ADDENDA

ASHRAE Addendum q to
ASHRAE Guideline 36-2018

High Performance Sequences of Operation for HVAC Systems

Approved by ASHRAE on July 9, 2021.

This addendum was approved by a Standing Guideline Project Committee (SGPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the guideline. Instructions for how to submit a change can be found on the ASHRAE® website (https://www.ashrae.org/continuous-maintenance).

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Development of ASHRAE Guidelines follows procedures similar to those for ASHRAE Standards except that (a) committee balance is desired but not required, (b) an effort is made to achieve consensus but consensus is not required, (c) Guidelines are not appealable, and (d) Guidelines are not submitted to ANSI for approval.

The Senior Manager of Standards of ASHRAE should be contacted for

a. interpretation of the contents of this Guideline,
b. participation in the next review of the Guideline,
c. offering constructive criticism for improving the Guideline, or
d. permission to reprint portions of the Guideline.

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

FOREWORD

This addendum includes control sequences for 2-pipe heating, 2-pipe cooling, and 4-pipe heating/cooling fan-coil units (FCUs). It assumes the fan is variable speed but the sequences will still work with constant speed fans. The distinction between FCUs and air handling units (AHUs) is that FCUs do not have any ventilation capability – they either serve spaces that do not require ventilation (e.g. equipment rooms) or ventilation is provided by an independent system, e.g. dedicated outdoor air system, in parallel or in series.

Note: In this addendum, changes to the current guideline are indicated in the text by underlining (for additions) and strikethrough (for deletions) unless the instructions specifically mention some other means of indicating the changes.

Addendum q to Guideline 36-2018

Add Section 3.1.7 (to be 3.1.9 if addenda x and y are approved first) as follows:

3.1.7 Fan Coil Unit (FCU) Design Information

3.1.71 Cool_SAT, lowest cooling supply air temperature set point

Cool_SAT is typically the design coil leaving air temperature. It is not used for heating-only FCUs.

3.1.7.2 Heat_SAT, highest heating supply air temperature set point

Heat_SAT is typically the design coil leaving air temperature. It is not used for cooling-only FCUs.

3.1.7.3 DP100, filter high limit differential pressure at design airflow

Add Section 3.2.3 (to be 3.2.5 if addenda x and y are approved first) as follows:

3.2.3 Fan Coil Unit Information

a. MinHeatSpeed. The speed that provides supply airflow equal to the design heating minimum airflow scheduled on plans. If no minimum airflow is provided on plans, default to 20% of the maximum heating speed.

b. MinCoolSpeed. The speed that provides supply airflow equal to the design cooling minimum airflow scheduled on plans. If no minimum airflow is provided on plans, default to 20% of the maximum cooling speed.

c. DeadbandSpeed. If the fan is desired to operate when the zone is in deadband, set this value to less than or equal to MinSpeed. If the fan is to shut off when the zone is in deadband, set this value to 0.

d. 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.

e. MaxCoolSpeed. The speed that provides supply airflow equal to the design cooling airflow scheduled on plans.

FCU control sequences are intended for fans with variable speed drives or electrically commutated motors (EMCs). Control sequences will also work with constant speed motors without revision; speed will simply not change. Minimum speeds must address minimum airflow for electric heaters or DX heating or cooling.

Add Section 4.10 (to be 4.12 if addenda x and y are approved first) as follows:

4.10 Fan Coil Unit

Required?	Description	Type	Device
R	Fan start/stop	DO	Connect to VFD Run or to contactor for ECMs
R	Fan speed	AO	Connect to VFD or ECM Speed
O	Supply fan status	DI	Connect to VFD Status or ECM Status or to current switch
R	Supply air temperature	AI	Duct temperature sensor
O	Return air temperature	AI	Duct temperature sensor
O	Filter pressure drop	AI	DP transducer across filter
For FCUs with a cooling coil, include the following point:			
R	Cooling signal	AO	Modulating CHW valve OR Floating actuator OR Variable-capacity compressor
For FCUs with a heating coil, include the following point:			
R	Heating signal	AO	Modulating valve OR Floating actuator OR Modulating electric heating coil OR Variable-capacity heat pump compressor
R	Zone temperature	AI	Room temperature sensor
A	Local override (if applicable)	DI	Zone thermostat override switch
A	Occupancy sensor (if applicable)	DI	Occupancy sensor
A	Window switch (if applicable)	DI	Window switch
A	Zone temperature set point adjustment (if applicable)	AI	Zone thermostat adjustment
A	Zone CO2 level (if applicable)	AI	Room CO2 sensor

Add Section 5.20 (to be 5.22 if addenda x and y are approved first) as follows:

5.20 Fan Coil Unit

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

5.20.2 See Section 3.1.7 for Cool_SAT, Heat_SAT, and DP100.

5.20.3 See Section 3.2.3 for MinSpeed, DeadbandSpeed, MaxHeatSpeed, and MaxCoolSpeed.

5.20.4 Supply Fan Speed and Supply Air Temperature Control

5.20.4.1 The supply fan shall run whenever the unit is in any mode other than unoccupied mode.

5.20.4.2 Provide a ramp function to prevent changes in fan speed of more than 10% per minute.

5.20.4.3 When the supply fan is proven on, fan speed and supply air temperature set points are controlled as shown in Figures 5.20.4.3. The points of transition along the x-axis shown and described are representative. Separate gains shall be provided for each section of the control map, that are determined by the contractor to provide stable control. Alternatively, the contractor shall adjust the precise value of the x-axis thresholds shown in Figure 5.20.4.3 to provide stable control.

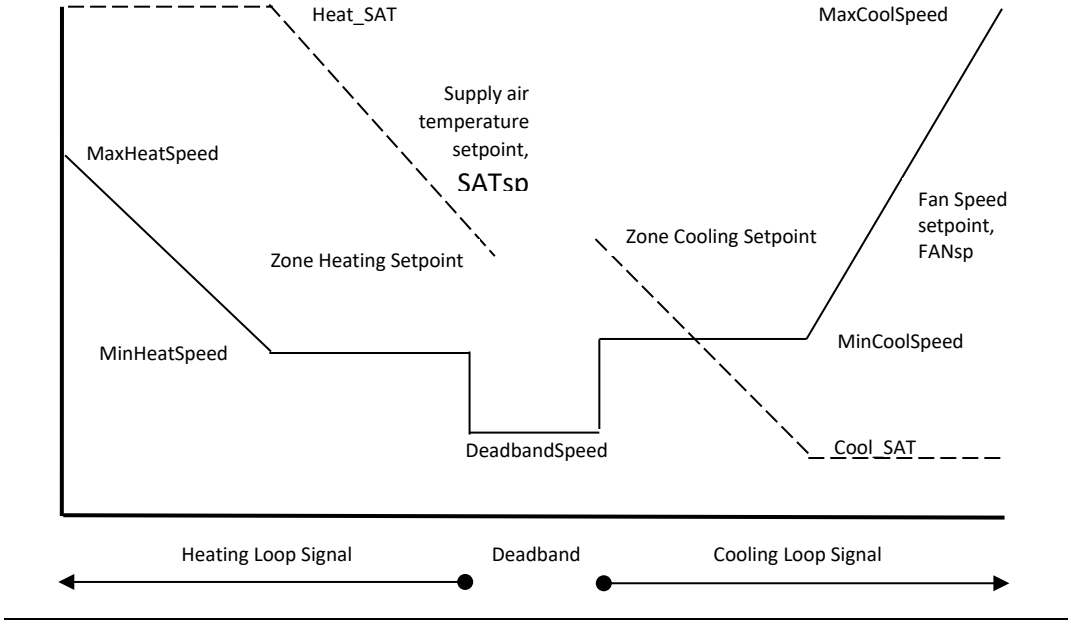

Figure 5.20.4.3 Control diagram for FCU.

a. If there is a heating coil, when Zone State is Heating

1. For a heating-loop signal of 100% to 50%, FANsp is reset from MaxHeatSpeed to MinHeatSpeed.
2. For a heating-loop signal of 50% to 0%, FANsp set point is MinHeatSpeed.
3. For a heating-loop signal of 100% to 50%, SATsp is Heat_SAT.
4. For a heating-loop signal of 50% to 0%, SATsp is reset from Heat_SAT to the active zone heating setpoint.
5. The heating coil shall be modulated with a PID loop to maintain the discharge temperature at SATsp.
6. Cooling coil OFF

b. When Zone State is Deadband

1. FANsp shall be DeadbandSpeed. If DeadbandSpeed is zero, shut the fan off.

2. Cooling coil OFF

3. Heating coil OFF

c. If there is a cooling coil, when Zone State is Cooling

1. For a cooling-loop signal of 0% to 50%, FANsp is MinCoolSpeed.

2. For a cooling-loop signal of 50% to 100%, FANsp is reset from MinCoolSpeed to MaxCoolSpeed.

3. For a cooling-loop signal of 0% to 50%, SATsp is reset from the active zone cooling setpoint to Cool_SAT.

4. For a cooling-loop signal of 50% to 100%, SATsp is Cool_SAT.

5. The cooling coil shall be modulated with a PID loop to maintain the discharge temperature at SATsp.

6. Heating coil OFF

5.20.5 Alarms

5.20.5.1 Maintenance interval alarm when fan has operated for more than 1500 hours: Level 4. Reset interval counter when alarm is acknowledged.

5.20.5.2 Fan alarm is indicated by the status being different from the command for a period of 15 seconds.

a. Commanded on, status off: Level 2

b. Commanded off, status on: Level 4

5.20.5.3 Filter pressure drop exceeds the larger of the alarm limit or 12.5 Pa (0.05") for 10 minutes when fan speed exceeds 20% of MaxCoolSpeed: Level 4. The alarm limit shall vary with fan speed as follows:

$$DP_x = DP_{100}(x)^{1.4}$$

where DP100 is the high limit pressure drop at design airflow (determine limit from filter manufacturer) and DPx is the high limit at the current fan speed x (expressed as a fraction). For instance, the setpoint at 50% of design speed would be $(0.5)^{1.4}$ or 38% of the design high limit pressure drop. See Section 3.2.3 for MaxCoolSpeed and Section 3.1.7 for DP100.

Automatic Fault Detection and Diagnostics (AFDD) is a sophisticated system for detecting and diagnosing fan-coil faults. To function correctly, AFDD requires specific sensors and data be available, as detailed in the sequences below. If this information is not available, AFDD tests that do not apply should be deleted.

5.20.6 Automatic Fault Detection and Diagnostics

The AFDD routines for FCUs continually assess FCU 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. 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 FCU is equipped with heating and cooling coils. If any of these components are not present, the associated tests and variables should be omitted from the programming.

5.20.6.1 AFDD conditions are evaluated continuously and separately for each operating FCU.

5.20.6.2 The OS of each FCU shall be defined by the commanded positions of the heating-coil control valve and cooling-coil control valve in accordance with Table 5.20.6.2 and Figure 5.20.6.2.

Table 5.20.6.2 FCU Operating States

Operating State	Heating Valve Position	Cooling Valve Position
#1: Heating	> 0	= 0
#2: Cooling	= 0	> 0
#3 No Heating or Cooling	= 0	= 0
#4 Unknown	No other OS applies	

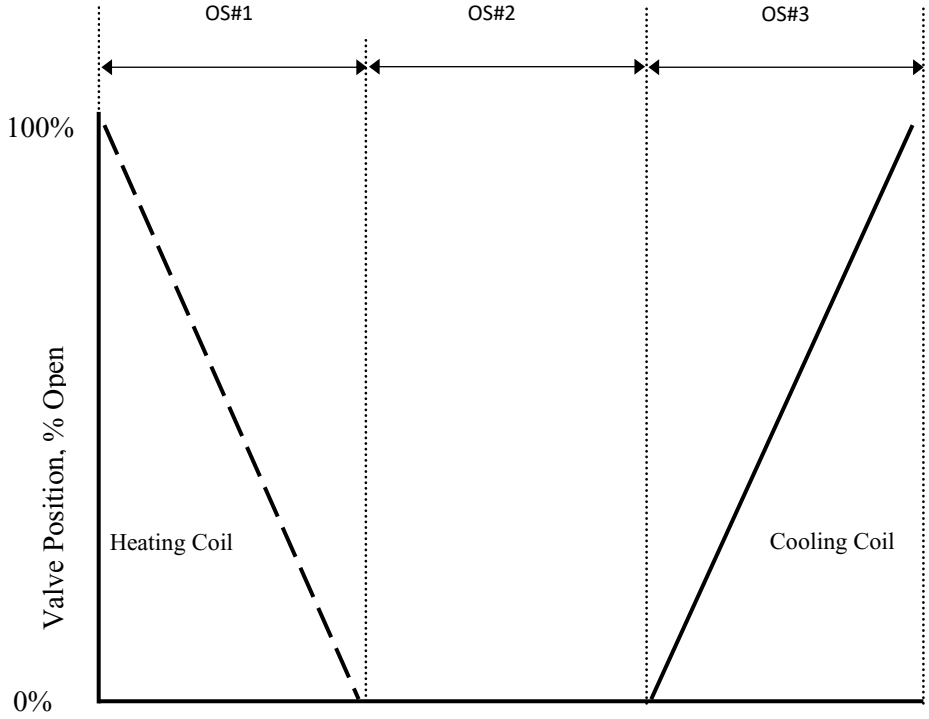

Figure 5.20.6.2 FCU operating states.

The OS is distinct from, and should not be confused with, the zone status (cooling, heating, deadband).

OS#1 through OS#3 (see Table 5.20.6.2) represent normal operation during which a fault may nevertheless occur if so determined by the fault condition tests in Section 5.20.6.6. By contrast, OS#4 may represent an abnormal or incorrect condition (such as simultaneous heating and cooling) arising from a controller failure or programming error.

5.20.6.3 The following points must be available to the AFDD routines for each FCU:

For the AFDD routines to be effective, an averaging sensor is recommended for the supply air temperature but it is noted that in most cases a single point sensor will be provided with the FCU.

a. SAT = supply air temperature

b. RAT = return air temperature (if present)

c. SATsp = supply air temperature set point

d. HC = heating-coil valve position command; 0% d HC d 100%

e. CC = cooling-coil valve position command; 0% d CC d 100%

f. FS = fan-speed command; 0% d FS d 100%

5.20.6.4 The following values must be continuously calculated by the AFDD routines for each FCU:

a. Five-minute rolling averages with 1-minute sampling of the following point values; operator shall have the ability to adjust the averaging window and sampling period for each point independently.

1. SAT_{avg} = rolling average of supply air temperature

2. RAT_{avg} = rolling average of return air temperature (if fitted)

3. ΔOS = number of changes in OS during the previous 60 minutes (moving window)

5.20.6.5 The internal variables shown in Table 5.20.6.5 shall be defined for each FCU. 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.

Table 5.20.6.5 FCU Internal Variables

Variable Name	Description	Default Value
ΔT_{SF}	Temperature rise across supply fan	0.5°C (1°F)
ε_{SAT}	Temperature error threshold for SAT sensor	1°C (2°F)
ε_{RAT}	Temperature error threshold for RAT sensor	1°C (2°F)
$\Delta OSmax$	Maximum number of changes in Operating State during the previous 60 minutes (moving window)	7
ModeDelay	Time in minutes to suspend Fault Condition evaluation after a change in mode	30
AlarmDelay	Time in minutes that a Fault Condition must persist before triggering an alarm	30
TestModeDelay	Time in minutes that Test Mode is enabled	120

The purpose of TestModeDelay is to ensure that normal fault reporting occurs after the testing and commissioning process is completed as described in Section 5.20.6.12.

5.20.6.6 Table 5.20.6.6 shows potential fault conditions that can be evaluated by the AFDD routines. If the equation statement is TRUE, then the specified fault condition exists. The fault conditions to be evaluated at any given time will depend on the OS of the AHU.

The equations in Table 5.20.6.6 assume that the SAT sensor is located downstream of the supply fan and the RAT sensor is located upstream of the supply fan. If actual sensor locations differ from these assumptions, it may be necessary to add or delete fan heat correction factors.

Table 5.20.6.6 FCU Fault Conditions

FC #1	**Equation**	$\Delta OS > \Delta OS_{MAX}$	**Applies to OS #1 – #4**
	Description	Too many changes in Operating State	
	Possible Diagnosis	Unstable control due to poorly tuned loop or mechanical problem	
FC #2	**Equation**	$SAT_{AVG} < SATSP - \_{SAT}$ and HC e 99%	**Applies to OS #1**
	Description	SAT too low in full heating	
	Possible Diagnosis	SAT sensor error Cooling coil valve leaking or stuck open Heating coil valve stuck closed or actuator failure Fouled or undersized heating coil HW temperature too low or HW unavailable Gas or electric heat is unavailable DX cooling is stuck on	
FC #3	**Equation**	$SAT_{AVG} > SAT_{SP} + \_{SAT}$ and CC e 99%	**Applies to OS #3**
	Description	SAT too high in full cooling	
	Possible Diagnosis	SAT sensor error Cooling coil valve stuck closed or actuator failure Fouled or undersized cooling coil CHW temperature too high or CHW unavailable DX cooling unavailable Gas or electric heat stuck on Heating coil valve leaking or stuck open	

FC#4	**Equation**	$SAT_{AVG} - RAT\ e\sqrt{\varepsilon_{RAT}^2 + \varepsilon_{SAT}^2} + \Delta T_{SF}$	**Applies to OS #2 (cooling only FCU with RAT)**
	Description	Temperature drop across inactive cooling coil	
	Possible Diagnosis	RAT sensor error SAT sensor error Cooling coil valve stuck open or leaking DX cooling stuck on	
FC#5	**Equation**	$SAT_{AVG} - RAT\ d\sqrt{\varepsilon_{RAT}^2 + \varepsilon_{SAT}^2} + \Delta T_{SF}$	**Applies to OS #2 (heating only FCU with RAT)**
	Description	Temperature rise across inactive heating coil	
	Possible Diagnosis	RAT sensor error SAT sensor error Heating coil valve stuck open or leaking Gas or electric heat stuck on	

5.20.6.7 A subset of all potential fault conditions is evaluated by the AFDD routines. The set of applicable fault conditions depends on the OS of the FCU.

a. In OS#1 (Heating), the following fault conditions shall be evaluated:

1. FC#1: Too many changes in OS
2. FC#2: SAT too low in full heating

b. In OS#2 (Deadband), the following fault conditions shall be evaluated:

1. FC#5: Temperature drop across inactive heating coil (heating only FCU
2. FC#4: Temperature drop across inactive cooling coil (cooling only FCU

c. In OS#3 (Cooling), the following fault conditions shall be evaluated:

1. FC#1: Too many changes in OS
2. FC#3: SAT too high in full cooling

d. In OS#4 (other), the following fault conditions shall be evaluated:

1. FC#1: Too many changes in OS

5.20.6.8 For each FCU, the operator shall be able to suppress the alarm for any fault condition.

5.20.6.9 Evaluation of fault conditions shall be suspended under the following conditions:

a. When FCU is not operating

b. For a period of ModeDelay minutes following a change in mode (e.g., from warm-up or cool-down to occupied) of any zone group served by the FCU.

5.20.6.10 Fault conditions that are not applicable to the current OS shall not be evaluated.

5.20.6.11 A fault condition that evaluates as true must do so continuously for AlarmDelay minutes before it is reported to the operator.

5.20.6.12 Test mode shall temporarily set ModeDelay and AlarmDelay to 0 minutes for a period of TestModeDelay minutes to allow instant testing of the AFDD system and ensure normal fault detection occurs after testing is complete.

5.20.6.13 When a fault condition is reported to the operator, it shall be a Level 3 alarm and shall include the description of the fault and the list of possible diagnoses from Table 5.20.6.6.

5.20.7 Testing/Commissioning Overrides. Provide software switches that interlock to a CHW and hot-water plant level to

a. force HW valve full open if there is a hot-water coil,

b. force HW valve full closed if there is a hot-water coil,

c. force CHW valve full open if there is a CHW coil, and

d. force CHW valve full closed if there is a CHW coil.

Per Section 5.1.10, all hardware points can be overridden through the BAS. Each of the following points is interlocked so that they can be overridden as a group on a plant level.

For example, the CxA can check for valve leakage by simultaneously forcing closed all CHW valves at all coils 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 FCU demands.

5.20.8 Plant Requests

5.20.8.1 If There Is a Chilled-Water Coil, Chilled-Water Reset Requests

a. All requests shall be suppressed (send 0 requests) if fan is not at MaxCoolSpeed.

The previous sequence is to prevent CHWST reset until fan is at full speed since chiller plant energy is much larger than FC fan energy.

b. If the supply air temperature is 10°F greater than setpoint for 5 minutes, send 3 requests,

c. Else if the supply air temperature is 5°F greater than setpoint for 5 minutes, send 2 requests,

d. Else if the CHW valve position is greater than 95%, send 1 request until the CHW valve position is less than 85%.

e. Else if the CHW valve position is less than 95%, send 0 requests.

5.20.8.2 If There Is a Chilled-Water Coil, Chiller Plant Requests. Send the chiller plant that serves the system a chiller plant request as follows:

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

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

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

a. All requests shall be suppressed (send 0 requests) if fan is not at MaxHeatSpeed.

The previous sequence is to prevent HWST reset until fan is at full speed since heating plant energy is much larger than FC fan energy.

b. If the supply air temperature is 17°C (30°F) less than SATsp for 5 minutes, send 3 requests.

c. Else if the supply air temperature is 8°C (15°F) less than SATsp for 5 minutes, send 2 requests.

d. Else if HW valve position is greater than 95%, send 1 request until the HW valve position is less than 85%.

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

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

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

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

Add the following figures to Informative Appendix A:

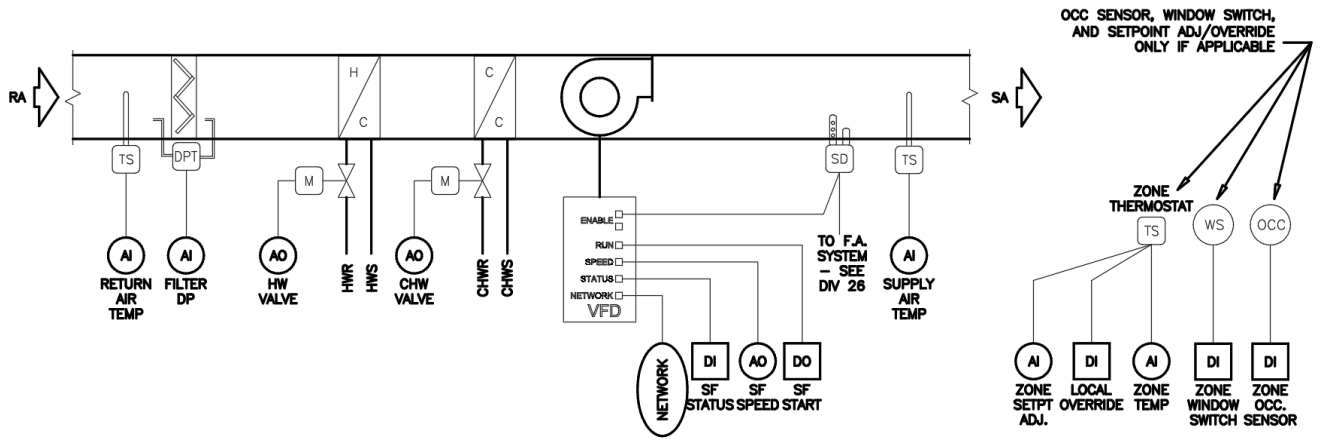

Figure A-14 Fan Coil Unit with variable volume fan, heating and cooling coils

Add the following initialism to Informative Appendix B:

FCU Fan coil unit

POLICY STATEMENT DEFINING ASHRAE'S CONCERN FOR THE ENVIRONMENTAL IMPACT OF ITS ACTIVITIES

ASHRAE is concerned with the impact of its members' activities on both the indoor and outdoor environment. ASHRAE's members will strive to minimize any possible deleterious effect on the indoor and outdoor environment of the systems and components in their responsibility while maximizing the beneficial effects these systems provide, consistent with accepted Standards and the practical state of the art.

ASHRAE's short-range goal is to ensure that the systems and components within its scope do not impact the indoor and outdoor environment to a greater extent than specified by the Standards and Guidelines as established by itself and other responsible bodies.

As an ongoing goal, ASHRAE will, through its Standards Committee and extensive Technical Committee structure, continue to generate up-to-date Standards and Guidelines where appropriate and adopt, recommend, and promote those new and revised Standards developed by other responsible organizations.

Through its *Handbook*, appropriate chapters will contain up-to-date Standards and design considerations as the material is systematically revised.

ASHRAE will take the lead with respect to dissemination of environmental information of its primary interest and will seek out and disseminate information from other responsible organizations that is pertinent, as guides to updating Standards and Guidelines.

The effects of the design and selection of equipment and systems will be considered within the scope of the system's intended use and expected misuse. The disposal of hazardous materials, if any, will also be considered.

ASHRAE's primary concern for environmental impact will be at the site where equipment within ASHRAE's scope operates. However, energy source selection and the possible environmental impact due to the energy source and energy transportation will be considered where possible. Recommendations concerning energy source selection should be made by its members.

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7/21