Return Fan DP Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Return Fan DP Derivative Gain |  |  | § 4.7 H | X | X |  |  | |

Table 4.24.8 Dual-Fan, Dual Duct Heating-Only Ventilating Air Handling Unit – Relief Damper Control with Return Fan, Airflow Tracking, and Actuated Relief Dampers

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Return Fan Airflow Setpoint |  | cfm | § 4.24 K. 2 |  |  | X |  | |
|  | Return Fan Airflow Control-Loop |  | - | § 4.24 K. 2 |  |  | X |  | |
|  | Return Fan Airflow Proportional Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Return Fan Airflow Integral Gain |  | - | § 4.7 H | X | X |  |  | |
|  | Return Fan Airflow Derivative Gain |  | - | § 4.7 H | X | X |  |  | |

* + 1. Supply Fan Control
       1. Supply Fan Start/Stop
          1. Supply fan shall run when system is in the cooldown mode, setup mode, or occupied mode.
          2. If there are any VAV-reheat boxes on perimeter zone, 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 air flow monitoring station (AFMS).

* + - * 1. 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.

* + - 1. Static Pressure Set-Point Reset
         1. Static pressure set point. Set point shall be reset using T&R logic (see Section 4.7 N) using the parameters shown in Table 4.24.9. The T&R reset parameters in Table 4.24.9 are suggested as a starting point; they will most likely require adjustment during the commissioning/tuning phase.

Table 4.24.9: Trim & Response Variables – Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit Static Pressure Reset

|  |  |  |
| --- | --- | --- |
| Variable | Definition | Sample Values |
| Device | Associated Device | Supply Fan |
| SP0 | Initial T&R set point | 0.5 in. of water |
| SPmin | Minimum allowed T&R set point | 0.1 in. of water |
| SPmax | Maximum allowed T&R set point | Max\_DSP (~1.5 iwc) |
| Td | Delay timer | 20 minutes |
| T | Time step | 5 minutes |
| I | Number of ignored requests | 2 |
| R | Number of requests from downstream devices | (sum) |
| SPtrim | T&R set point trim amount (devices are satisfied) | -0.05 in. of water |
| SPres | T&R set point response amount (devices are unsatisfied) | +0.06 in. of water |
| SPrex-max | Max T&R set point response amount per time step | +0.13 in. of water |

* + - 1. Static Pressure Control
         1. 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.

* + 1. Supply Air Temperature Control
       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.
       2. Supply Air Temperature Set Point

If using this logic, the engineer should oversize interior zones and rooms with high heating loads (design them to be satisfied by the coolest SAT) so these zones do not drive the T&R block to the minimum SAT set point.

* + - * 1. See Section 4.5 F. 1 for Min\_HtgSAT, Max\_HtgSAT, OAT\_Min, and OAT\_Max set points.

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.

T-max shall be reset using T&R logic (see Section 4.7 N) between Min\_HtgSAT and Max\_HtgSAT.

The parameters shown in Table 4.24.10 are suggested as a starting place, but they will require adjustment during the commissioning/tuning phase.

* + - * 1. The net result of this SAT reset strategy is depicted in the Figure 4.23.1 for Min\_ HtgSAT = 55°F, Max\_ HtgSAT = 65°F, OAT\_Max = 70°F, and OAT\_Min = 60°F.
        2. During warm-up mode, set point shall be Max\_HtgSAT.



Figure 4.24.1: Example Supply Air Temperature Reset Diagram

Table 4.24.10: Trim & Response Variables – Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit Supply Air Temperature Reset

|  |  |  |
| --- | --- | --- |
| Variable | Definition | Sample Values |
| Device | Associated Device | Cooling Coil |
| SP0 | Initial T&R set point | SPmax (65°F) |
| SPmin | Minimum allowed T&R set point | Min\_ClgSAT (57 °F) |
| SPmax | Maximum allowed T&R set point | Max\_ClgSAT (65 °F) |
| Td | Delay timer | 20 minutes |
| T | Time step | 5 minutes |
| I | Number of ignored requests | 2 |
| R | Number of requests from downstream devices | (sum) |
| SPtrim | T&R set point trim amount (devices are satisfied) | +0.2°F |
| SPres | T&R set point response amount (devices are unsatisfied) | -0.3°F |
| SPrex-max | Max T&R set point response amount per time step | -1.0°F |

* + - 1. Supply air temperature shall be controlled to set point using a control loop whose output is mapped to sequence the, outdoor air damper, return air damper, and heatiing coil as shown in Figure 4.24.1.
         1. Economizer damper maximum position MaxOA-P is limited for economizer high-limit lockout (see Section 4.5 H. 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 out-door air AFMS. It is not a valid choice if minimum out-door air control is being done by DP (i.e., if is being used).

Delete this flag note after selection has been made.

* + - * 1. 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 4.24 D and 4.24 E).
        2. 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 0).
        3. The points of transition along the x-axis shown and described in Figure 4.24.1 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 4.24.1 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 4.23.2) Outdoor air and return air dampers are sequenced rather than complementary (as per traditional sequences) to reduce fan power at part loads.

2. Return-fan control with airflow tracking (Figure 4.23.3)

3. Return-fan control with direct building pressure controls (Figure 4.23.4)

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.

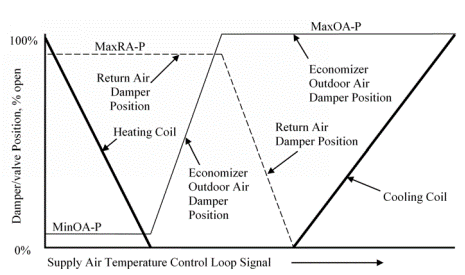


Figure 4.24.2 Supply Air Temperature Loop Mapping with Relief Damper or Relief Fan

The figure above does not illustrate the outdoor air damper position (MaxOA-P) going to minimum at the economizer lockout temperature. That occurrence is only based on the outside air temperature (dry-bulb); the SAT cooling loop does not depend on when that occurs.

Economizer high limit lockout setpoint is defined in Section 4.5 D. 3 Economizer High Limit.

Economizer lockout sequences are defined in Section 4.5 H. 1.

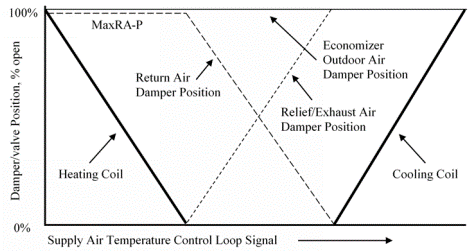


Figure 4.24.3 Supply Air Temperature Loop Mapping with Return Fan Control with Airflow Tracking

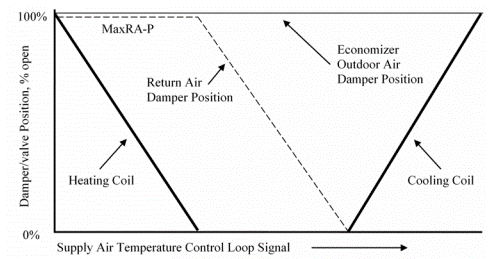


Figure 4.24.4 Supply Air Temperature Loop Mapping with Return Fan Control with Direct Building Pressure Controls

* + 1. 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 4.24 C. 1 and delete Section 4.24 C. 2.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.24 C. 2 and delete Section 4.24 C. 1.

* + - 1. Outdoor Airflow Set Point for ASHRAE Standard 62.1-2016 Ventilation CO2 DCV at the system level is not yet implemented for Standard 62.1 compliance, pending the results of RP-1747.
         1. See Section 4.8 A. 3. f for zone outdoor air requirement Voz.
         2. See Section 4.5 D. 2. a 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.

* + - * 1. 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 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.

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.

* + - * 1. 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.
        2. For each zone in occupied mode, calculate the zone primary outdoor air fraction Zpz:

Zpz = 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.

* + - * 1. Calculate the maximum zone outdoor air fraction Zp:

Zp = max(Zpz)

* + - * 1. Calculate the current system ventilation efficiency Ev:

Ev = 1 + (Vou/Vps) – Zp

* + - * 1. 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:

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.24 C. 2 and delete Section 4.24 C. 1.

• If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep 4.24 C. 1 and delete Section 4.24 C. 2.

* + - 1. Outdoor Airflow Set Point for California Title 24 Ventilation
         1. See Section 4.8 A. 4. bfor zone outdoor air rates Zone-Abs-OA-min and Zone-Des-OA-min.
         2. See Section 4.5 D. 2. b for set points AbsMinOA and DesMinOA.
         3. Effective outdoor air absolute minimum and design minimum set points are recalculated continuously based on the mode of the zones being served.

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.

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 4.24 C. 1 or Section 4.24 C. 2 should remain. The other sub-section 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 air-flow measurement station (AFMS)?

Control logic selections should be made as follows:

• For AHUs with separate dedicated dampers and OA measurement by ΔP, use Section 4.24 D and delete Sections 4.24 E and 0.

• For AHUs with separate dedicated dampers and OA measurement by AFMS, use Section 4.24 E and delete Sections 4.24 D and 0.

• For AHUs with a single common damper and OA measurement by AFMS, use Section 04.22 E. 4 and delete Sections 4.24 D and 4.24 E.

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.

* + 1. Minimum Outdoor Air Control with a Separate Minimum Outdoor Air Damper and Differential Pressure Control

The engineer must select between ventilation logic options:

• If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 4.24 D. 1 and delete Section 4.24 D. 2.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.24 D. 2 and delete Section 4.24 D. 1.

* + - 1. DP Set Point for ASHRAE Standard 62.1 Ventilation
         1. See Section 4.6 A. 5 for design OA DP set points.
         2. See Section 4.24 C. 2. c for calculation of current outdoor air set point MinOAsp.
         3. The minimum outdoor air DP set point MinDPsp shall be calculated as

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.24 D. 2 and delete Section 4.24 D. 1.

• If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 4.24 D. 1 and delete Section 4.24 D. 2.

* + - 1. DP set point for California Title 24 Ventilation
         1. See Section 4.6 A. 5 for design OA DP set points.
         2. See Section 4.24 C. 2. c for calculation of current set points AbsMinOA\* and DesMinOA\*.
         3. See zone CO2 control logic under terminal unit sequences.
         4. The active minimum DP set points AbsDPsp\* and DesD-Psp\* shall be determined by the following equations:

This equation prevents excess outdoor air from being sup-plied during periods of partial occupancy.

* + - * 1. The minimum outdoor air DP set point MinDPsp shall be reset based on the highest zone CO2 control-loop signal from AbsDPsp\* at 50% signal to DesDPsp\* at 100% signal.
        2. The minimum outdoor air set point MinOAsp shall be reset based on the highest zone CO2 control-loop signal from AbsMinOA\* at 50% signal to DesMinOA\* at 100% signal.

The requirement below was added to provide a quick way to check which zone is driving the minimum outdoor air DP set point.

* + - * 1. The control system shall identify the zone that corresponds to the maximum CO2 loop by the zone name or terminal unit number.

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

When the sequences are complete, only one of Section 4.24 D. 1 and Section 4.24 D. 2 should remain. The other section should be deleted along with these flag notes.

* + - 1. 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.
      2. Outdoor Air and Return Air Dampers
         1. For units with return fans

Minimum outdoor air control is enabled when return damper position exceeds MRA-P because it cannot be assumed that the combination of the minimum and the economizer outdoor air dampers are providing sufficient outdoor air under these conditions. The 20% threshold can be increased to ensure minimum outdoor airflow will be maintained but at the expense of fan energy. This threshold could be determined empirically during TAB work as well.

When the supply air fan is proven on and the system is in occupied mode and MinDPsp is greater than zero, the system shall calculate MRA-P. The value of MRA-P shall scale from 95% when supply fan speed is at 100% design speed proportionally down to 20% when the fan is at minimum speed. When MRA-P is not being calculated for any reason, it shall be set to 100%.

Minimum outdoor air control shall be enabled when the unit is in Occupied Mode and either of the following conditions are true for 10 minutes:

The economizer high limit conditions are exceeded.

When the minimum outdoor air damper is open and the return air damper position is greater than MRA-P.

When minimum outdoor air control is enabled, the normal sequencing of economizer outdoor air and return air dampers shall be suspended per the following sequence:

Fully open return air damper; and

Wait 15 seconds, then close the economizer outdoor air damper; and

Wait 3 minutes, then release return air damper position for control by the SAT control loop in Section 4.24 B Economizer outdoor air damper remains closed.

The maximum return air damper position endpoint MaxRA-P shall be modulated from 100% to 0% to maintain DP across the minimum outdoor air damper at set point MinDPsp.

Minimum outdoor air control shall be disabled when the unit is no longer in Occupied Mode, or both of the following conditions are true for 10 minutes:

The economizer high limit conditions in Section 4.5 F. 3 are not exceeded.

The minimum outdoor air damper is closed or the return air damper position is 10% below MRA-P.

When minimum outdoor air control is disabled:

Economizer outdoor air damper shall be fully opened.

MaxRA-P shall be set to 100%.

Economizer and return air damper positions shall be controlled by the SAT control loop.

* + - * 1. For units with relief dampers or relief fans

Minimum outdoor air control is enabled when economizer damper position is less than MOA-P because it cannot be assumed that the combination of the minimum and the economizer outdoor air dampers are providing sufficient outdoor air under these conditions.

Minimum outdoor air control is disabled when return damper position is less than MRA-P, because the economizer damper has been closed to enable an accurate airflow measurement through the minimum outdoor air damper. The 20% and 80% thresholds can be increased/decreased to ensure minimum outdoor airflow will be maintained but at the expense of fan energy. This threshold could be determined empirically during TAB work as well.

When the supply air fan is proven on and the system is in occupied mode and MinDPsp is greater than zero, the system shall calculate MOA-P. The value of MOA-P shall scale from 5% when supply-fan speed is at 100% design speed proportionally up to 80% when the fan is at minimum speed. When MOA-P is not being calculated for any reason, it shall be set to 0%.

When the supply air fan is proven on and the system is in occupied mode and MinDPsp is greater than zero, the system shall calculate MRA-P. The value of MRA-P shall scale from 95% when supply fan speed is at 100% design speed proportionally down to 20% when the fan is at minimum speed. When MRA-P is not being calculated for any reason, it shall be set to 100%.

Minimum outdoor air control shall be enabled when the unit is in Occupied Mode and either of the following conditions are true for 10 minutes:

The economizer high limit conditions in Section 4.5 F. 3 are exceeded.

When the minimum outdoor air damper is open and the economizer outdoor air damper position is less than MOA-P.

When minimum outdoor air control is enabled, the normal sequencing of economizer outdoor air and return air dampers per Section 4.24 B shall be suspended per the following sequence:

Fully open return air damper; and

Wait 15 seconds, then close the economizer outdoor air damper; and

Wait 3 minutes, then release return air damper position for control by the SAT control loop in Section 4.24 B. Economizer outdoor air damper remains closed.

The maximum return air damper position endpoint MaxRA-P shall be modulated from 100% to 0% to maintain DP across the minimum outdoor air damper at set point MinDPsp.

Minimum outdoor air control shall be disabled when the unit is no longer in Occupied Mode, or both of the following conditions are true for 10 minutes:

The economizer high limit conditions are not exceeded.

The minimum outdoor air damper is closed or the return air damper position is 10% below MRA-P.

When minimum outdoor air control is disabled:

MaxRA-P shall be set to 100%.

b. Economizer and return air damper positions shall be controlled by the SAT control loop

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 air-flow measurement station (AFMS)?

Control logic selections should be made as follows:

• For AHUs with separate dedicated dampers and OA measurement by ΔP, use Section 4.24 D and delete Sections 4.24 E and 0.

• For AHUs with separate dedicated dampers and OA measurement by AFMS, use Section 4.24 E and delete Sections 4.24 D and 0.

• For AHUs with a single common damper and OA measurement by AFMS, use Section 0 and delete Sections 4.24 D and 4.24 E.

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.

* + 1. Minimum Outdoor Air Control with a Separate Minimum Outdoor Air Damper 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 4.24 E. 1 and delete Section 4.24 E. 2.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.24 E. 1 and delete Section 4.24 E. 2.

* + - 1. Outdoor Airflow Set Point for ASHRAE Standard 62.1-2016 Ventilation
         1. See Section 4.24 C. 1. h for calculation of current outdoor air set point MinOAsp.

• If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 4.24 E. 1 and delete Section 4.24 E. 2.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 4.24 E. 1 and delete Section 4.24 E. 2.

* + - 1. Outdoor Airflow Set Point for California Title 24 Ventilation
         1. See Section 4.24 C. 2. c for calculation of current set points AbsMinOA\* and DesMinOA\*.
         2. See zone CO2 control logic under terminal unit sequences.
         3. The minimum outdoor air set point MinOAsp shall be reset based on the highest zone CO2 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 4.24 E. 1 and Section 4.24 E. 2 should remain. The other section should be deleted along with these flag notes.

* + - 1. Minimum Outdoor Air Control Loop
         1. 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.
         2. 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%.
      2. Outdoor Air and Return Air Dampers
         1. For units with return air fans

Minimum outdoor air control is enabled when return damper position exceeds MRA-P because it cannot be assumed that the combination of the minimum and the economizer outdoor air dampers are providing sufficient outdoor air under these conditions. The 20% threshold can be increased to ensure minimum outdoor airflow will be maintained but at the expense of fan energy. This threshold could be determined empirically during TAB work as well.

When the supply air fan is proven on and the system is in occupied mode and MinOAsp is greater than zero, the system shall calculate MRA-P. The value of MRA-P shall scale from 95% when supply fan speed is at 100% design speed proportionally down to 20% when the fan is at minimum speed. When MRA-P is not being calculated for any reason, it shall be set to 100%.

Minimum outdoor air control shall be enabled when the unit is in Occupied Mode and either of the following conditions are true for 10 minutes:

The economizer high limit conditions are exceeded.

When the minimum outdoor air damper is open and the return air damper position is greater than MRA-P.

When minimum outdoor air control is enabled, the normal sequencing of economizer outdoor air and return air dampers per Section 4.24 B shall be suspended per the following sequence:

Fully open return air damper; and

Wait 15 seconds, then close the economizer outdoor air damper; and

Wait 3 minutes, then release return air damper position for control by the SAT control loop in Section 4.24 B. Economizer outdoor air damper remains closed.

The maximum return air damper position endpoint MaxRA-P shall be modulated from 100% to 0% to maintain airflow across the minimum outdoor air damper at set point MinOAsp.

Minimum outdoor air control shall be disabled when the unit is no longer in

Occupied Mode, or both of the following conditions are true for 10 minutes:

The economizer high limit conditions in Section 4.5 F. 3 are not exceeded.

The minimum outdoor air damper is closed or the return air damper position is 10% below MRA-P.

When minimum outdoor air control is disabled:

Economizer outdoor air damper shall be fully opened.

MaxRA-P shall be set to 100%.

Economizer and return air damper positions shall be controlled by the SAT control loop per Section 4.24 B.

* + - * 1. For units with relief dampers or relief fans

Minimum outdoor air control is enabled when economizer damper position is less than MOA-P because it cannot be assumed that the combination of the minimum and the economizer outdoor air dampers are providing sufficient outdoor air under these conditions.

Minimum outdoor air control is disabled when return damper position is less than MRA-P, because the economizer damper has been closed to enable an accurate airflow measurement through the minimum outdoor air damper.

The 20% and 80% thresholds can be increased/decreased to ensure minimum outdoor airflow will be maintained but at the expense of fan energy. This threshold could be determined empirically during TAB work as well.

When the supply air fan is proven on and the system is in occupied mode and MinOAsp is greater than zero, the system shall calculate MOA-P. The value of MOA-P shall scale from 5% when supply-fan speed is at 100% design speed proportionally up to 80% when the fan is at minimum speed. When MOA-P is not being calculated for any reason, it shall be set to 0%.

When the supply air fan is proven on and the system is in occupied mode and MinOAsp is greater than zero, the system shall calculate MRA-P. The value of MRA-P shall scale from 95% when supply fan speed is at 100% design speed proportionally down to 20% when the fan is at minimum speed. When MRA-P is not being calculated for any reason, it shall be set to 100%.

Minimum outdoor air control shall be enabled when the unit is in Occupied Mode and either of the following conditions are true for 10 minutes:

The economizer high limit conditions in Section 4.5 F. 3 are exceeded.

When the minimum outdoor air damper is open and the economizer outdoor air damper position is less than MOA-P.

When minimum outdoor air control is enabled, the normal sequencing of economizer outdoor air and return air dampers per Section 4.24 B shall be suspended per the following sequence:

Fully open return air damper; and

Wait 15 seconds, then close the economizer outdoor air damper; and

Wait 3 minutes, then release return air damper position for control by the SAT control loop in Section 4.24 B. Economizer outdoor air damper remains closed.

The maximum return air damper position endpoint MaxRA-P shall be modulated from 100% to 0% to maintain airflow across the minimum outdoor air damper at set point MinOAsp.

Minimum outdoor air control shall be disabled when the unit is no longer in Occupied Mode, or both of the following conditions are true for 10 minutes:

The economizer high limit conditions in Section 4.5 F. 3 are not exceeded.

The minimum outdoor air damper is closed or the return air damper position is 10% below MRA-P.

When minimum outdoor air control is disabled:

MaxRA-P shall be set to 100%.

Economizer and return air damper positions shall be controlled by the SAT control loop per Section 4.24 B.

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 air-flow measurement station (AFMS)?

Control logic selections should be made as follows:

Control logic selections should be made as follows:

• For AHUs with separate dedicated dampers and OA measurement by ΔP, use Section 4.24 D and delete Sections 4.24 E and 0.

• For AHUs with separate dedicated dampers and OA measurement by AFMS, use Section 4.24 E and delete Sections 4.24 D and 0.

• For AHUs with a single common damper and OA measurement by AFMS, use Section 0 and delete Sections 4.24 D and 4.24 E.

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.

* + 1. 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 4.24 F. 1 and delete Section 0.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 0 and delete Section 4.24 F. 1.

* + - 1. Outdoor Airflow Set Point for ASHRAE Standard 62.1-2016 Ventilation
         1. a. See Section 4.24 C. 1 for calculation of current outdoor air set point MinOAsp.

• If the project is to comply with ASHRAE Standard 62.1 ventilation requirements, keep Section 4.24 F. 1 and delete Section 0.

• If the project is to comply with California Title 24 ventilation requirements, keep Section 0 and delete Section 4.24 F. 1.

* + - 1. Outdoor Airflow Set Point for California Title 24 Ventilation
         1. See Section 4.24 C. 2. c for calculation of current set points AbsMinOA\* and DesMinOA\*.
         2. See zone CO2 control logic under terminal unit sequences.
         3. The minimum outdoor air set point MinOAsp shall be reset based on the highest zone CO2 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 4.24 F. 1 or Section 0. should remain. The other section should be deleted along with these flag notes.

* + - 1. Minimum Outdoor Air Control Loop
         1. 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.
         2. For units with return fans:

The following logic limits the return damper position to ensure that minimum outdoor air is maintained at all times, while the actual return damper position is modulated by the SAT control loop.

The outdoor airflow rate shall be maintained at the minimum outdoor damper outdoor airflow setpoint MinOAsp by a direct-acting control loop whose output is mapped to the return air damper maximum position endpoint MaxRA-P.

The following logic directly controls the return damper position to ensure that exactly the minimum outdoor air – and no more – is provided when economizer lockout conditions are exceeded. When economizer lockout no longer applies, return damper control reverts to the SAT control loop.

While the unit is in Occupied Mode, if the economizer high limit conditions are exceeded for 10 minutes, outdoor air shall be controlled to the minimum outdoor airflow. When this occurs, the normal sequencing of the return air damper by the SAT control loop is suspended, and the return air damper position shall be modulated directly to maintain measured airflow at MinOAsp (i.e. return damper position shall equal MaxRA-P). The economizer damper shall remain open.

If the economizer high limit conditions in Section 4.5 F. 3 are not exceeded for 10 minutes, or the unit is no longer in Occupied Mode, release return damper to control by the SAT control loop (i.e. return damper position is limited by MaxRA-P endpoint, but is not directly controlled to equal MaxRA-P).

* + - * 1. For units with relief dampers or relief fans:

The following logic limits the return and economizer damper positions to ensure that minimum outdoor air is maintained at all times, while the actual damper positions are modulated by the SAT control loop.

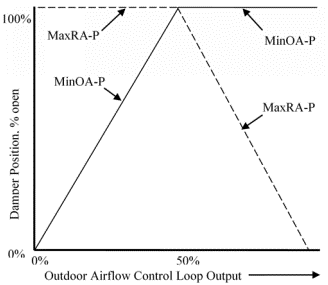
The outdoor airflow rate shall be maintained at the minimum outdoor air set point MinOAsp by a reverse-acting control loop whose output is mapped to economizer damper minimum position MinOA-P and return air damper maximum position MaxRA-P as indicated in Figure 4.24.5.

Figure 4.24.5: Minimum Outdoor Airflow Control Loop Mapping with a Single Damper

While the unit is in Occupied Mode, if the economizer high limit conditions are exceeded for 10 minutes, outdoor air shall be controlled to the minimum outdoor airflow. When this occurs, the normal sequencing of the return air damper by the SAT control loop is suspended:

Fully open return air damper

Wait 15 seconds, then set MaxOA-P equal to MinOA-P

Wait 3 minutes, then modulate return air damper to maintain measured airflow at MinOAsp (i.e. return damper position shall equal MaxRA-P).

If the economizer high limit conditions in Section 4.5 F. 3 are not exceeded for 10 minutes, or the unit is no longer in Occupied Mode, set MaxOA-P = 100% and release return damper to control by the SAT control loop (i.e. return damper position is limited by MaxRA-P endpoint, but is not directly controlled to equal MaxRA-P).

This concludes the section where the minimum outdoor air control logic is selected.

When the sequences are complete, only one of Section 4.24 D, 4.24 E, and 0 should remain. The other two sections should be deleted along with these flag notes.

* + 1. Economizer High-Limit Lockout
       1. The normal sequencing of the economizer dampers in Sections 4.24 B through 0 shall be disabled in accordance with Section 4.7 Q.
       2. When economizer is enabled, MaxOA-P = 100%.
       3. Once the economizer is disabled, it shall not be reenabled within 10 minutes, and vice versa.

Economizer high-limit lockout setpoint is defined in Section 4.5 F. 3.

* + - 1. When the economizer is disabled,
         1. return air damper shall be fully opened;
         2. wait 15 seconds, then set MaxOA-P equal to MinOA-P; and
         3. 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 4.24 H and delete sections 4.24 I, 4.24 J, and 4.24 K

• For AHUs using actuated relief dampers without a fan, use Section 4.24 I and delete sections 4.24 H, 4.24 J, and 4.24 K.

• For AHUs using a return fan with direct building pressure control, use Section 4.24 Jand delete Sections 4.24 I, 4.24 H, 4.24 K.

• For AHUs using a return fan with airflow tracking control, use section use Section 4.24 K and delete sections 4.24 I, 4.24 H, and 4.24 J.

• For AHUs using non-actuated barometric relief only, delete all four Sections 4.24 H, 4.24 I, 4.24 J, and 4.24 K.

A building pressure sensor is required for options in Sections 4.24 H, 4.24 I, 4.24 J.

* + 1. Control of Actuated Relief Dampers without Fans
       1. Relief dampers shall be enabled when the associated supply fan is proven ON, and disabled otherwise.
       2. When enabled, use a P-only control loop to modulate relief dampers to maintain 0.05 in. of water building static pressure. Close damper when disabled.
    2. 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.

* + - 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.
      2. A relief fan shall be enabled when its associated supply fan is proven ON, and shall be disabled otherwise.
      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.
      4. A P-only control loop maintains the building pressure at a set point of 0.05 in. of water with an out-put 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.

* + - 1. 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.
         1. 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.
         2. 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.
         3. 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).
      2. For fans in a Level 2 alarm and status is OFF, discharge damper shall be closed when stage is above Stage 0.
    1. Return-Fan Control—Direct Building Pressure
       1. Return fan operates whenever the associated supply fan is proven ON and shall be off otherwise.
       2. Return fans shall be controlled to maintain return-fan discharge static pressure at set point (Section 4.24 J. 5).
       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.
       4. Building static pressure shall be time aver-aged with a sliding 5-minute window (to dampen fluctuations). 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.

* + - 1. 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 4.24.6, to maintain the building pressure at a set point of 0.05 in. of water.
         1. From 0% to 50%, the building pressure control loop shall modulate the exhaust dampers from 0% to 100% open.
         2. 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 4.6 A. 4 for RFDSPmin and RFDSPmax.

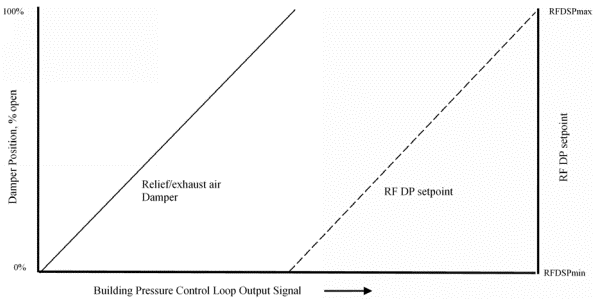


Figure 4.24.6 Exhaust Damper Position and Return Fan DP Reset Loop Mapping

* + 1. Return-Fan Control— Airflow Tracking
       1. Return fan operates whenever associated supply fan is proven ON.
       2. Return-fan speed shall be controlled to maintain return airflow equal to supply airflow less differential S-R-DIFF, as determined per Section 4.6 A. 5.
       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 4.24 B. 3.

Airflow tracking requires a measurement of supply airflow and return airflow. AFMS at both fans 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 4.24 H, 4.24 I, 4.24 J, and 4.24 K 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.

* + 1. Alarms

Table 4.24.11 Alarm List – Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Level | Definition | Applicable Spec Section |
|  | Maintenance Interval | 4 | Accumulated maintenance run hours >1500 hours | 4.24 L. 1 |
|  | Fan Remains Off | 2 | Fan commanded ON, fan status OFF | 4.24 L. 2. a |
|  | Fan Remains On | 4 | Fan commanded OFF, fan status ON | 4.24 L. 2. b |
|  | High Filter Pressure Drop | 4 | See spec section, based on current speed and design high-limit. | 4.24 L. 3 |
|  | High Building Pressure | 3 | Building pressure greater than 0.10 in of w.c. | 4.24 L. 4 |
|  | Low Building Pressure | 4 | Building pressure less than 0.0 in. w.c. | 4.24 L. 5 |

* + - 1. Maintenance interval alarm when fan has operated for more than 1500 hours: Level 4. Reset interval count when alarm is acknowledged.
      2. Fan alarm is indicated by the status being different from the command for a period of 15 seconds.
         1. a. Commanded ON, status OFF: Level 2
         2. b. Commanded OFF, status ON: Level 4
      3. Filter pressure drop exceeds alarm limit or 0.05 in. of water for 10 minutes when airflow (expressed as a percentage of design airflow or design speed if total airflow if unknown) exceeds 20%: Level 4. The alarm limit shall vary with total airflow (if available; use fan speed if total airflow is not known) as follows:

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.

* + - 1. High building pressure (more than 0.10 in. of water) for 5 minutes: Level 3.
      2. Low building pressure less than 0.0 in. of water, i.e., negative for 5 minutes: Level 3.

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.

* + 1. 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.

* + - 1. AFDD conditions are evaluated continuously and separately for each operating AHU.
      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 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.

* + - * 1. SAT = supply air temperature
        2. MAT = mixed air temperature
        3. RAT = return air temperature
        4. OAT = outdoor air temperature
        5. DSP = duct static pressure
        6. SATSP = supply air temperature set point
        7. DSPSP = duct static pressure set point
        8. HC = heating-coil valve position command; 0% ≤ HC ≤ 100%
        9. FS = fan speed command; 0% ≤ FS ≤ 100%
        10. HCET = heating-coil entering temperature (Depending on the AHU configuration, this could be the MAT or a separate sensor for this specific purpose.)
        11. HCLT = heating-coil leaving temperature (Depending on the AHU configuration, this could be the SAT or a separate sensor for this specific purpose.)
      1. The following values must be continuously calculated by the AFDD routines for each AHU:
         1. 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.

SATavg = rolling average of supply air temperature

MATavg = rolling average of mixed air temperature

RATavg = rolling average of return air temperature

OATavg = rolling average of outdoor air temperature

DSPavg = rolling average of duct static pressure

HCETavg = rolling average of heating-coil entering temperature

HCLTavg = rolling average of heating-coil leaving temperature

* + - * 1. %OA = actual outdoor air fraction as a percentage = (MAT – RAT)/(OAT – RAT), or per airflow measurement station if available.
        2. %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.
        3. OS = number of changes in operating state during the previous 60 minutes (moving window)
      1. The internal variables shown in Table 4.24.13 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 4.24 M. 10.

Table 4.24.12 Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit Internal Variables

|  |  |  |
| --- | --- | --- |
| Variable Name | Description | Default Value |
| ΔTSF | Temperature rise across supply fan | 1°F |
| ΔTmin | Minimum difference between OAT and RAT to evaluate economizer error conditions (FC#6) | 10°F |
| εSAT | Temperature error threshold for SAT sensor | 2°F |
| εRAT | Temperature error threshold for RAT sensor | 2°F |
| εMAT | Temperature error threshold for MAT sensor | 5°F |
| εOAT | Temperature error threshold for OAT sensor | 2°F if local to unit;  5°F if global sensor |
| εF | Airflow error threshold | 30% |
| εVFDSPD | VFD Speed Error Threshold | 5% |
| εDSP | DSP error threshold | 0.1 inch of water |
| εHCET | Heating coil entering temperature sensor error; Either equals εMAT **OR** dedicated sensor error |  |
| εHCLT | Heating coil leaving temperature sensor error; Either equals εSAT **OR** dedicated sensor error |
| 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 |

* + - 1. Table 4.24.13 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 4.24.13 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 #6 through #7 at a minimum. Other Title 24 AFDD requirements, including acceptance tests, are not met through these fault conditions.

Omit FC-2, FC-3, FC-6, FC-7 if no MAT sensor is used

Table 4.24.13: Dual-Fan, Dual Duct Cooling-Only Ventilating Air Handling Unit AHU Fault Conditions

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Fault Condition | Description | Equation(s) | Possible Diagnosis | Applicable Operating States | | | | | |
| 1 | 2 | 3 | 4 | 5 |
| Heating | Economizer Free Cooling | Economizer + Mech. Cooling | Mechanical Cooling | Unknown/ Dehumidifying |
| 1 | Duct static pressure too low with fan at full speed | **AND** | * Problem with VFD * Mechanical problem with fan * Fan undersized * SAT set point too high (too much zone demand) | X | X | X | X | X |
| 2 | MAT too low, should be between OAT & RAT |  | * RAT sensor error * MAT sensor error * OAT sensor error | X | X | X | X | X |
| 3 | MAT too high, should be between OAT & RAT |  | * RAT sensor error * MAT sensor error * OAT sensor error | X | X | X | X | X |
| 4 | OA fraction too low or too high; should equal %OAmin | **AND** | * RAT sensor error * MAT sensor error * OAT sensor error * Leaking or stuck economizer damper or actuator | X | X | X | X | X |
| 5 | SAT too low in full heating | **AND** | * 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 | X | X | X | X | X |
| 6 | SAT too low; should be greater than MAT |  | * SAT sensor error * MAT 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 | X | X | X | X | X |
| 7 | Temperature rise across inactive Heating coil | **AND** | * HCET sensor error * HCLT sensor error * Heating-coil valve stuck open or leaking * Gas or electric heat stuck ON | X | X | X | X | X |
| Footnotes:  Variables that appear in this table are defined in Section 4.24 M. 2 and 4.24 M. 3.  Internal variables shall be programmed for each air handler, as defined in 4.24 M. 4. | | | | | | | | |

* + - 1. For each air handler, the operator shall be able to suppress the alarm for any fault condition.
      2. Evaluation of fault conditions shall be sus-pended under the following conditions:
         1. When AHU is not operating
         2. For a period of ModeDelay minutes following a change in mode (e.g., from warm-up to occupied) of any zone group served by the AHU
      3. Fault conditions that are not applicable to the current OS shall not be evaluated.
      4. A fault condition that evaluates as TRUE must do so continuously for AlarmDelay minutes before it is reported to the operator.
      5. 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.
      6. 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 0.
    1. Testing/Commissioning Overrides. Provide software switches that interlock to a hot-water plant level to
       - 1. force HW valve full open if there is a hot-water coil,
         2. force HW valve full closed if there is a hot-water coil,

Per Section 4.7 K, 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 4.10 E.

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.

* + 1. Plant Requests
       1. If There Is a Hot-Water Coil, Hot-Water Reset Requests
          1. If the supply air temperature is 30°F less than set point for 5 minutes, send 3 requests.
          2. Else if the supply air temperature is 15°F less than set point for 5 minutes, send 2 requests.
          3. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
          4. Else if the HW valve position is less than 95%, send 0 requests.
       2. 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:
          1. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.
          2. Else if the HW valve position is less than 95%, send 0 requests.

## Dual-Fan Dual-Duct Heating-Only, Recirculating Air-Handling Unit

This section describes a heating-only air handler servicing the hot duct of a dual-duct air handling distribution system. The heating-only air handler does not ventilate the space, it only recirculates air from the return air plenum.

Table 4.25.1 Dual-Duct, Dual-Fan Heating-Only, Recirculating Air Handling Unit – Hardware Points List

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Type | Device | Required |
|  | Return Air Temperature | AI |  |  |
|  | Filter DP | AI |  |  |
|  | Hot Water Valve | AO |  |  |
|  | Hot Duct Fan VFD - Status | DI |  | R |
|  | Hot Duct Fan VFD - Start | DO |  | R |
|  | Hot Duct Fan VFD - Speed | AO |  | R |
|  | Hot Duct Fan High Static | DO |  |  |
|  | Hot Duct Supply Temperature | AI |  |  |
|  | Hot Duct Static Pressure | AI |  |  |

Table 4.25.2 Dual-Duct, Dual-Fan Heating-Only, Recirculating Air Handling Unit – Software Points List

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Duct Design Maximum Static Pressure | Max\_DSP |  | § 4.6 A. 1 | X | X |  | Field Measured | |
|  | Supply Fan – Minimum Speed |  |  | § 4.6 A. 2. a. i | X | X |  | Field Measured | |
|  | System Mode |  |  | § 4.21 A |  |  | X |  | |
|  | Totalized Airflow from VAVs | Vps |  | § 4.25 A. 1. b |  |  | X |  | |
|  | Hot Duct Static Pressure Setpoint |  | in. w.c. | § 4.25 A. 2. a |  |  | X |  | |
|  | Hot DSP SP Loop |  |  | § 4.25 A. 2. a |  |  | X |  | |
|  | Hot DSP SP Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Hot DSP SP Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Hot DSP SP Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | Hot DSP Minimum Setpoint | DSP\_SPmin | in. w.c. | Table 4.25.3 | X | X |  |  | |
|  | Hot DSP Maximum Setpoint | DSP\_SPmax | in. w.c. | Table 4.25.3 |  |  | X | Equals Max\_DSP | |
|  | Hot DSP Delay Timer | DSP\_Td | min. | Table 4.25.3 | X | X |  |  | |
|  | Hot DSP Time Step | DSP\_T | min. | Table 4.25.3 | X | X |  |  | |
|  | Hot DSP Ignored Requests Threshold | DSP\_I | - | Table 4.25.3 | X | X |  |  | |
|  | Hot DSP Totalized Requests from VAVs | DSP\_R | - | Table 4.25.3 | X | X |  |  | |
|  | Hot DSP Trim Amount | DSP\_SPtrim | in. w.c. | Table 4.25.3 | X | X |  |  | |
|  | Hot DSP Respond Amount | DSP\_SPres | in. w.c. | Table 4.25.3 | X | X |  |  | |
|  | Hot DSP Maximum Response | DSP\_SPres-max | in. w.c. | Table 4.25.3 | X | X |  |  | |
|  | Hot Duct Air Temperature Setpoint |  | °F | § 4.25 B. 2 |  |  | X |  | |
|  | HDAT SP Loop |  |  | § .22 B. 2 |  |  | X |  | |
|  | HDAT SP Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | HDAT SP Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | HDAT SP Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally Not Used | |
|  | HDAT Minimum Setpoint | HDAT\_SPmin | °F | Table 4.25.4 | X | X |  |  | |
|  | HDAT Maximum Setpoint | HDAT\_SPmax | °F | Table 4.25.4 |  |  | X | Equals Max\_DSP | |
|  | HDAT Delay Timer | HDAT\_Td | min. | Table 4.25.4 | X | X |  |  | |
|  | HDAT Time Step | HDAT\_T | min. | Table 4.25.4 | X | X |  |  | |
|  | HDAT Ignored Requests Threshold | HDAT\_I | - | Table 4.25.4 | X | X |  |  | |
|  | HDAT Totalized Requests from VAVs | HDAT\_R | - | Table 4.25.4 | X | X |  |  | |
|  | HDAT Trim Amount | HDAT\_SPtrim | °F | Table 4.25.4 | X | X |  |  | |
|  | HDAT Respond Amount | HDAT\_SPres | °F | Table 4.25.4 | X | X |  |  | |
|  | HDAT Maximum Response | HDAT\_SPres-max | °F | Table 4.25.4 | X | X |  |  | |
|  | Hot Water Reset Requests |  |  | § 4.25 F. 1 |  |  | X |  | |
|  | Hot Water Plant Requests |  |  | § 4.25 F. 2 |  |  | X |  | |

* + 1. Supply Fan Control
       1. Supply Fan Start/Stop
          1. 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.

* + - * 1. 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.
      1. Static Pressure Set-Point Reset
         1. Static pressure set point. Set point shall be reset using T&R logic (see Section 4.7N) using the parameters in Table 4.25.3. The T&R reset parameters in Table 4.25.3 are suggested as a starting place; they will most likely require adjustment during the commissioning/tuning phase.
      2. Static Pressure Control
         1. 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 FSD designs, the dampers are interlocked to the fan status rather than being controlled by smoke detectors).

Table 4.25.3 Dual-Duct, Dual-Fan Heating-Only, Recirculating Air Handling Unit Static Pressure T&R Reset

|  |  |  |
| --- | --- | --- |
| Variable | Definition | Sample Values |
| Device | Associated Device | Hot Deck Supply Fan |
| SP0 | Initial T&R set point | 0.5 inches water column |
| SPmin | Minimum allowed T&R set point | 0.1 inches water column |
| SPmax | Maximum allowed T&R set point | Max\_DSP (~1.5 iwc) |
| Td | Delay timer | 20 min |
| T | Time step | 5 min |
| I | Number of ignored requests | 2 |
| R | Number of requests from downstream devices | (sum) |
| SPtrim | T&R set point trim amount (devices are satisfied) | -0.05 inches water column |
| SPres | T&R set point response amount (devices are unsatisfied) | +0.06 inches water column |
| SPres-max | Max T&R set point response amount per time step | +0.13 inches water column |

* + 1. Supply Air Temperature Control
       1. Control loop is enabled when the supply air fan is proven ON and disabled and output set to zero otherwise.
       2. Supply Air Temperature Set Point
          1. During occupied mode (Table 4.25.4). Set point shall be reset using T&R logic (see Section 4.7N) between 70°F and Max\_HtgSAT. See Section 4.5 E. 1 for Max\_HtgSAT.

The T&R reset parameters in Table Table 4.25.4 are suggested as a starting place; they will most likely require adjustment during the commissioning/tuning phase.

* + - * 1. During warm-up and setback modes. Set point shall be Max\_HtgSAT.
      1. Supply air temperature shall be maintained at set point by a PID loop modulating the heating coil.

Table 4.25.4 Dual-Duct, Dual-Fan Heating-Only, Recirculating Air Handling Unit Air Temperature T&R Reset

|  |  |  |
| --- | --- | --- |
| Variable | Definition | Sample Value |
| Device | Associated Device | Hot Deck Heating Coil |
| SP0 | Initial T&R set point | SPmax (~100 °F) |
| SPmin | Minimum allowed T&R set point | 70°F |
| SPmax | Maximum allowed T&R set point | Max\_HtgSAT (~100 °F) |
| Td | Delay timer | 20 min |
| T | Time step | 5 min |
| I | Number of ignored requests | 2 |
| R | Number of requests from downstream devices | (sum) |
| SPtrim | T&R set point trim amount (devices are satisfied) | -0.4°F |
| SPres | T&R set point response amount (devices are unsatisfied) | +0.6°F |
| SPres-max | Max T&R set point response amount per time step | +1.4°F |

* + 1. Alarms

Table 4.25.5 Alarm List - Dual-Duct, Dual-Fan Heating-Only, Recirculating Air Handling Unit

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Level | Definition | Applicable Spec Section |
| 1 | Maintenance Interval | 4 | Accumulated maintenance run hours >1500 hours | 4.25 C. 1 |
| 2 | Hot Duct Fan Remains Off | 2 | Fan commanded ON, fan status OFF | 4.25 C. 2. a |
| 3 | Hot Duct Fan Remains On | 4 | Fan commanded OFF, fan status ON | 4.25 C. 2. b |
| 4 | Hot duct Filter Pressure Drop | 4 | See spec section, based on current speed and design high-limit. | 4.25 C. 3 |
| 5 | High Building Pressure | 3 | Building pressure greater than 0.10 in of w.c. | 4.25 C. 4 |
| 6 | Low Building Pressure | 4 | Building pressure less than 0.0 in. w.c. | 4.25 C. 5 |

* + - 1. Maintenance interval alarm when fan has operated for more than 1500 hours: Level 4. Reset interval counter when alarm is acknowledged.
      2. Fan alarm is indicated by the status being different from the command for a period of 15 seconds.
         1. Commanded ON, status OFF: Level 2
         2. Commanded OFF, status ON: Level 4
      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:

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.

* + - 1. High building pressure (more than 0.10 in. of water): Level 3.
      2. Low building pressure (less than 0 Pa [0.0 in. of water], i.e., negative): Level 4.
    1. 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 4.22 M and 4.26 O.

* + - 1. AFDD conditions are evaluated continuously and separately for each operating AHU.
      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.
         1. SAT = supply air temperature
         2. RAT = return air temperature
         3. DSP = duct static pressure
         4. SATSP = supply air temperature set point
         5. DSPSP = duct static pressure set point
         6. HC = heating coil valve position command; 0% ≤ HC ≤ 100%
         7. FS = fan speed command; 0% ≤ FS ≤ 100%
      3. The following values must be continuously calculated by the AFDD routines for each AHU:
         1. 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
         2. SATavg = rolling average of supply air temperature
         3. RATavg = rolling average of return air temperature
         4. DSPavg = rolling average of duct static pressure
      4. The internal variables shown in Table 4.25.6 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.

* + - 1. Table 4.25.7 shows potential fault conditions that can be evaluated by the AFDD routines. If the equation statement is TRUE, then the specified fault condition exists.

Table 4.25.6: Dual-Duct, Dual-Fan Heating-Only, Recirculating Air Handling Unit AFDD Internal Variables

|  |  |  |
| --- | --- | --- |
| Variable Name | Description | Default Value |
| ΔTSF | Temperature rise across supply fan | 1°F |
| εSAT | Temperature error threshold for SAT sensor | 2°F |
| εRAT | Temperature error threshold for RAT sensor | 2°F |
| εVFDSPD | VFD Speed Error Threshold | 5% |
| εDSP | DSP error threshold | 0.1 inch 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 4.25.7: Dual-Duct, Dual-Fan Heating-Only, Recirculating Air Handling Unit Fault conditions

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Fault Condition | Description | Equation(s) | Possible Diagnosis | Applicable Operating States | | | | | |
| 1 | 2 | 3 | 4 | 5 |
| Heating | Economizer Free Cooling | Economizer + Mech. Cooling | Mechanical Cooling | Unknown/ Dehumidifying |
| 1 | Duct static pressure too low with fan at full speed | **AND** | * Problem with VFD * Mechanical problem with fan * Fan undersized * SAT set point too high (too much zone demand) | X | X | X | X | X |
| 2 | SAT too low in full heating |  | * 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 | X | X | X | X | X |
| 3 | Temperature rise across inactive coil | **AND** | * HCET sensor error * HCLT sensor error * Heating-coil valve stuck open or leaking * Gas or electric heat stuck ON | X | X | X | X | X |
| Footnotes:  Variables that appear in this table are defined in Section 4.25 D. 2 and 4.25 D. 3.  Internal variables shall be programmed for each air handler, as defined in 4.25 D. 4. | | | | | | | | |

* + - 1. For each air handler, the operator shall be able to suppress the alarm for any fault condition.
      2. Evaluation of fault conditions shall be suspended under the following conditions:
         1. When AHU is not operating
         2. For a period of ModeDelay minutes following a change in mode (e.g., from warm-up to occupied) of any zone group served by the AHU
      3. A fault condition that evaluates as TRUE must do so continuously for AlarmDelay minutes before it is reported to the operator.
      4. 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. 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 4.25.7.
    1. Testing/Commissioning Overrides. Provide software switches that interlock to a CHW and hot-water plant level to
       - 1. force hot water valve full open and
         2. force hot water valve full closed.

Per Section 4.7 K, 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 4.10 E.

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 it will 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.

* + 1. Plant Requests
       1. Hot-Water Reset Requests
          1. If the supply air temperature is 30°F less than set point for 5 minutes, send 3 requests.
          2. Else if the supply air temperature is 15°F less than set point for 5 minutes, send 2 requests.
          3. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
          4. Else if the HW valve position is less than 95%, send 0 requests.
       2. Heating Hot-Water Plant Requests. Send the heating hot-water plant that serves the AHU a heating hot-water plant request as follows:
          1. a. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.
          2. Else if the HW valve position is less than 95%, send 0 requests.

## Single-Zone VAV Air-Handling Unit

Table 4.26.1 Single-Zone VAV Air Handler – Hardware Points List

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Type | Device | Required |
|  | Exhaust Air Damper | AO |  | Define |
|  | Outside Air/Return Air Damper | AO |  | R |
|  | Mixed Air Temperature | AI |  | R |
|  | Filter DP | AI |  | R |
|  | Hot Water Valve | AO |  | R |
|  | Chilled Water Valve | AO |  | R |
|  | Supply Fan VFD Status | DI |  | R |
|  | Supply Fan VFD Speed | AO |  | R |
|  | Supply Fan VFD Start | DO |  | R |
|  | Supply Air Temperature | AI |  | R |
|  | Return Fan VFD Status | DI |  | Define |
|  | Return Fan VFD Speed | AO |  | Define |
|  | Return Fan VFD Start | DO |  | Define |
|  | Return Air Temperature | AI |  | R |
|  | Zone Temp | AI |  | R |
|  | Zone CO2 | AI |  | Define |
|  | Zone Window Switch | DI |  | Define |
|  | Zone Occupancy Sensor | DI |  | Define |
|  | Zone Setpoint Adjusts | AI |  | Define |
|  | Zone Local Override | DI |  | Define |

Table 4.26.2 Single-Zone VAV Air Handler – Software Points List (Excluding Ventilation)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Cooling SAT Minimum | CoolSAT |  | § 4.5 D. 1. a | X | X |  |  | |
|  | Heating SAT Maximum | HeatSAT |  |  | X | X |  |  | |
|  | Maximum SAT Dew Point | MaxDPT |  |  | X | X |  |  | |
|  | Minimum Fan Speed | MinSpeed |  |  | X | X |  |  | |
|  | Maximum Speed for Heating | MaxHeatSpeed |  |  | X | X |  |  | |
|  | Maximum Speed for Cooling | MasCoolSpeed |  |  | X | X |  |  | |
|  | Minimum Economizer Damper Position at Minimum Vent Rate | MinPosMin |  |  | X | X |  |  | |
|  | Maximum Economizer Damper Position at Minimum Vent Rate | MinPosMax |  |  | X | X |  |  | |
|  | Design Ventilation Position Minimum | DesPosMin |  |  | X | X |  |  | |
|  | Design Ventilation Position Maximum | DesPosMax |  |  | X | X |  |  | |
|  | Minimum Relief Damper Position | MinRelief |  |  | X | X |  |  | |
|  | Maximum Relief Damper Position | MaxRelief |  |  | X | X |  |  | |
|  | Supply-Return Fan Speed Differential | S-R-Diff |  |  | X | X |  |  | |
|  | Medium Speed setpoint | MedSpeed |  | § 4.26 D. 3. b |  |  | X |  | |
|  | End Point #1 |  |  | § 4.26 D. 3. b. i |  |  | X |  | |
|  | End Point #2 |  |  | § 4.26 D. 3. b. ii |  |  | X |  | |
|  | Heating Loop |  |  | 4.26 D. 5 |  |  |  |  | |
|  | Heating Loop Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Heating Loop Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Heating Loop Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally, not used | |
|  | Supply Air Temperature SP | SATsp |  | § 4.26 D. 5 |  |  | X |  | |
|  | Supply Air Temperature Cooling SP | SATsp-C |  | § 4.26 D. 5 |  |  | X |  | |
|  | Deadband Temperature Value |  |  |  | X | X |  |  | |
|  | Cooling Loop |  |  | § 4.26 D. 5 |  |  | X |  | |
|  | Cooling Loop Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Cooling Loop Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | Cooling Loop Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally, not used | |
|  | SAT Loop |  |  | § 4.26 E. 2. a |  |  | X |  | |
|  | SAT Loop Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | SAT Loop Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | SAT Loop Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally, not used | |
|  | SAT Cooling SP Loop |  |  | § 4.26 E. 3 |  |  | X |  | |
|  | SAT Cooling Loop Proportional Gain |  |  | § 4.7 H | X | X |  |  | |
|  | SAT Cooling Loop Integral Gain |  |  | § 4.7 H | X | X |  |  | |
|  | SAT Cooling Loop Derivative Gain |  |  | § 4.7 H | X | X |  | Ideally, not used | |
|  | Calculated Minimum Ventilation Setpoint | MinPos\* |  | § 4.26 F. 2. b |  |  | X |  | |
|  | Calculated Design Ventilation Setpoint | DesPos\* |  | § 4.26 F. 2. c |  |  | X |  | |
|  | Freeze Protection Stage 1 Enabled Setpoint |  | °F | § 4.26 M. 1 | X | X |  |  | |
|  | Freeze Protection Stage 1 Enabled Timer |  | min. | § 4.26 M. 1 | X | X |  |  | |
|  | Freeze Protection SAT Setpoint Min |  | °F | § 4.26 M. 1 | X | X |  |  | |
|  | Freeze Protection Stage 1 Disabled Setpoint |  | °F | § 4.26 M. 1 | X | X |  |  | |
|  | Freeze Protection Stage 1 Disabled Timer |  | min. | § 4.26 M. 1 | X | X |  |  | |
|  | Freeze Protection Stage 2 Setpoint |  | °F | § 4.26 M. 2 | X | X |  |  | |
|  | Freeze Protection Stage 2 Timer |  | min. | § 4.26 M. 2 | X | X |  |  | |
|  | Freeze Protection Stage 2 Duration |  | min. | § 4.26 M. 2 | X | X |  |  | |
|  | Freeze Protection Stage 3 Setpoint |  | °F | § 4.26 M. 3 | X | X |  |  | |
|  | Freeze Protection Stage 3 Timer |  | min. | § 4.26 M. 3 | X | X |  |  | |
|  | Freeze Protection Stage 3 SAT Setpoint |  | °F | § 4.26 M. 3 | X | X |  |  | |

Table 4.26.3 Single-Zone VAV Air Handler – Software Points – ASHRAE 62.1/90.1 Ventilation

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Minimum Ventilation Rate | MinOA | cfm | § 4.5 H. 2. a. i | X | X |  |  | |
|  | Design Maximum Ventilation Rate | DesOA | cfm | § 4.5 H. 2. a. ii | X | X |  |  | |
|  | Economizer High Limit |  | °F | 4.5 H. 1 | X | X |  |  | |

Table 4.26.4 Single-Zone VAV Air Handler – Software Points – Title 24 Ventilation

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Description | Name | Units | Applicable Spec Section | Point Details | | | | Notes |
| Define | Adjustable | Calculated |  | |
|  | Minimum Ventilation Rate | MinOA | cfm | § 4.5 H. 2. b. i | X | X |  |  | |
|  | Design Maximum Ventilation Rate | DesOA | cfm | § 4.5 H. 2. b. ii | X | X |  |  | |
|  | Economizer High Limit |  | °F | § 4.5 H. 1 | X | X |  |  | |

* + 1. See “Generic Thermal Zones” (Section 4.9) for set points, loops, control modes, alarms, etc.
    2. See Section 4.5 H. 1 for Cool\_SAT, Heat\_SAT, and MaxDPT.
    3. See Section 4.6 C for MinSpeed, MaxHeatSpeed, MaxCoolSpeed, MinPosMin, MinPosMax, DesPosMin, Des-PosMax, MinRelief, MaxRelief, and S-R-DIFF.
    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, 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.

* + - 1. The supply fan shall run whenever the unit is in any mode other than unoccupied mode.
      2. Provide a ramp function to prevent changes in fan speed of more than 10% per minute.
      3. Minimum, medium, and maximum fan speeds shall be as follows:
         1. Minimum speed MinSpeed, maximum cooling speed MaxCoolSpeed, and maximum heating speed MaxHeat-Speed shall be determined per Section 4.6 C. 1
         2. 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 Max-CoolSpeed when outdoor air temperature is less than or equal to Endpoint #2.

Endpoint #1: the lesser of zone temperature +0.5°C (1°F and maximum supply air dew point MaxDPT.

Endpoint #2: the lesser of zone temperature minus 10°F and the maximum supply air dew point Max-DPT minus 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.

* + - 1. Minimum and maximum supply air temperature set points shall be as follows:
         1. 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 70°F and no higher than 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 90°F in a datacenter could cause unnecessary heating if this limit were not in place.

* + - 1. When the supply fan is proven ON, fan speed and supply air temperature set points are controlled as shown in Figure 4.26.1, Figure 4.26.2 and Figure 4.26.3. 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 4.26.1 to provide stable control.

Figure 4.26.2 and Figure 4.26.3 separates Figure 4.26.1 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.

* + - * 1. For a heating-loop signal of 100% to 50%, fan speed is reset from MaxHeatSpeed to MinSpeed.
        2. For a heating-loop signal of 50% to 0%, fan speed set point is MinSpeed.
        3. In deadband, fan speed set point is MinSpeed.
        4. For a cooling-loop signal of 0% to 25%, fan speed is Min-Speed.
        5. For a cooling-loop signal of 25% to 50%, fan speed is reset from MinSpeed to MedSpeed.
        6. For a cooling-loop signal of 50% to 75%, fan speed is MedSpeed.
        7. For a cooling-loop signal of 75% to 100%, fan speed is reset from MedSpeed to MaxCoolSpeed.
        8. For a heating-loop signal of 100% to 50%, SATsp is Heat\_SAT.
        9. For a heating-loop signal of 50% to 0%, SATsp is reset from Heat\_SAT to the deadband value.
        10. In deadband, SATsp is the deadband value.
        11. For a cooling-loop signal of 0% to 25%, SATsp is reset from the deadband value to Cool\_SAT minus 2°F, while SATsp-C is the deadband value.
        12. For a cooling-loop signal of 25% to 50%, SATsp and SATsp-C are unchanged.
        13. For a cooling-loop signal of 50% to 75%, SATsp remains at Cool\_SAT minus 2°F, SATsp-C is reset from the deadband value to Cool\_SAT.
        14. For a cooling-loop signal of 75% to 100%, SATsp and SATsp-C are unchanged.

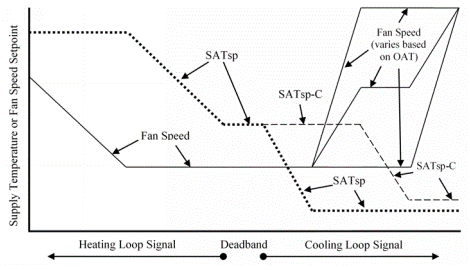


Figure 4.26.1: Single Zone VAV AHU Heating & Cooling g Control Loop Mapping

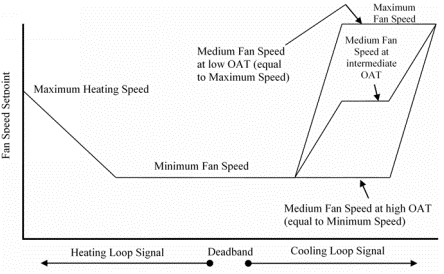


Figure 4.26.2: Single Zone VAV AHU Fan Speed Control Loop Mapping

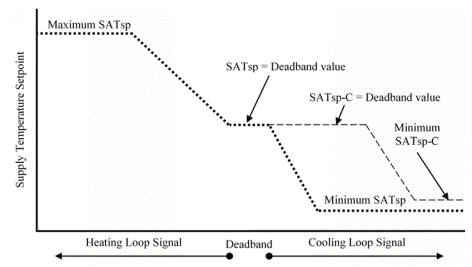


Figure 4.26.3: Single Zone VAV AHU Supply Air Temperature Control Loop Mapping

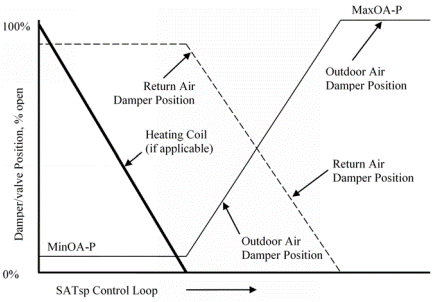


Figure 4.26.4: Single Zone VAV AHU Supply Air Temperature Setpoint Loop Mapping

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.

* + 1. Supply Air Temperature Control
       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.
       2. The control loop for SATsp is enabled when the supply air fan is proven ON and disabled and set to neutral otherwise.
          1. 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 4.26.4. 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 4.26F and 4.26G.

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.

* + - * 1. The points of transition along the x-axis shown in Figure 4.26.4 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 4.26.4 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.

* + - 1. 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.
    1. 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.

* + - 1. See Section 4.8 for calculation of zone minimum outdoor airflow set point, MinOAsp.

The engineer must select among control logic options for minimum outdoor airflow control. This decision is based on whether the unit has an outdoor airflow measurement station.

* + - 1. Outdoor Air Damper Control for Units without an Outdoor Airflow Measurement Station

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 Demand Control Ventilation. This logic assumes that there is no airflow measurement station across the outdoor air intake and controls OA volume indirectly via damper position setpoints. 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 (above) and the control logic below.

* + - * 1. See Section 4.6 C. 2 for minimum damper position set points MinPosMin, MinPosMax, DesPosMin, and DesPosMax.
        2. 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.
        3. 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.
        4. If MinOAsp is zero, MinOA-P shall be zero (i.e., outdoor air damper fully closed).
        5. If MinOAsp is nonzero, then the outdoor air damper minimum position MinOA-P shall be the value between Min-Pos\* and DesPos\* that is proportional to the value of MinOAsp between MinOA and DesOA. Figure 4.26.5 illustrates this (points are chosen arbitrarily and are not meant to be representative).

This is effectively three sequential linear interpolation functions, as shown below.

* + - 1. Outdoor Air Damper Control for Units with an Outdoor Airflow Measurement Station

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 Demand Control Ventilation. This logic assumes that there is an airflow measurement station across the outdoor air intake and controls OA volume directly via control over the minimum OA damper position. Other configurations are possible and would require modifications to the points list (above) and the control logic below.

* + - * 1. 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.
        2. The minimum outdoor airflow rate shall be maintained at the minimum outdoor air setpoint MinOAsp by a reverse-acting control loop whose output is mapped to MinOA-P.

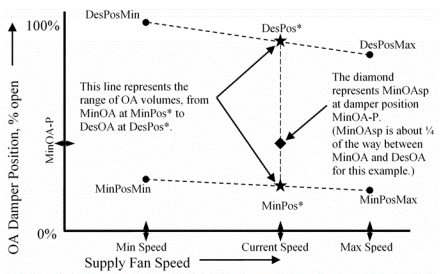


Figure 4.26.5: SZVAV AHU Minimum Outdoor Air Control As a Function of Supply Fan Speed

* + 1. 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.

* + - 1. The normal sequencing of the economizer dampers shall be disabled in accordance with Section 4.7 Q.
      2. Once the economizer is disabled, it shall not be reenabled within 10 minutes and vice versa.
      3. When economizer is enabled, MaxOA-P = 100%. When economizer is disabled, set MaxOA-P equal to MinOA-P.
         1. See Section 4.26 E and Section 4.26 F 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 4.26 H and delete Sections 4.26 I, 4.26 J, 4.26 K, and 4.26 L.

• For AHUs using actuated relief dampers with relief fan(s), use Section 4.26 I and delete Sections 4.26 H, 4.26 J, 4.26 K, and 4.26 L.

• For AHUs using a return fan with speed tracking, use Section 4.26 J and delete Section 4.26 H, 4.26 I, 4.26 K, and 4.26 L.

• For AHUs that rely on separate exhaust fans, use Section 4.26 K and delete Sections 4.26 H, 4.26 I, 4.26 J, and 4.26 L.

• For AHUs using a return fans controlled to building pressure, use Section 4.26 L and delete Section 4.26 H, 4.26 I, , 4.26 J, and 4.26 K.

• For AHUs using nonactuated barometric relief only, delete all three Sections 4.26 H, 4.26 I, 4.26 J, 4.26 K, and 4.26 L.

A building pressure sensor is required for the option in Section 4.26 I and 4.26 L. One is not required for Sections 4.26 H, 4.26 J, and 4.26 K.

* + 1. Control of Actuated Relief Dampers without Fans
       1. See Section 4.6 C. 3 for relief-damper position set points.
       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.
       3. Relief-damper position shall be reset linearly from MinRelief to MaxRelief as the minimum outdoor airflow setpoint, MinOAsp is reset from MinOA to DesOA.
    2. Relief-Fan Control

Retain this section if there are no multizone units with relief fan control on-site, 1. Through 6. Delete sections 7 through 12.

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.

* + - 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.
      2. A relief fan shall be enabled when its associated supply fan is proven ON, and shall be disabled otherwise.
      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.
      4. A P-only control loop maintains the building pressure at a set point of 0.05 in. of water with an out-put 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.

* + - 1. 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.
         1. 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.
         2. 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.
         3. 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).
      2. For fans in a Level 2 alarm and status is OFF, discharge damper shall be closed when stage is above Stage 0.

Retain this section if there are multizone units with relief fan control on-site., 7.0 Through 12.0

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.

* + - 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.
      2. A relief fan shall be enabled when its associated supply fan is proven ON, and shall be disabled otherwise.
      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.
      4. A P-only control loop maintains the building pressure at a set point of 0.05 in. of water with an out-put 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.

* + - 1. 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.
         1. 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.
         2. 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.
         3. 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).
      2. For fans in a Level 2 alarm and status is OFF, discharge damper shall be closed when stage is above Stage 0.
    1. Return-Fan Control – Speed Tracking

Exhaust damper may be barometric (no actuator). In that case, delete Sections 4.26 J. 1.

* + - 1. Exhaust damper shall open whenever associated supply fan and return fan are proven ON and shall be closed otherwise.
      2. Return fan shall run whenever associated supply fan is proven ON.
      3. The active differential airflow setpoint S-R-SPD-DIFF\* shall be S-R-SPD-DIFF adjusted by the active minimum outdoor airflow setpoint, MinOAsp relative to the design outdoor airflow setpoint, DesOA.
      4. Return-fan speed shall be, controlled to maintain return fan speed equal to supply fan speed less differential S-R-SPD-DIFF\*.
    1. Exhaust Fan Control
       1. Exhaust Fan Start/Stop
          1. Exhaust fan shall operate when any of the associated system supply fans is proven on and any associated Zone Group is in the Occupied Mode. See Section 4.10 for Zone Group assignments.
          2. Exhaust fan shall run when zone temperature rises above the active cooling setpoint until zone temperature falls more than 2°F below the active cooling setpoint for 2 minutes.

The room temperature control method should only be used in non-occupied spaces where ventilation is not required (i.e., equipment rooms).

* + 1. Return Fan Control – Direct Building Pressure
       1. Return fan operates whenever the associated supply fan is proven ON and shall be off otherwise.
       2. Return fans shall be controlled to maintain return-fan discharge static pressure at set point (Section 4.26 I. 4).
       3. Building static pressure shall be time aver-aged with a sliding 5-minute window and 15 seconds sampling rate (to dampen fluctuations). The averaged value shall be that displayed and used for control.
          1. Where multiple building pressure sensors are used, the highest of the averaged values for sensors within a pressure zone shall be 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.

* + - 1. A single P-only control loop for each pressure zone shall modulate to maintain the building pressure at a setpoint of 0.05 in. of water with an output ranging from 0% to 100%. The loop shall be enabled when the supply and return fans for any unit within the pressure zone are proven ON and the minimum outdoor air damper is open. The exhaust dampers shall be closed with loop output set to zero otherwise. All exhaust damper and return fan static pressure setpoints for units in an associated pressure zone shall be sequenced based on building pressure control loop output signal.

A pressure zone is defined as an enclosed area with interconnected return air paths. All operating relief dampers and return fans that serve a pressure zone shall be controlled as if they were one system, using the same control loop, even if they are associated with different AHUs. The appropriate boundaries for pressure zones, establishing which return fans run together, will need to be determined by the engineer based on building geometry.

* + - * 1. From 0% to 50%, the building pressure control loop shall modulate the exhaust dampers from 0% to 100% open.
        2. 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 4.6 A. 4 for RFDSPmin and RFDSPmax.

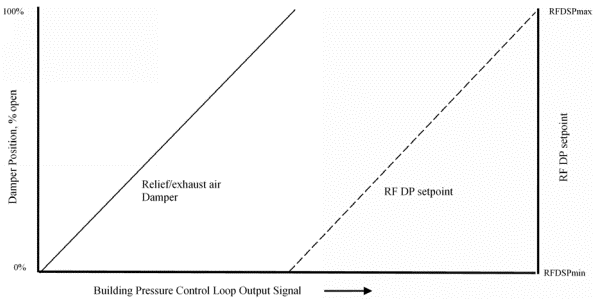


Figure 4.26.6 Exhaust Damper Position and Return Fan DP Reset Loop Mapping

This concludes the section where the control logic for return/relief/exhaust is selected.

When the sequences are complete, at most one of Sections 4.26 H, 4.26 I, 4.26 J, 4.26 K, 4.26 L should remain. If relief is barometric (without actuators) only, then all five 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 per-form 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.

* + 1. 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).

* + - 1. If the supply air temperature drops below 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 42°F. Disable this function when supply air temperature rises above 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.

* + - 1. If the supply air temperature drops below 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 4.26 M. 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 42°F]), after which one of three possibilities will occur:

a. If it is warm enough that the SAT rises above 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 38°F and 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 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.

* + - 1. Upon signal from the freeze-stat (if installed), or if supply air temperature drops below 38°F for 15 minutes or below 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 80°F, and set a Level 2 alarm indicating the unit is shut down by freeze protection.
         1. 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 work-station. (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 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.

* + 1. Alarms

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| # | Description | Level | Definition | Applicable Spec Section |
|  | Freeze Protection Stage 2 | 3 | When Freeze Protection Stage 2 Occurs | 4.26 M. 2 |
|  | Freeze Protection Stage 3 | 2 | When Freeze Protection Stage 3 Occurs | 4.26 M. 3 |
|  | Maintenance Interval | 4 | Accumulated maintenance run hours >1500 hours | 4.26 N. 1 |
|  | Cold Duct Fan Remains Off | 2 | Fan commanded ON, fan status OFF | 4.26 N. 2. a |
|  | Cold Duct Fan Remains On | 4 | Fan commanded OFF, fan status ON | 4.26 N. 2. b |

* + - 1. Maintenance interval alarm when fan has operated for more than 1,500 hours: Level 4. Reset interval counter when alarm is acknowledged.
      2. Fan alarm is indicated by the status being different from the command for a period of 15 seconds.
         1. Commanded ON, status OFF: Level 2
         2. Commanded OFF, status ON: Level 4
      3. Filter pressure drop exceeds the larger of the alarm limit or 0.05 in. of water for 10 minutes when fan speed exceeds 20% of MaxCoolSpeed: Level 4. The alarm limit shall vary with fan speed as follows:

DPx = DP100(x)1.4

Where DP100 is the high-limit pressure drop at the design airflow (determine limit from filter manufacturer) and DPx is the high-limit at the current fan speed x (expressed as a fraction). For instance, the setpoint at 50% of the design speed would be (0.5)1.4, or 38% of the design high-limit pressure drop.

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.

* + 1. 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.

* + - 1. AFDD conditions are evaluated continuously and separately for each operating AHU.
      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 4.26.5 and Figure 4.26.7.

Table 4.26.5 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, < 100% |
| #3 Mechanical + economizer cooling | = 0 | > 0 | = 100% |
| #4 Mechanical cooling, minimum OA | = 0 | > 0 | = min |
| #5 Unknown or dehumidification | No other OS Applies | | |

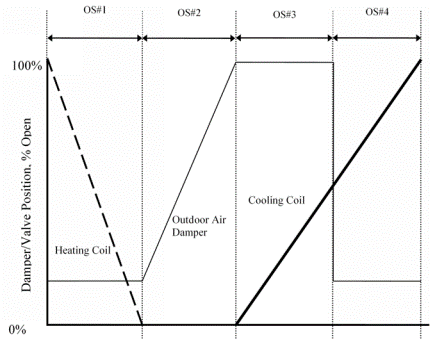


Figure 4.26.7: SZVAV AHU Operating States

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 4.26.5) represent normal operation during which a fault may nevertheless occur if so determined by the fault condition tests in 0. 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.

* + - 1. 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.

* + - * 1. SAT = supply air temperature
        2. MAT = mixed air temperature
        3. RAT = return air temperature
        4. OAT = outdoor air temperature
        5. DSP = duct static pressure
        6. SATsp = supply air temperature set point for heating coil and economizer control
        7. SATsp-C = supply air temperature set point for cooling coil control
        8. HC = heating-coil valve position command; 0% ≤ HC ≤ 100%
        9. CC = cooling-coil valve position command; 0% ≤ CC ≤ 100%
        10. FS = fan-speed command; 0% ≤ FS ≤ 100%
        11. CCET = cooling-coil entering temperature (Depending on the AHU configuration, this could be the MAT or a separate sensor for this specific purpose).
        12. CCLT = cooling-coil leaving temperature (Depending on the AHU configuration, this could be the SAT or a separate sensor for this specific purpose.)
        13. HCET = heating-coil entering temperature (Depending on the AHU configuration, this could be the MAT or a separate sensor for this specific purpose.)
        14. HCLT = heating-coil leaving temperature (Depending on the AHU configuration, this could be the SAT or a separate sensor for this specific purpose.)
      1. The following values must be continuously calculated by the AFDD routines for each AHU:
         1. 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.

SATavg = rolling average of supply air temperature

MATavg = rolling average of mixed air temperature

RATavg = rolling average of return air temperature

OATavg = rolling average of outdoor air temperature

CCETavg = rolling average of cooling-coil entering temperature

CCLTavg = rolling average of cooling-coil leaving temperature

HCETavg = rolling average of heating-coil entering temperature

HCLTavg = rolling average of heating-coil leaving temperature

ΔOS = number of changes in OS during the previous 60 minutes (moving window)

* + - 1. The internal variables shown in Table 4.26.6 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 4.26 O. 12

Table 4.26.6 SZVAV AHU Internal Variables

|  |  |  |
| --- | --- | --- |
| Variable Name | Description | Default Value |
| ΔTSF | Temperature rise across supply fan | 1°F |
| ΔTmin | Minimum difference between OAT and RAT to evaluate economizer error conditions (FC#6) | 10°F |
| εSAT | Temperature error threshold for SAT sensor | 2°F |
| εRAT | Temperature error threshold for RAT sensor | 2°F |
| εMAT | Temperature error threshold for MAT sensor | 5°F |
| εOAT | Temperature error threshold for OAT sensor | 2°F if local to unit;  5°F if global sensor |
| εCCET | Cooling coil entering temperature sensor error; Either equals εMAT **OR** dedicated sensor error | Varies; see description |
| εCCLT | Cooling coil leaving temperature sensor error; Either equals εSAT **OR** dedicated sensor error |
| εHCET | Heating coil entering temperature sensor error; Either equals εMAT **OR** dedicated sensor error |
| εHCLT | Heating coil leaving temperature sensor error; Either equals εSAT **OR** dedicated sensor error |
| ΔOSmax | Maximum number of changes in Operating State during the previous 60 minutes (rolling/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 |

* + - 1. Table 4.26.7 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 4.26.7

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.

Table 4.26.7 SZVAV AHU Internal Fault Conditions

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Fault Condition | Description | Equation(s) | Possible Diagnosis | Applicable Operating States | | | | | |
| 1 | 2 | 3 | 4 | 5 |
| Heating | Economizer Free Cooling | Economizer + Mech. Cooling | Mechanical Cooling | Unknown/ Dehumidifying |
| 1 | Duct static pressure too low with fan at full speed | This fault condition is not used for single-zone VAV AHUs, as it requires a static pressure setpoint input. | | X | X | X | X | X |
| 2 | MAT too low, should be between OAT & RAT |  | * RAT sensor error * MAT sensor error * OAT sensor error | X | X | X | X | X |
| 3 | MAT too high, should be between OAT & RAT |  | * RAT sensor error * MAT sensor error * OAT sensor error | X | X | X | X | X |
| 4 | Too many changes in operating state |  | * Unstable control due to poorly tuned loop or mechanical problem | X | X | X | X | X |
| 5 | SAT too low; should be higher than MAT |  | * 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 | X |  |  |  |  |
| 6 | OA fraction too low or too high; should equal %OAmin | **AND** | * RAT sensor error * MAT sensor error * OAT sensor error * Leaking or stuck economizer damper or actuator | X | X | X | X |  |
| 7 | SAT too low in full heating | **AND** | * 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 | X |  |  |  |  |
| 8 | SAT and MAT should be approximately equal when Free-Cooling |  | * 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 |  | X |  |  |  |
| 9 | OAT too high for free cooling without additional mechanical cooling |  | * SAT sensor error * OAT sensor error * Cooling-coil valve leaking or stuck open * DX cooling stuck ON |  | X |  |  |  |
| 10 | OAT and MAT should be approximately equal |  | * MAT sensor error * OAT sensor error * Leaking or stuck economizer damper or actuator |  |  | X |  |  |
| 11 | OAT too low for 100% OA cooling |  | * 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 |  |  | X |  |  |
| 12 | SAT too high; should be less than MAT |  | * SAT sensor error * MAT sensor error * Cooling-coil valve stuck closed or actuator failure * Fouled or undersized cooling coil * CHW temperature too high or CHW unavailable * DX cooling unavailable * Gas or electric heat stuck ON * Heating-coil valve leaking or stuck open |  |  | X | X |  |
| 13 | SAT too high in full cooling | **AND** | * 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 |  |  | X | X |  |
| 14 | Temperature drop across inactive cooling coil | \*Omit the term if the fan is not located between the CCET and CCLT sensors. | * CCET sensor error * CCLT sensor error * Cooling-coil valve stuck open or leaking * DX cooling stuck ON | X | X |  |  |  |
| 15 | Temperature rise across inactive heating coil | \*Omit the term if the fan is not located between the HCET and HCLT sensors. | * HCET sensor error * HCLT sensor error * Heating-coil valve stuck open or leaking * Gas or electric heat stuck ON. |  | X | X | X |  |
| Footnotes:  Variables that appear in this table are defined in Section 4.26 O. 3 and 4.26 O. 4.  Internal variables shall be programmed for each air handler, as defined in 4.26 O. 5. | | | | | | | | |

* + - 1. 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 a MAT sensor is not installed, omit FCs #2, #3, #5, #8, #10, and #12:
         1. In OS#1 (Heating), the following fault conditions shall be evaluated:

FC#2: MAT too low; should be between RAT and OAT

FC#3: MAT too high; should be between RAT and OAT

FC#4: Too many changes in OS

FC#5: SAT too low; should be higher than MAT

FC#6: OA fraction too high; MAT should be closer to RAT than to OAT

FC#7: SAT too low in full heating

FC#14: Temperature drop across inactive cooling coil

* + - * 1. In OS#2 (modulating economizer), the following fault conditions shall be evaluated:

FC#2: MAT too low; should be between RAT and OAT

FC#3: MAT too high; should be between RAT and OAT

FC#4: Too many changes in OS

FC#8: SAT and MAT should be approximately equal

FC#9: OAT too high for free cooling without mechanical cooling

FC#14: Temperature drop across inactive cooling coil

FC#15: Temperature rise across inactive heating coil

* + - * 1. In OS#3 (mechanical + 100% economizer cooling), the following fault conditions shall be evaluated:

FC#2: MAT too low; should be between RAT and OAT

FC#3: MAT too high; should be between RAT and OAT

FC#4: Too many changes in OS

FC#10: OAT and MAT should be approximately equal

FC#11: OAT too low for 100% OA

FC#12: SAT too high; should be less than MAT

FC#13: SAT too high in full cooling

FC#15: Temperature rise across inactive heating coil

* + - * 1. In OS#4 (mechanical cooling, minimum OA), the following fault conditions shall be evaluated:

FC#2: MAT too low; should be between RAT and OAT

FC#3: MAT too high; should be between RAT and OAT

FC#4: Too many changes in OS

FC#6: OA fraction too high; MAT should be closer to RAT than to OAT

FC#12: SAT too high; should be less than MAT

FC#13: SAT too high in full cooling

FC#15: Temperature rise across inactive heating coil

* + - * 1. In OS#5 (other), the following fault conditions shall be evaluated:

FC#2: MAT too low; should be between RAT and OAT

FC#3: MAT too high; should be between RAT and OAT

FC#4: Too many changes in OS

* + - 1. For each air handler, the operator shall be able to suppress the alarm for any fault condition.
      2. Evaluation of fault conditions shall be sus-pended under the following conditions:
         1. When AHU is not operating
         2. For a period of ModeDelay minutes following a change in mode (e.g., from warm-up to occupied) of any zone group served by the AHU
      3. Fault conditions that are not applicable to the current OS shall not be evaluated.
      4. A fault condition that evaluates as TRUE must do so continuously for AlarmDelay minutes before it is reported to the operator.
      5. 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.
      6. 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 4.26.7.
    1. Testing/Commissioning Overrides. Provide software switches that interlock to a CHW and hot-water plant level to
       - 1. force HW valve full open if there is a hot-water coil,
         2. force HW valve full closed if there is a hot-water coil,
         3. force CHW valve full open if there is a CHW coil, and
         4. force CHW valve full closed if there is a CHW coil.

Per Section 4.7 K, 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.

* + 1. Alarms
       1. Maintenance interval alarm when fan has operated for more than 3,000 hours: Level 4. Reset interval counter when alarm is acknowledged.
       2. Fan alarm is indicated by the status being different from the command for a period of 15 seconds.
          1. Commanded ON, Status OFF: Level 2
          2. Commanded OFF, Status OFF: Level 4
    2. Plant Requests
       1. Chilled-Water Reset Requests
          1. If the supply air temperature exceeds SATsp-C by 5°F for 2 minutes, send 3 requests.
          2. Else if the supply air temperature exceeds SATsp-C by 3°F for 2 minutes, send 2 requests.
          3. Else if the CHW valve position is greater than 95%, send 1 request until the CHW valve position is less than 85%.
          4. Else if the CHW valve position is less than 95%, send 0 requests.
       2. Chiller Plant Requests. Send the chiller plant that serves the system a chiller plant request as follows:
          1. If the CHW valve position is greater than 95%, send 1 request until the CHW valve position is less than 10%.
          2. Else if the CHW valve position is less than 95%, send 0 requests.
       3. If There Is a Hot-Water Coil, Hot-Water Reset Requests
          1. If the supply air temperature is 30°F less than SATsp for 5 minutes, send 3 requests.
          2. Else if the supply air temperature is 15°F less than SATsp for 5 minutes, send 2 requests.
          3. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.
          4. Else if the HW valve position is less than 95%, send 0 requests.
       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:
          1. If the HW valve position is greater than 95%, send 1 request until the HW valve position is less than 10%.
          2. Else if the HW valve position is less than 95%, send 0 requests.