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Mechanical Systems

Overview

The objective of the Energy Code for mechanical systems is to reduce energy consumption while maintaining occupant comfort by:

- Maximizing equipment efficiency at design conditions and during part load operation
- Minimizing distribution losses of heating and cooling systems
- Optimizing system control to minimize unnecessary operation and simultaneous use of heating and cooling energy

An important goal of the Energy Code is also to ensure that indoor air quality is adequate for occupant comfort and health. The 2025 Energy Code incorporates requirements for outdoor air ventilation that must be met during normally occupied hours.

This chapter summarizes the requirements for space conditioning, ventilation, and service water heating systems for non-process loads in nonresidential buildings. Chapter 10 covers process loads in nonresidential buildings and spaces.

Acceptance requirements apply to all covered systems regardless of whether the prescriptive or performance compliance approach is used.

Chapter 12 details the mandated acceptance test requirements, which are summarized at the end of each section.

What's New for 2025

- New prescriptive requirements for single zone space conditioning system types for alterations
- New prescriptive requirements for multizone space conditioning systems in some building types and climate zones for new construction
- Changes to prescriptive requirements for HVAC system controls
- New prescriptive efficiency requirements for axial fan, open-circuit cooling towers
- Updates to cooling tower controls requirements
- New prescriptive requirements for simultaneous mechanical heat recovery
- New mandatory requirement for a 130°F limit to hot water supply temperatures for space conditioning hydronic systems

HVAC Energy Use

Please refer to Chapter 4.1.2 of the *2022 Nonresidential and Multifamily Compliance Manual.*

Prescriptive and Performance Compliance Approaches

Please refer to Chapter 4.1.3 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Prescriptive Compliance Approach

Please refer to Chapter 4.1.3.1 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Performance Compliance Approach

The performance compliance approach, Section 140.1, allows the designer to trade off energy use between different building systems. This approach provides greater design flexibility but requires extra effort and a computer simulation of the building. The design must meet or exceed all mandatory requirements.

Performance approach trade-offs can be applied to the following disciplines: mechanical, lighting, envelope, and covered processes. The performance approach requires creating an energy model using approved Energy Commission compliance software for the proposed design that reflects the feature of the proposed building. The software will automatically create a standard design model based on the features of the proposed design which meets mandatory and prescriptive requirements (per the Alternative Calculation Method Reference Manual). The compliance software will compare the energy use of the two designs.

The proposed design complies with the Energy Code if it results in lower long-term system cost (LSC) energy use than the standard design.

The performance approach may only be used to model the performance of mechanical systems that are covered under the building permit application (see Performance Approach for more detail).

Equipment Requirements

Please refer to Chapter 4.2 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Mandatory Requirements

Mechanical equipment must be certified by the manufacturer as complying with the mandatory requirements in the following sections:

- Section 110.0 - General and Certification Requirements for Systems and Equipment
- Section 110.1 - Mandatory Requirements for Appliances.
- Section 110.2 - Mandatory Requirements for Space-Conditioning Equipment
    - Efficiency
    - Gas- and Oil-Fired Furnace Standby Loss Controls
    - Low Leakage Air-Handling Units
- Section 110.3 - Mandatory Requirements for Service Water-Heating Systems and Equipment
    - Certification by Manufacturers
    - Efficiency
- Section 110.4 - Mandatory Requirements for Pool and Spa Systems and Equipment
    - Certification by Manufacturers
- Section 110.5 - Natural Gas Central Furnaces, Cooking Equipment, Pool and Spa Heaters, and Fireplaces: Pilot Lights Prohibited
- Section 110.12 – Mandatory Requirements for Demand Management

Mechanical equipment must be specified and installed in accordance with sections:

- Section 110.2 - Mandatory Requirements for Space-Conditioning Equipment
    - Controls for Heat Pumps with Supplementary Heaters

    - Thermostats
    - Open and Closed-Circuit Cooling Towers (blowdown control)
- Section 110.3 - Mandatory Requirements for Service Water-Heating Systems and Equipment
- Section 110.4 - Mandatory Requirements for Pool and Spa Systems and Equipment
    - Installation
    - Heating Source Sizing
    - Controls for Heat Pump Pool Heaters with Supplementary Heating
- Section 110.12 – Mandatory Requirements for Demand Management
- Section 120.1 - Requirements for Ventilation and Indoor Air Quality
- Section 120.2 - Required Controls for Space-Conditioning Systems (see HVAC System Control Requirements)
    - Zonal thermostatic controls
    - Occupant Controlled Smart Thermostats (OCST)
    - Dampers for air supply and exhaust equipment
    - Isolation area devices
    - Economizer Fault Detection and Diagnostics
    - Direct Digital Controls (DDC)
    - Optimum Start/Stop Controls
    - HVAC Hot Water Temperature
- Section 120.3 - Requirements for Pipe Insulation
- Section 120.4 - Requirements for Air Distribution System Ducts and Plenums
- Section 120.5 - Required Nonresidential Mechanical System Acceptance
- Section 120.8 - Commissioning
- Section 120.9 – Commercial Boilers
- Section 120.10 – Fan Energy Index

Space-Conditioning Equipment Efficiency

Reference: Section 110.2(a)

All space conditioning equipment installed in a nonresidential building, subject to these regulations, must be certified as meeting certain minimum efficiency and control requirements. These requirements are contained in Section 110.2 and vary based on the type and capacity of the equipment.

Where more than one efficiency standard or test method is listed, the requirements of both shall apply. For example, air-cooled air conditioners have an EER requirement for full-load operation and an IEER for part-load operation. The air conditioner must have both a rated EER and IEER equal to or higher than the minimum standard specified in the Energy Code at the specified Air-Conditioning, Heating, and Refrigeration Institute (AHRI) standard rating conditions. Where equipment serves more than one function, it must comply with the efficiency standards applicable to each function.

When there is a requirement for equipment rated at its “maximum rated capacity” or “minimum rated capacity,” the proper capacity shall be maintained by the controls during steady state operation. For example, a boiler with high/low firing must meet the efficiency requirements when operating at both its maximum capacity and minimum capacity.

Three exceptions exist to the listed minimum efficiency for specific equipment.

Exception 1 applies to water-cooled centrifugal water-chilling packages not designed for operation at ANSI/AHRI Standard 550/590 test conditions, which are:

- 44 degrees Fahrenheit (F) leaving chilled water temperature
- 85 degrees F entering condenser water temperature
- Three gallons per minute per ton condenser water flow

Packages not designed to operate at these conditions must have maximum adjusted full load and NPLV ratings, which can be calculated in kW/ton, using the following equations.

$$Full\ Load\ Rating_{max,adj} = \frac{(Full\ Load\ Rating)}{K_{adj}}$$

$$NPLV\ Rating_{max,adj} = \frac{(IPLV\ Rating)}{K_{adj}}$$

The values for the Full Load and IPLV ratings are found in Table 110.2-D .. K_{adj} is the product of A and B, as in the following equation.

$$K_{adj} = A \times B$$

A is calculated by entering the value for $LIFT$ into the fourth level polynomial:

$$A = (1.4592 \times 10^{-7})(LIFT^4) - (3.46496 \times 10^{-5})(LIFT^3) + (3.14196 \times 10^{-3})(LIFT^2) - (0.147199)(LIFT) + 3.9302$$

$LIFT$ is calculated using the following equation.

$$LIFT = LvgCond - LvgEvap$$

Where,

- $LvgCond$ = Full-load leaving condenser fluid temperature (°F)
- $LvgEvap$ = Full-load leaving evaporator fluid temperature (°F)

B is found using the following equation.

$$B = (0.0015)(LvgEvap) + 0.934$$

Where,

- $LvgEvap$ = Full-load leaving evaporator fluid temperature (°F)

The maximum adjusted full-load and NPLV rating values are only applicable for centrifugal chillers meeting all of the following full-load design ranges:

- Minimum leaving evaporator fluid temperature: 36 degrees F
- Maximum leaving condenser fluid temperature: 115 degrees F
- LIFT greater than or equal to 20 degrees F and less than or equal to 80 degrees F

Centrifugal chillers designed to operate outside of these ranges are not covered by this exception and therefore have no minimum efficiency requirements.

Exception 2 is for positive displacement (air-cooled and water-cooled) chillers with a leaving evaporator fluid temperature higher than 32 degrees F. This equipment shall comply with Table 110.2-D in the Energy Code when tested or certified with water at standard rating conditions, per the referenced test procedure.

Exception 3 is for equipment primarily serving refrigerated warehouses or commercial refrigeration systems. These systems must comply with the efficiency requirements of Energy Code Section 120.6(a) or (b). For more information, see Chapter 10.

Equipment Not Covered by the Appliance Efficiency Regulations

Please refer to Chapter 4.2.3 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Controls for Heat Pumps with Supplementary Heaters

Reference: Section 110.2(b)

The Energy Code discourages the use of supplementary heating when the primary heating source has sufficient capacity to meet the load. Heat pumps may contain electric resistance heat strips or a gas fired furnace which serves as a supplementary heating source. If this type of system is used, then controls must be put in place to prevent the use of the supplementary heating when the heating load can be satisfied with the heat pump alone. The controls must set a cut-on temperature for heat pump heating higher than the cut-on temperature for supplementary heating. The cut-off temperature for heat pump heating must also be set higher than the cut-off temperature for supplementary heating. Consideration for cut-on temperatures in relation to cut-off temperatures should also be made to ensure that equipment provides heating when the space is occupied and to avoid sudden switching between heat pump and supplementary heating.

Exceptions exist for these control requirements if one of the following applies:

- During defrost.
- During transient periods such as start-ups and following room thermostat setpoint advances (or another control mechanism designed to preclude unnecessary operation).
- The heat pump is a room air-conditioner heat pump.

Thermostats

Please refer to Chapter 4.2.5 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Furnace Standby Loss Controls

Please refer to Chapter 4.2.6 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Open- and Closed-Circuit Cooling Towers

Reference: Section 110.2(e)

All open and closed-circuit cooling towers with rated capacity of 150 tons or greater must have a control system that maximizes the achievable cycles of concentration based on the local water quality conditions. The controls system must be conductivity based and must automate bleed and chemical feed based on conductivity. The installation criteria for the conductivity controllers must be in accordance with the manufacturer’s specifications to maximize accuracy. Controls performance shall be verified by an acceptance test per NA 7.5.18.

The makeup water line must be equipped with an analog flow meter and an alarm to prevent overflow of the sump in the event of makeup water valve failure. The alarm system must send an audible signal or an alert through an energy management control system (EMCS). The functionality of this alarm system shall be verified per NA 7.5.18.

Drift eliminators are louvered or comb-like devices that are installed at the top of the cooling tower to capture air stream water particles. These drift eliminators are required to achieve drift reduction to 0.002 percent of the circulated water volume for counter-flow towers and 0.005 percent for crossflow towers.

Additionally, the designer must use the equations documented in Section 110.2(e)2 to calculate the maximum achievable cycles of concentration based on local water quality conditions (which are reported annually by the local utility), and the parameters identified in Table 110.2-A-1. The target maximum achievable cycles of concentration must be cataloged in the mechanical compliance documentation (NRCC-MCH-E) and reviewed and approved by the Professional Engineer (P.E.) of record.

Cooling towers shall not allow blowdown until one or more of the recirculating water parameters listed in Table 110.2-A-1 reaches the maximum values specified.

Pilot Lights

Please refer to Chapter 4.2.8 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Commercial Boilers

Reference: Section 120.9, Section 140.4(k)8, Section 140.5

A commercial boiler is a type of boiler with a capacity (rated maximum input) of 300,000 Btu/h or more and serving a space heating or water heating load in a commercial building.

There are two types of commercial packaged boilers:

- Boilers designed to operate with a nonpositive vent static pressure, sometimes referred to as natural draft or atmospheric boilers; and
    - Forced draft boilers, which rely on a fan to provide the appropriate amount of air into the combustion chamber.

Combustion air positive shut-off

Combustion air positive shut-off is a means of restricting air flow through a boiler combustion chamber during standby periods and is used to reduce standby heat loss. A flue damper and a vent damper are two examples of combustion air positive shut-off devices. Natural draft boilers receive the most benefit from combustion air positive shut-off because they have less resistance to airflow than forced draft boilers. Forced draft boilers rely on the driving force of the fan to push the combustion gases through an air path that has relatively higher resistance to flow than in a natural draft boiler. Positive shut off on a forced draft boiler is most important on systems with a tall stack height or multiple boiler systems sharing a common stack.

Combustion air positive shut-off shall be provided on all newly installed commercial boilers as follows:

- All natural draft boilers with an input capacity of 2.5 MMBtu/h (2,500,000 Btu/h) and above, in which the boiler is designed to operate with a non-positive vent static pressure
- All natural draft and forced-draft boilers where one stack serves two or more boilers with a total combined input capacity per stack of 2.5 MMBtu/h (2,500,000 Btu/h).

Combustion air fan motor requirements

Electricity savings are available from efficient part-load operation achieved by decreasing combustion air fan speed as the boiler firing rate decreases.

Combustion air fan motors of 10 horsepower or more in newly installed boilers must:

- Be driven by a variable speed drive; or
- Include controls that limit fan motor demand to no more than 30 percent of total design wattage, at 50 percent of design air volume.

Stack-gas oxygen concentration requirements

Boilers mix air with fuel (usually natural gas although sometimes diesel or oil) to supply oxygen during combustion. Stoichiometric combustion is the ideal air/fuel ratio where the mixing proportion is correct, the fuel is completely burned, and the oxygen is entirely consumed. Boilers operate most efficiently when the combustion air flow rate is slightly higher than the stoichiometric air-fuel ratio. However, common practice almost always relies on excess air to ensure complete combustion, avoid unburned fuel and potential explosion, and prevent soot and smoke in the exhaust. The drawbacks of excess air are increased stack heat loss and reduced combustion efficiency.

Newly installed boilers with an input capacity of 5 MMBtu/h (5,000,000 Btu/h) and greater shall maintain stack-gas oxygen concentrations at less than or equal to 5 percent by volume on a dry basis over firing rates of 20 percent to 100 percent. Combustion air volume shall be controlled with respect to firing rate or measured flue gas oxygen concentration. Use of a common gas and combustion air control linkage or jack shaft is prohibited. Boilers with steady state full-load thermal efficiency of 90 percent or higher are not subject to this requirement.

There are two control systems to meet stack-gas oxygen requirements:

- Parallel positioning combustion
- Oxygen trim

Parallel positioning combustion control

A parallel positioning combustion control system optimizes the combustion excess air based on the firing rate of the boiler to improve the combustion efficiency of the boiler. These systems allow excess air to remain relatively low throughout a burner's firing range. Maintaining low excess air levels at all firing rates provides significant fuel and cost savings while still maintaining a safe margin of excess air to insure complete combustion. These systems include individual servo motors allowing the fuel supply valve and the combustion air damper to operate independently of each other. This system relies on preset fuel mapping (i.e., a pre-programmed combustion curve) to establish proper air damper positions (as a function of the fuel valve position) throughout the full range of burner fire rate. Developing the combustion curve is a manual process. It is performed in the field with a flue-gas analyzer in the exhaust stack, determining the air damper positions as a function of the firing rate/fuel valve position. The combustion curve is developed at multiple points (firing rates), typically 10 to 25 points

Oxygen trim control

Oxygen trim control systems measure the flue gas oxygen concentration to optimize combustion efficiency, and can provide higher levels of efficiency than parallel positioning combustion control systems based only on firing rate, as oxygen trim control can also account for the relative humidity of the combustion air. This control strategy relies on parallel positioning hardware and software as the basis but goes a step further to allow operation closer to stoichiometric conditions. Oxygen trim control converts parallel positioning to a closed-loop control configuration with the addition of an exhaust gas analyzer and proportional-integral-derivative (PID) controller. This strategy continuously measures the oxygen content in the flue gas and adjusts the combustion air flow, thus continually tuning the air-fuel mixture.

High capacity space heating gas boiler systems

Gas-fired hot water boiler systems with capacity between 1 and 10 million Btu/h, installed in newly constructed commercial buildings, shall have a capacity-weighted average thermal efficiency of 90 percent. In order to achieve a thermal efficiency at or over 90 percent, all or some of the boilers must have condensing capability. Condensing boilers condense moisture out of flue gas, recovering latent heat from water vapor. These boilers include a means of collecting and draining this condensate from its heat exchanger. Boilers within the same building but on separate loops are not considered to be a part of the same system. Weighted thermal efficiencies are calculated based off the input each boiler provides to the total system capacity.

Boiler systems in Climate Zones 7, 8, and 15 are not subject to this requirement.

Additionally, gas boilers with input capacity of less than 300,000 Btu/h are subject to the efficiency standards listed in Section 110.2 and shall not be included in the calculation of total system input or efficiency.

Additional requirements for the hot water distribution systems served by these boilers help optimize condensing capabilities.

- First, space heating coils and heat exchangers must be sized so that under design conditions the return temperature of the hot water to the boilers is 120°F or less. Condensing operation requires a sufficient difference in temperatures between the inlet and outlet water.
- Second, hot water space heating systems are designed so that under all conditions the return water entering the boiler(s) must be 120°F or less, or flow rates for supply hot water that recirculates directly into the return system must be no greater than 20 percent of the design flow of the operating boiler. This flow rate requirement increases the likelihood that the boiler system will operate in the condensing range by increasing the amount of time the heating medium, water, contacts the heat exchanger.

There are three exceptions to this condensing requirement:

- Space heating boilers where 25 percent of the annual space heating capacity is provided by on-site renewable energy (wind, photovoltaics , solar thermal) or site-recovered energy (heat recovery chiller, condenser desuperheater, refrigeration heat recovery, etc.).
    - Space heating boilers installed in individual dwelling units.

- Systems where 50 percent of more of the design heating load is served using perimeter convective heating, radiant ceiling panels, or both.

Example 4-1

Question:

If I have the following 4 boilers, how do I calculate weighted average thermal efficiency? Boiler 1 with capacity 500,000 Btu/h; Boiler 2 with capacity 600,000 Btu/h and serving an individual dwelling unit; Boiler 3 with capacity 250,000 Btu/h; Boiler 4 with capacity 750,000 Btu/h. Boiler 1 has thermal efficiency (TE) of 90%, Boiler 2 has a TE of 87%, Boiler 3 has a TE of 95%, and Boiler 4 has a TE of 95%.

Answer:

Since Boiler 2 serves an individual dwelling unit, it is not included in the weighted efficiency calculation. Similarly, since Boiler 3 has a capacity below 300,000 Btu/h, it is not included either. To calculate the weighted average thermal efficiency of Boilers 1 and 4, multiply both boilers' thermal efficiency by their capacity, add the two values together, and divide by the combined capacity. So, multiply 90% TE and 500,000 Btu/h and multiply 95% TE and 750,000 Btu/h. Add these two products together and divide by 1,250,000 Btu/h. The result is a weighted thermal efficiency of 93%.

Fan Energy Index

Please refer to Chapter 4.3 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Ventilation and Indoor Air Quality Requirements

Reference: Section 120.1

All of the ventilation and indoor air quality requirements are mandatory measures. Some measures require acceptance testing, which is addressed in Chapter 13.

Within a building, all space that is normally used by humans must be continuously ventilated (with outdoor air) during occupied hours, using either natural or mechanical ventilation as specified in Section 120.1(c). Ventilation requirements for healthcare facilities shall conform to the requirements in Chapter 4 of the California Mechanical Code.

"Spaces normally used by humans" refers to spaces where people can be reasonably expected to remain for an extended period of time. Spaces where occupancy will be brief and intermittent that do not have any unusual sources of air contaminants do not need to be directly ventilated. For example:

- A closet, provided it is not normally occupied
- A storeroom that is only infrequently or briefly occupied. However, a storeroom that can be expected to be occupied for extended periods for clean-up or inventory must be ventilated, preferably with systems controlled by a local switch so that the ventilation system operates only when the space is occupied.

"Continuously ventilated during occupied hours" implies that minimum ventilation must be provided throughout the entire occupied period. Variable air volume (VAV) systems must provide the code-required ventilation over the full range of operating supply airflow.

Therefore, some means of dynamically controlling the minimum ventilation air must be provided.

Air Filtration

Reference: Section 120.1(c)1

Indoor air quality of occupied spaces may be degraded if poor quality outdoor air is brought in without first being cleaned. Particles less than 2.5 µm are referred to as "fine" particles, and because of their small size, can lodge deeply into the lungs. There is a strong correlation between exposure to fine particles and premature mortality. Other effects of particulate matter exposure include respiratory and cardiovascular disease. Because of these adverse health effects, advances in filtration technology, and market availability of said technology, removal of fine particulate contaminants by use of filtration is reasonable and achievable.

Air filter efficiency

The Energy Code requires that filters have a particle removal efficiency equal to or greater than the minimum efficiency reporting value (MERV) 13 when tested in accordance with ASHRAE Standard 52.2, or a particle size efficiency rating equal to or greater than 50 percent in the 0.3-1.0 µm range, and equal to or greater than 85 percent in the 1.0-3.0 µm range when tested in accordance with AHRI Standard 680.

Mechanical system types requiring air filtration

The following system types are required to provide air filtration:

- Mechanical space-conditioning (heating or cooling) systems that utilize forced air ducts greater than 10 feet in length to supply air to an occupied space. The total is determined by summing the lengths of all the supply and return ducts for the forced air system.

Mechanical supply-only ventilation systems and makeup air systems that provide outside air to an occupied space.

- The supply side of mechanical balanced ventilation systems, including heat recovery ventilators and energy recovery ventilators that provide outside air to an occupied space.

Note that for heat recovery ventilators and energy recovery ventilators, the filters may be downstream of a system thermal conditioning component, provided there is ancillary filtration upstream of the system's thermal conditioning component.

Air Filter Requirements

Space conditioning systems and ventilation systems in nonresidential and hotel/motel occupancies may use either of the two following compliance approaches:

- Install a filter grille or accessible filter rack sized by the system designer to accommodate a minimum nominal 2-inch depth filter and install the appropriate filter.
- Install a filter grille or accessible filter rack that accommodates a minimum nominal 1-inch depth filter and install the appropriate filter. The filter/grille must be sized for a face velocity of less than or equal to 150 ft per minute. The installed filter must be labeled to indicate that the pressure drop across the filter at the design airflow rate is less than or equal to 0.1-inch w.c. (25 PA).

To calculate the air filter face area in sq ft, use the following equation:

$$A_{face} = \frac{Q_{filter}}{V_{face}}$$

Since air filters are sold using nominal sizes in terms of inches, convert the face area to sq in by multiplying the face area (sq ft) by a conversion factor of 144 sq inch/sq ft.

Field verification and diagnostic testing of system airflow in accordance with the procedures in NA1 (Energy Code Compliance (ECC)-Verification) is not required for nonresidential and hotel/motel occupancies.

Energy Code Factors that Affect Air Filter Pressure Drop

Please refer to Chapter 4.4.1.1.1 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Filter Access and Filter Grille Sticker – Design Airflow and Pressure Drop

Please refer to Chapter 4.4.1.1.2 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Air Filter Selection

Please refer to Chapter 4.4.1.1.3 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Natural Ventilation Requirements

Reference: Section 120.1(c)2

The 2019 Energy Code changed the specifications for spaces that are to be naturally ventilated by adopting ASHRAE 62.1. Under these new requirements, naturally ventilated spaces or portions of spaces must be permanently open to and within certain distances of operable wall openings to the outdoors. The space being ventilated, the size of the operable opening, and the control of the opening are all considered under these new requirements. Naturally ventilated spaces must also include a mechanical ventilation system that complies with Section 120.1(c)3, except when: (1) the space has openings to the outdoors that are permanently open or has controls that prevent the opening from being closed during periods of expected occupancy; (2) or is not served by a space-conditioning system. This requirement for mechanical ventilation back-up to a naturally ventilated space protects the occupants during times or events when the outdoor air quality is not adequate for ventilation without filtration and does not rely on an individual to open the opening.

The space to be naturally ventilated is determined based on the configuration of the walls (cross-ventilation, single-sided, or adjacent walls) and the ceiling height. For spaces with an operable opening on only one side of the zone, only the floor area within two times the ceiling height from the opening is permitted to be naturally ventilated. For zones with openings on two opposite sides of the zone, only the floor areas within five times the ceiling height from the openings are permitted to be naturally ventilated. For zones with operable openings on two adjacent sides of the zone (two sides of a corner), only the floor areas along a line drawn between the outside edges of the two openings that are the farthest apart meet the requirement. Floor areas not along these lines connecting the windows must meet the one side or two opposite side opening calculation to be permitted to be naturally ventilated. The ceiling height for all of these cases is the minimum ceiling height, except when the ceiling is sloped upwards from the opening. In that case, the ceiling height is calculated as the average within 20 feet of the opening.

Zones or portions of zones being naturally ventilated must have a permanently open airflow path to openings directly connected to the outdoors. The minimum openable area is required to be 4 percent of the net occupiable floor area being naturally ventilated. Where openings are covered with louvers or otherwise obstructed, the openable area must be based on the free unobstructed area through the opening. Where interior spaces without direct openings to the outdoors are ventilated through adjoining rooms, the opening between rooms must be permanently unobstructed and have a free area of not less than 8 percent of the area of the interior room nor less than 25 sq. ft.

The means to open required operable openings must be readily accessible to building occupants whenever the space is occupied. The operable opening must be monitored to coordinate the operation of the operable opening and the mechanical ventilation system. This is achieved through window contact switches or another type of relay switch that interlocks the operable opening with the mechanical ventilation system. (Section 140.4(n))

Mechanical Ventilation

Reference: Section 120.1(c)3, Table 120.1-A

Mechanical outdoor ventilation must be provided for all spaces normally occupied. The Energy Code requires that a mechanical ventilation system provide outdoor air equal to or exceeding the ventilation rates required for each of the spaces that it serves. At the space, the required ventilation can be provided either directly through supply air or indirectly through transfer of air from the plenum or an adjacent space (see Direct Air Transfer for updates to transfer air classification). The required minimum ventilation airflow rate at the space can be provided by an equal quantity of supply or transfer air. At the air-handling unit, the minimum outside airflow rate must be the sum of the ventilation requirements of each of the spaces that it serves. The designer may specify higher outside air ventilation rates based on the owner's preference or specific ventilation needs associated with the space. However, specifying more ventilation air than the minimum allowable ventilation rates increases energy consumption and electrical peak demand and increases the costs of operating the HVAC equipment. Thus, the designer should have a compelling reason to specify higher design minimum outside air rates than the calculated minimum outside air requirements.

The minimum outside air (OSA) as measured by acceptance testing, is required to be within 10 percent of the design minimum for both VAV and constant volume units. The design minimum outside airflow rate can be no less than the calculated minimum outside airflow rate.

In summary:

- Ventilation compliance at the space is satisfied by providing supply and/or transfer air.
- Ventilation compliance at the air handling system level is satisfied by providing, at minimum, the outdoor air that represents the sum of the ventilation requirements of all the spaces that it serves.

For each space requiring mechanical ventilation, the ventilation rate (V_z) must be the larger of either:

- The net occupiable floor area (A_z) of the space multiplied by the area-based outdoor air rate (R_a) from Table 120.1-A. This provides dilution for the building-borne contaminants like off-gassing of paints and carpets; or
  - The outdoor airflow per person (R_p) multiplied by the expected number of occupants (P_z). R_p shall be 15 cubic feet per minute per person. The expected number of occupants for each space (P_z) shall be the number specified by the building designer or the default occupancy density in Table 120.1-A times the net occupiable floor area of the space, whichever is greater. For spaces with fixed seating (such as a theater or auditorium), the expected number of occupants for each space (P_z) shall be the number of fixed seats or as determined by the California Building Code.

As previously stated, each ventilation system must provide outdoor ventilation air as follows:

1. For a ventilation system serving a single space, the required system outdoor airflow rate is equal to the design outdoor ventilation rate of the space.
2. For a ventilation system serving multiple spaces, the required outdoor air quantity delivered by the system must not be less than the sum of the required outdoor ventilation rate to each space. The Energy Code does not require that each space actually receive its exact calculated outdoor air quantity. Instead, the supply air to any given space may be any combination of recirculated air, outdoor air, or air transferred directly from other spaces, provided:
   i. The total amount of outdoor air delivered by the ventilation system(s) to all spaces is at least as large as the sum of the space design quantities.
   ii. Each space always receives supply airflow, including recirculated air and/or transfer air, no less than the calculated outdoor ventilation rate.
   iii. When using transfer air, none of the spaces from which air is transferred has any unusual sources of contaminants.

Example 4-2: Ventilation for a Two-Room Building

Question:

Consider a building with two spaces, each having an area of 1,000 sq ft. One space is used for general administrative functions, and the other is used as a classroom. It is estimated that the office will contain seven people, and the classroom will contain 50 people (fixed seating). What are the required outdoor ventilation rates?

Answer:

- For the office area, the design outdoor ventilation airflow rate is the larger of:
  - 7 people x 15 cfm/person = 105 cfm; or
  - 1,000 ft² x 0.15 cfm/ft² = 150 cfm
  - For this space, the design ventilation rate is 150 cfm.
- For the classroom, the design outdoor ventilation air is the larger of:
  - 50 people x 15 cfm/person = 750 cfm; or
  - 1,000 ft² x 0.15 cfm/ft² = 150 cfm
  - For this space the design ventilation rate is 750 cfm.

Assume the total supply air necessary to satisfy cooling loads is 1,000 cfm for the office and 1,500 cfm for the classroom. If each space is served by a separate system, then the required outdoor ventilation rate of each system is 150 cfm and 750 cfm, respectively. This corresponds to an outside air fraction of 15 percent in the office HVAC unit, and 50 percent in the classroom unit.

If both spaces are served by a central system, then the total supply will be (1,000 + 1,500) cfm = 2500 cfm. The required outdoor ventilation rate is (150 + 750) = 900 cfm total. The actual outdoor air ventilation rate for each space is:

- Office outside air = 900 cfm x (1,000 cfm / 2,500 cfm) = 360 cfm
- Classroom outside air = 900 cfm x (1,500 cfm / 2,500 cfm) = 540 cfm

While this simplistic analysis suggests that the actual outside air cfm to the classroom is less than design (540 cfm vs. 750 cfm), the analysis does not take credit for the dilution effect of the air recirculated from the office. The office is over-ventilated (360 cfm vs. 150 cfm) so the concentration of pollutants in the office return air is low enough that it can be used, along with the 540 cfm of outdoor air, to dilute pollutants in the classroom. The Energy Code allows this design provided that the system always delivers at least 750 cfm to the classroom (including transfer or recirculated air), and that any transfer air is free of unusual contaminants.

Exhaust Ventilation

Reference: Section 120.1(c)4, Table 120.1-A, Table 120.1-B

The exhaust ventilation requirements are aligned with ASHRAE 62.1 and require certain occupancy categories to be exhausted to the outdoors, as listed in Table 120.1-A. Exhaust flow rates must meet or exceed the minimum rates specified in Table 120.1-B. The spaces listed are expected to have contaminants not generally found in adjacent occupied spaces. Therefore, the air supplied to the space to replace the air exhausted may be any combination of outdoor air, recirculated air, and transfer air – all of which are expected to have low or zero concentration of the pollutants generated in the listed spaces. For example, the exhaust from a toilet room can draw air from either the outdoors, adjacent spaces, or from a return air duct or plenum. Because these sources of makeup air have essentially zero concentration of toilet-room odors, they are equally good at diluting odors in the toilet room.

The rates specified must be provided during all periods when the space is expected to be occupied, similar to the requirement for ventilation air.

Air Classification and Recirculation Limitations

Reference: Section 120.1(g), Table 120.1-A, Table 120.1-B, Table 120.1-C

Air from difference occupancy categories are assigned an air class numberthat determines limits on transferring or recirculating that air. This air classification system offers designers clear guidance on what air can and cannot be used for transfer, makeup, or recirculation air. In the past, the Energy Code allowed air transfer as long as the air did not have "unusual sources of indoor air contaminants," which resulted in arbitrary enforcement of this rule. Now, all spaces listed in Table 120.1-A are assigned an air class and specific direction is given for each class in alignment with ASHRAE 62.1.

Class 1: This class consists of air with low contaminant concentration, low sensory-irritation intensity or inoffensive odor, and is suitable for recirculation or transfer to any space. Some examples include classrooms, lecture halls, and lobbies.

Class 2: This class consists of air with moderate contaminant concentration and mild sensory-irritation intensity or mildly offensive odors. Class 2 air is suitable for recirculation or transfer to any space with Class 2 or Class 3 air that is utilized for the same or similar purpose and involves the same or similar pollutant sources. Class 2 air may be transferred to toilet rooms and to any Class 4 air occupancies. Class 2 air is not suitable for recirculation or transfer to dissimilar spaces with Class 2 or Class 3 air. It is also not suitable in spaces with Class 1 air, unless the Class 1 space uses an energy recovery device. In this case, recirculation from leakage, carryover, or transfer from the exhaust side of the energy recovery device is permitted. The amount of Class 2 air allowed to be transferred or recirculated shall not exceed 10 percent of the outdoor air intake flow.

Thus, HVAC systems serving spaces with Class 2 air shall not share the same air handler as spaces with Class 1 air. Some examples of Class 2 spaces include warehouses, restaurants, and auto repair rooms.

Class 3: This class consists of air with significant contaminant concentration and significant sensory-irritation intensity or offensive odor. Recirculation of Class 3 air is only permitted within the space of origin. It is not suitable for recirculation or transfer to any other spaces. However, when a space uses an energy recovery device, then recirculation from leakage carryover or transfer from the exhaust side of the energy recovery device is permitted. In this case the amount of Class 3 air allowed to be transferred or recirculated shall not exceed 5 percent of the outdoor air intake flow. HVAC systems serving spaces with Class 3 air shall not share the same air handler serving spaces with Class 1 or Class 2 air. Some examples of Class 3 spaces include general manufacturing (excludes heavy industrial and processes using chemicals) and janitor closets.

Class 4: This class consist of air with highly objectionable fumes or gases or with potentially dangerous particles, bioaerosols, or gases at concentrations high enough to be considered harmful. Class 4 air is not suitable for recirculation or transfer within the space of origin or to any other space. No leakage of Class 4 air from energy recovery devices is allowed. Some examples of Class 4 spaces include spray paint booths and chemical storage rooms.

In addition to Table 120.1-A and Table 120.1-B, the Energy Code also includes air classifications for specific airstreams and sources as detailed in Table 120.1-C. In the event that Table 120.1-A, Table 120.1-B, and Table 120.1-C do not list the space or location, the air classification of the most similar space listed in terms of occupant activities or building construction shall be used.

For ancillary spaces that are designated as Class 1 air but support a Class 2 air space, re-designation of these ancillary spaces to Class 2 areas is allowed. For example, a bank lobby is designated as Class 1 while bank vaults or safety deposit areas are designated at Class 2. The ancillary space to the bank safety deposit area can be re-designated to Class 2 from Class 1.

Direct Air Transfer

Please refer to Chapter 4.4.6 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Distribution of Outdoor Air to Zonal Units

Reference: Section 120.1(e)

When a return plenum is used to distribute outside air to a zonal heating or cooling unit, the outside air supply must be connected either:

- Within 5 ft. of the unit; or
- Within 15 ft. of the unit, with the air directed substantially toward the unit, and with a discharge velocity of at least 500 ft per minute.

Water source heat pumps and fan coils are the most common application of this configuration. The unit fans should be controlled to run continuously during occupancy in order for the ventilation air to be circulated to the occupied space.

Not all spaces are required to have a direct source of outdoor air. Transfer air is allowed from adjacent spaces with direct outdoor air supply if the system supplying the outdoor air is capable of supplying the required outdoor air to all spaces at the same time. Air classification and recirculation limitations will apply, as explained above. An example of an appropriate use of transfer would be in buildings having central interior space-conditioning systems with outdoor air supply and zonal units on the perimeter without a direct outdoor air supply.

Ventilation System Operation and Controls

Outdoor Ventilation Air and VAV Systems

Reference: Section 120.1(d)

Except for systems employing Energy Commission-certified DCV devices or space occupancy sensors, the Energy Code requires that the minimum rate of outdoor air calculated per Section 120.1(c)3 be provided to each space *at all times* when the space is normally occupied according to Section 120.1(d)1. For spaces served by VAV systems, the minimum supply setting of each VAV box should be no less than the design outdoor ventilation rate calculated for the space, unless transfer air is used. If transfer air is used, the minimum box position, plus the transfer air, must meet the minimum ventilation rate.

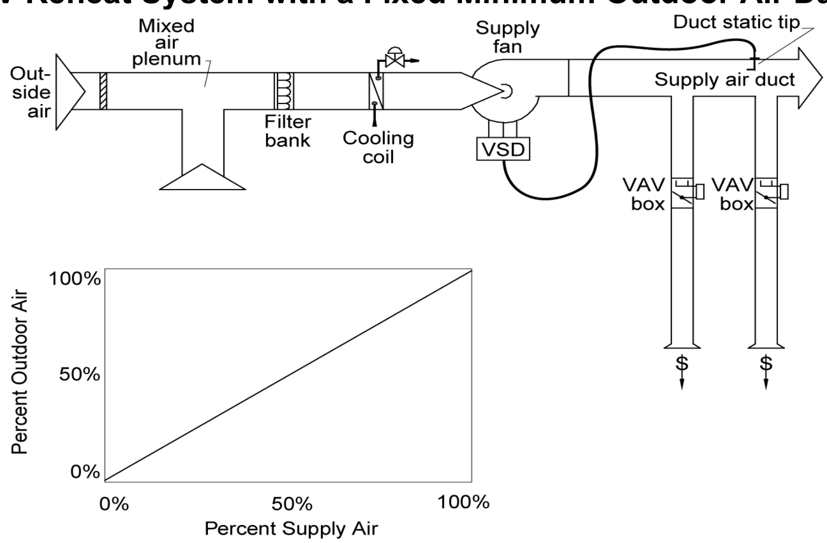
The design outdoor ventilation rate at the system level must always be maintained when the space is occupied, even when the fan has modulated to its minimum capacity per Section 120.1(d)1. Acceptance Requirements describes mandated acceptance test requirements for outside air ventilation in VAV air handling systems where the minimum outside air will be measured at full flow with all boxes at minimum position.

Figure 4- 1: VAV Reheat System with a Fixed Minimum Outdoor Air Damper Setpoint shows a typical VAV system. In standard practice, the testing and balancing contractor sets the minimum position setting for the outdoor air damper during construction. It is set under the conditions of design airflow for the system and remains in the same position throughout the full range of system operation, which does not meet code. As the system airflow drops, so will the pressure in the mixed air plenum. A fixed position on the minimum outdoor air damper will produce a varying outdoor airflow. Figure 4- 1: VAV Reheat System with a Fixed Minimum Outdoor Air Damper Setpoint shows this effect will be approximately linear (in other words, outdoor air airflow will drop directly in proportion to the supply airflow).

The following paragraphs present several methods used to dynamically control the minimum outdoor air in VAV systems.

Care should be taken to reduce the amount of outdoor air provided when the system is operating during the weekend or after hours with only a fraction of the zones active. Section 120.2(g) requires provision of "isolation zones" of 25,000 sq. ft. or less, which can be accomplished by having the VAV boxes return to fully closed when their associated zone is in unoccupied mode. When a space or group of spaces is returned to occupied mode (e.g., through off-hour scheduling or a janitor's override), only the boxes serving those zones need to be active. During this period when not all the zones are occupied, the ventilation air can be reduced to the required ventilation air of just those zones that are active. If all zones are of the same occupancy type (e.g., private offices), simply assign a floor area to each isolation zone and prorate the minimum ventilation area by the ratio of the sum of the floor areas presently active divided by the sum of all the floor areas served by the HVAC system.

Figure 4-1: VAV Reheat System with a Fixed Minimum Outdoor Air Damper Setpoint



Source: California Energy Commission

Fixed Minimum Damper Setpoint

This method does not comply with the Energy Code. The airflow at a fixed minimum damper position will vary with the pressure in the mixed air plenum. It is explicitly prohibited in Section 120.1(f)2.

Dual Minimum Setpoint Design

This method complies with the Energy Code. An inexpensive enhancement to the fixed damper setpoint design is the dual minimum setpoint design, commonly used on some packaged AC units. The minimum damper position is set proportionally based on fan speed or airflow between a setpoint determined when the fan is at full speed (or airflow) and minimum speed (or airflow). This method complies with the Energy Code but is not accurate over the entire range of airflow rates or when wind or stack effect pressure fluctuates. With DDC, this design has a relatively low cost.

Energy Balance Method

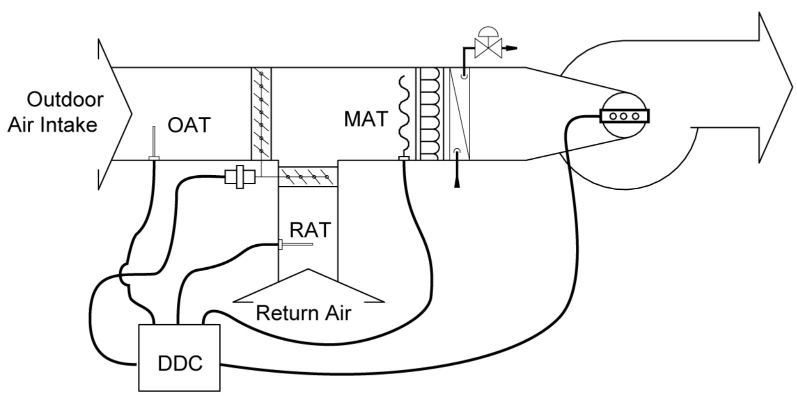
The energy balance method uses temperature sensors located outside, as well as in the return and mixed air plenums to determine the percentage of outdoor air in the supply air stream.

The outdoor airflow is then calculated using the equations shown in Figure 4- 2: Energy Balance Method of Controlling Minimum Outdoor Air. This method requires an airflow monitoring station on the supply fan.

While technically feasible, it may be difficult to meet the outside air acceptance requirements with this approach because:

- It is difficult to accurately measure the mixed air temperature, which is critical to the success of this strategy. Even with an averaging type of bulb, most mixing plenums have some stratification or horizontal separation between the outside and mixed airstreams.[1]
- Even with the best installation, high accuracy sensors, and field calibration of the sensors, the equation for percent outdoor air will become inaccurate as the return air temperature approaches the outdoor air temperature. When they are equal, this equation predicts an infinite percentage of outdoor air.
- The airflow monitoring station is likely to be inaccurate at low supply airflows.
- The denominator of the calculation amplifies sensor inaccuracy as the return air temperature approaches the outdoor air temperature.

Figure 4-2: Energy Balance Method of Controlling Minimum Outdoor Air



%OA = (MAT - RAT) / (OAT - RAT)

CFM - OA = %OA * CFM - SA

Source: California Energy Commission

Return Fan Tracking

This method is also technically feasible but will likely not meet the acceptance requirements because the cumulative error of the two airflow measurements can be large, particularly at low supply/return airflow rates. It only works theoretically when the minimum outdoor air rate equals the rate of air required to maintain building pressurization (the difference between supply air and return air rates). Return fan tracking (Figure 4- 3: Return Fan Tracking) uses airflow monitoring stations on both the supply and return fans. The theory behind this is that the difference between the supply and return fans should be made up by outdoor air and

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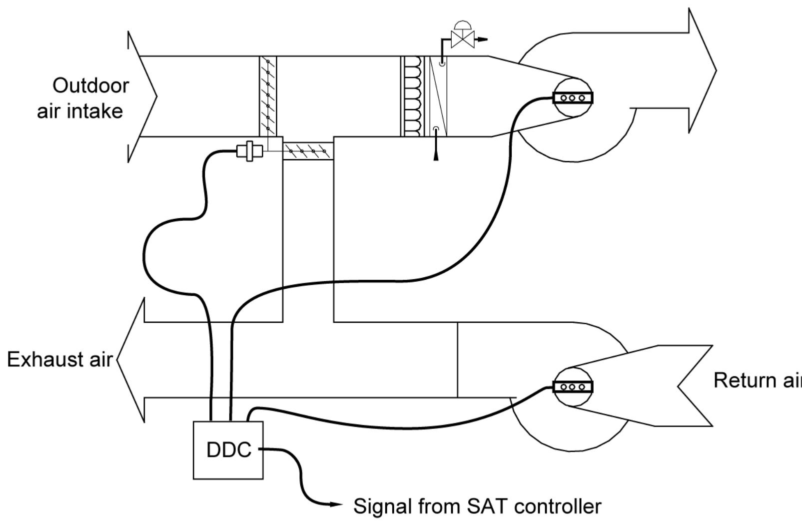
[1] This was the subject of ASHRAE Research Project 1045-RP, "Verifying Mixed Air Damper Temperature and Air Mixing Characteristics." Unless the return is over the outdoor air there are significant problems with stratification or airstream separation in mixing plenums.

controlling the flow of return air forces more ventilation into the building. Several problems occur with this method:

- The relative accuracy of airflow monitoring stations is poor, particularly at low airflows
- The high cost of airflow monitoring stations
- Building pressurization problems unless the ventilation air is equal to the desired building exfiltration plus the building exhaust

ASHRAE research has also demonstrated that in some cases this arrangement can cause outdoor air to be drawn into the system through the exhaust dampers due to negative pressures at the return fan discharge.

Figure 4-3: Return Fan Tracking

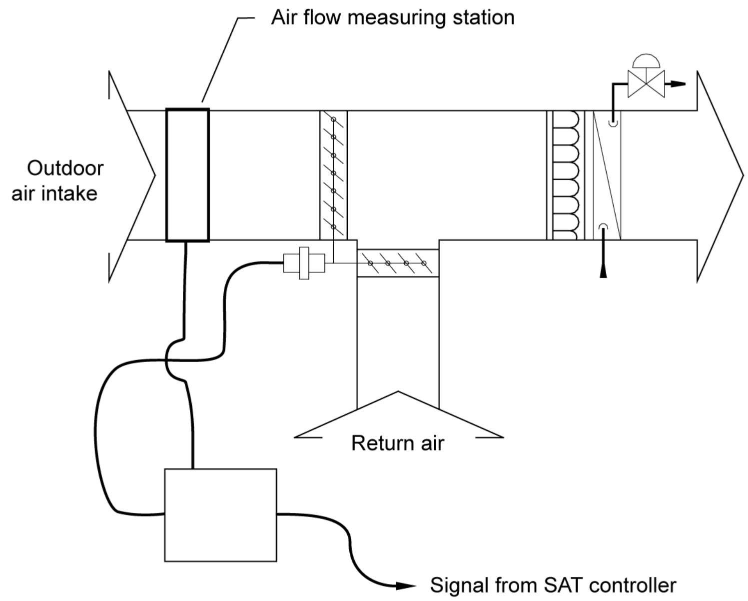


Source: California Energy Commission

Airflow Measurement of the Entire Outdoor Air Inlet

This method is technically feasible but will likely not meet the acceptance requirements, depending on the airflow measurement technology. Most airflow sensors will not be accurate within a 5 to 15 percent turndown (the normal commercial ventilation range). Controlling the outdoor air damper by direct measurement with an airflow monitoring station (Figure 4- 4: Airflow Measurement of 100 Percent Outdoor Air) can be an unreliable method. Its success relies on the turndown accuracy of the airflow monitoring station. Depending on the loads in a building, the ventilation airflow can be between 5 and 15 percent of the design airflow. If the outdoor airflow sensor is sized for the design flow for the airside economizer, this method has to have an airflow monitoring station that can turn down to the minimum ventilation flow (between 5 and 15 percent). Of the different types available, only a hot-wire anemometer array is likely to have this low-flow accuracy while traditional pitot arrays will not. One advantage of this approach is that it provides outdoor airflow readings under all operating conditions, not just when on minimum outdoor air. For highest accuracy, provide a damper and outdoor air sensor for the minimum ventilation air that is separate from the economizer outdoor air intake.

Figure 4-4: Airflow Measurement of 100 Percent Outdoor Air

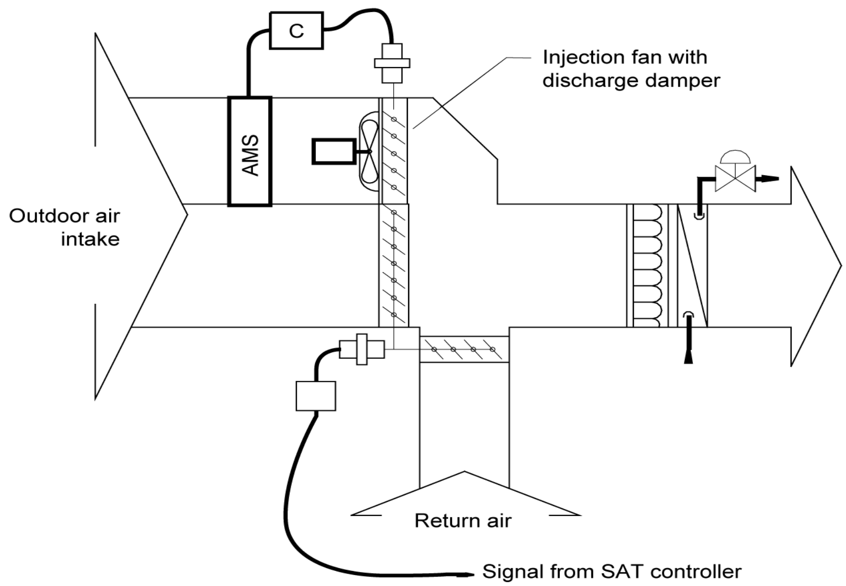


Source: California Energy Commission

Injection Fan Method

This method complies with the Energy Code, but it is expensive and may require additional space. An airflow sensor and damper are required since fan airflow rate will vary, as mixed air plenum pressure varies. The injection fan method (Figure 4- 5: Injection Fan with Dedicated Minimum Outdoor Air Damper) uses a separate outdoor air inlet and fan sized for the minimum ventilation airflow. This inlet contains an airflow monitoring station and a fan with capacity control (e.g., discharge damper; variable frequency drives [VFD]), which is modulated as required to achieve the desired ventilation rate. The discharge damper is required to shut off the intake when the air handling unit (AHU) is off and also to prevent excess outdoor air intake when the mixed air plenum is significantly negative under peak conditions. The fan is operating against a negative differential pressure and thus cannot stop flow just by slowing or stopping the fan. Though effective, the cost of this method is high and often requires additional space for the injection fan assembly.

Figure 4-5: Injection Fan with Dedicated Minimum Outdoor Air Damper



Source: California Energy Commission

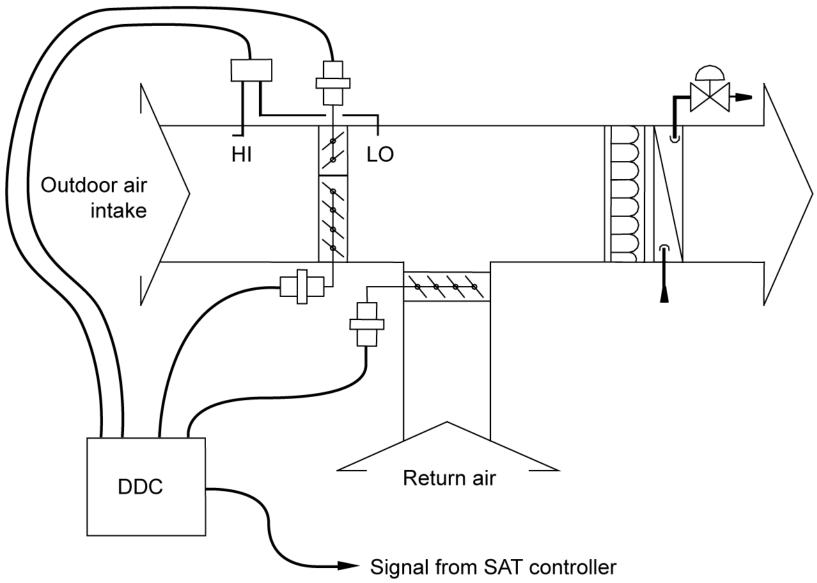
Dedicated Minimum Ventilation Damper with Pressure Control

This approach is low cost and takes little space. It can be accurate if the differential setpoint corresponding to the minimum outdoor air rate is properly set in the field. An inexpensive but effective design uses a minimum ventilation damper with differential pressure control (Figure 4- 6: Minimum Outdoor Air Damper with Pressure Control). In this method, the economizer damper is broken into two pieces: a small two position damper controlled for minimum ventilation air and a larger, modulating, maximum outdoor air damper that is used in economizer mode. A differential pressure transducer is placed across the minimum outdoor air damper. During start-up, the air balancer opens the minimum outside air (OA) damper and return air damper, closes the economizer OA damper, runs the supply fan at design airflow, measures the OA airflow, and adjusts the minimum OA damper position until the OA airflow equals the design minimum OA airflow. The linkages on the minimum OA damper are then adjusted so that the current position is the "full open" actuator position. At this point the design pressure (DP) across the minimum OA damper is measured. This value becomes the DP setpoint. The principle used here is that airflow is constant across a fixed orifice (the open damper) at fixed DP.

As the supply fan modulates when the economizer is off, the return air damper is controlled to maintain the DP setpoint across the minimum ventilation damper.

The main downside of this method is the complexity of controls and the potential problems determining the DP setpoint in the field. It is often difficult to measure the outdoor air rate due to turbulence and space constraints.

Figure 4-6: Minimum Outdoor Air Damper with Pressure Control



Source: California Energy Commission

Example 4-3: Minimum VAV cfm

Question:

If the minimum required ventilation rate for a space is 150 cfm, what is the minimum allowed airflow for its VAV box when the percentage of outdoor air in the supply air is 20 percent?

Answer:

The minimum allowed airflow may be as low as 150 cfm provided that enough outdoor air is supplied to all spaces combined to meet the requirements of Section 120.1(c)3 for each space individually.

Pre-Occupancy Purge

Reference: Section 120.1(d)2

Since many indoor air pollutants are out gassed from the building materials and furnishings, the Energy Code requires that buildings having a scheduled operation be purged before occupancy per Section 120.1(d)2. Immediately prior to occupancy, outdoor ventilation must be provided in an amount equal to the lesser of:

- The minimum required ventilation rate for 1 hour; or
- Three complete air changes.

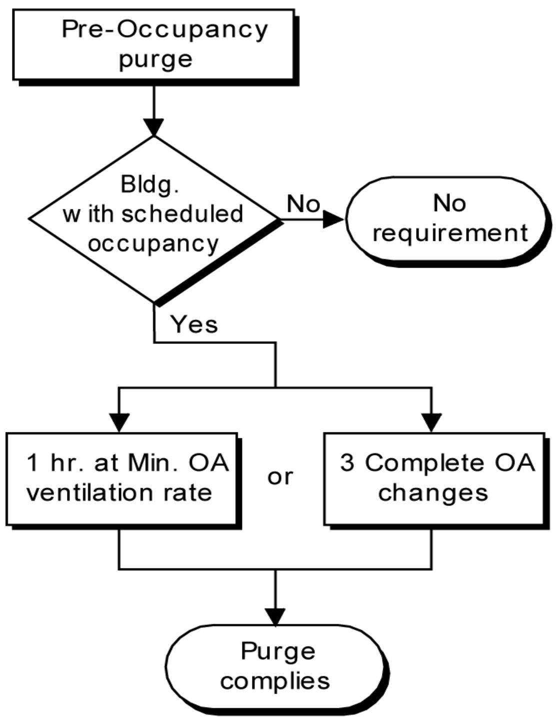
Either criterion can be used to comply with the Energy Code. Three complete air changes mean an amount of ventilation air equal to three times the volume of the occupied space. This air may be introduced at any rate provided for and allowed by the system, so that the actual purge period may be less than an hour.

A pre-occupancy purge is not required for buildings or spaces that are not occupied on a scheduled basis, such as storage rooms. Also, a purge is not required for spaces provided with natural ventilation.

Where pre-occupancy purge is required, it does not have to be coincident with morning warm-up (or cool-down). The simplest way to integrate the two controls is to schedule the system to be occupied one hour prior to the actual time of anticipated occupancy. This allows the optimal start, warm-up, or pull-down routines to bring the spaces up to (or down to) desired temperatures before opening the outdoor air damper for ventilation. This will reduce the required system heating capacity and ensure that the spaces will be at the desired temperatures and fully purged at the start of occupancy.

However, for spaces with occupancy controls which turn ventilation off when occupancy is not sensed, care must be taken in specifying controls and control sequences that the lack of sensed occupancy does not disable or override ventilation during the pre-occupancy purge period.

Figure 4-7: Pre-Occupancy Purge Flowchart



Source: California Energy Commission

Example 4-4: Purge Period

Question:

What is the length of time required to purge a space 10 ft high with an outdoor ventilation rate of 1.5 cfm/sq ft?

Answer:

For three air changes, each sq ft of space must be provided with:

OA volume = 3 x 10 = 30 cf/ft^2

At a rate of 1.5 cfm/sq ft, the time required is:

Time = 30 cf/ft^2 / 1.5 cfm/ft^2 = 20 minutes

Example 4-5: Purge with Natural Ventilation

Question:

In a building with natural ventilation, do the windows need to be left open all night to accomplish a building purge?

Answer:

No. A building purge is required only for buildings with mechanical ventilation systems.

Example 4-6: Purge with Occupancy Timer

Question:

How is a purge accomplished in a building without a regularly scheduled occupancy, whose system operation is controlled by an occupancy sensor?

Answer:

This building is most likely 24/7 accessible and a purge requirement would not apply for this building. The occupancy sensors and manual timers can only be used to control ventilation systems in buildings that are intermittently occupied without a predictable schedule.

Demand Controlled Ventilation

Reference: Section 120.1(d)3 and 4

Demand controlled ventilation systems reduce the amount of ventilation supply air in response to a measured level of carbon dioxide (CO_2) in the breathing zone. The Energy Code only permits CO_2 sensors for the purpose of meeting this requirement; volatile organic compounds (VOC) and so-called "indoor air quality (IAQ)" sensors are not approved as alternative devices to meet this requirement. The Energy Code only permits DCV systems to vary the ventilation component that corresponds to occupant bioeffluents (this is the basis for the 15 cfm/person portion of the ventilation requirement). The purpose of CO_2 sensors is to track occupancy in a space; however, there are many factors that must be considered when designing a DCV system. There is often a lag time in the detection of occupancy through the build-up of CO_2. This lag time may be increased by any factors that affect mixing, such as short circuiting of supply air or inadequate air circulation, as well as sensor placement and sensor accuracy. Build-up of odors, bioeffluents, and other health concerns may also delay changes in occupancy. Therefore, the designers must be careful to specify CO_2 based DCV systems that are designed to provide adequate ventilation to the space by ensuring proper mixing, avoiding short circuiting, and proper placement and calibration of the sensors.

The Energy Code requires the use of DCV systems for spaces. Those that have a design occupancy of 40 sq. ft./person or smaller (for areas without fixed seating where the design density for egress purposes is 40 sq. ft./person or smaller), and has at least one of the following:

- An air economizer
- Modulating outside air control
- Design outdoor airflow rate greater than 3,000 cfm

Exceptions to this requirement:

- The space exhaust is greater than the required ventilation rate minus 0.2 cfm/ft². This relates to the fact that spaces with high exhaust requirements won't be able to provide sufficient turndown to justify the cost of the DCV controls. An example of this is a restaurant seating area where the seating area air is used as make-up air for the kitchen hood exhaust.
- DCV devices are not allowed in spaces that have processes or operations that generate dusts, fumes, mists, vapors, or gases and are not provided with local exhaust ventilation, such as indoor operation of internal combustion engines, areas designated for unvented food service preparation, daycare, sickroom, science lab, barber shop, or beauty and nail salons.

  This exception recognizes that some spaces may need additional ventilation due to contaminants that are not occupant borne. It addresses spaces like theater stages where theatrical fog may be used or movie theater lobbies where unvented popcorn machines may be emitting odors and vapors into the space in either case justifying the need for higher ventilation rates. DCV devices shall not be installed in spaces included in this exception.
- Spaces with an area of less than 150 sq. ft., or a design occupancy of less than 10 people, per Section 120.1(c)3 (Table 120.1-A).

  This recognizes the fact that DCV devices may not be cost effective in small spaces such as a 15 ft. by 10 ft. conference room or spaces with only a few occupants at design conditions.

Although not required, the Energy Code permits design professionals to apply DCV on any intermittently occupied spaces served by either single-zone or multiple-zone equipment. Section 120.1(c)3 requires a minimum of 15 cfm of outdoor air per person multiplied by the expected number of occupants. However, it must be noted that these are minimum ventilation levels, and the designers may specify higher ventilation levels if there are health related concerns that warrant higher ventilation rates.

CO_2 based DCV is based on several studies (Berg-Munch et al. 1986, Cain et al. 1983, Fanger 1983 and 1988, Iwashita et al. 1990, Rasmussen et al. 1985) which concluded that about 15 cfm of outdoor air ventilation per person will control human body odor such that roughly 80 percent of unadapted persons (visitors) will find the odor to be at an acceptable level. As activity level increases and bioeffluents increase, the rate of outdoor air required to provide acceptable air quality increases proportionally, resulting in the same differential CO2 concentration.

A CO_2 sensor only tracks indoor contaminants that are generated by occupants themselves and, to a lesser extent, their activities. It will not track other pollutants, particularly volatile organic compounds that off-gas from furnishings and building materials. Hence, where permitted or required by the Energy Code, DCV systems cannot reduce the outdoor air ventilation rate below the lowest rate listed in Table 120.1-A (typically 0.15 cfm/ft²) during normally occupied times, as per Mechanical Ventilation.

DCV systems save energy if the occupancy varies significantly over time. Hence, they are most cost effective when applied to densely occupied spaces like auditoriums, conference rooms, lounges, or theaters. Because DCV systems must maintain the lowest ventilation rate listed in Table 120.1-A, they will not be applicable to sparsely occupied buildings such as offices where the floor rate always exceeds the minimum rate required by the occupants (See Table 120.1-A).

Where DCV is employed, the controls must meet all of the following requirements:

- Sensors must be provided in each room served by the system that has a design occupancy of 40 sq. ft. per person or less, with no less than one sensor per 10,000 sq. ft. of floor space. When a zone or a space is served by more than one sensor, signals from any sensor indicating that CO_2 is near or at the setpoint within a space, must trigger an increase in ventilation to the space. This requirement ensures that the space is adequately ventilated in case a sensor malfunctions. Design professionals should ensure that sensors are placed throughout a large space, so that all areas are monitored by a sensor.
- The CO_2 sensors must be located in the breathing zone (between three and six ft. above the floor or at the anticipated height of the occupant's head). Sensors in return air ducts are not allowed since they can result in under-ventilation due to CO_2 measurement error caused by short-circuiting of supply air into return grilles and leakage of outdoor air (or return air from other spaces) into return air ducts.
- The ventilation must be maintained that will result in a concentration of CO_2 at or below 600 ppm above the ambient level. The ambient levels can either be assumed to be 400 ppm or dynamically measured by a sensor that is installed within four feet of the outdoor air intake. At 400 ppm outside CO_2 concentration, the resulting DCV CO_2 setpoint would be 1000 ppm. (A 600-ppm differential is less than the 700 ppm that corresponds to the 15 cfm/person ventilation rate. This provides a margin of safety against sensor error, and because 1000 ppm CO_2 is a commonly recognized guideline value and referenced in earlier versions of ASHRAE Standard 62.1.) Note that the 1,000 PPM setpoint required by Title 24 is not the same approach to DCV as specified in the current version of ASHRAE 62.1 or ASHRAE 90.1 which do not have a fixed CO2 target for all spaces, and ASHRAE Standards 90.1 and 62.1 have lower ventilation rates per person. ASHRAE Guideline 36-2021, High-Performance Sequences of Operation for HVAC Systems, contains separate sequences of operation for complying with Title 24 and ASHRAE 90.1-2019.
- Regardless of the CO_2 sensor's reading, the system is not required to provide more than the minimum ventilation rate required by Section 120.1(c)3. This prevents a faulty sensor reading from causing a system to provide more than the code required ventilation for system without DCV control. This high limit can be implemented in the controls.
- The system shall always provide a minimum ventilation no less than R_a x A_z per Mechanical Ventilation for each space with a CO_2 sensor plus the greater of either the exhaust air rate or the rate required by other spaces served by the system, as listed in Table 120.1-A. This is a low limit setting that must be implemented in the controls.
- The CO_2 sensors must be factory-certified to have an accuracy within plus or minus 75 ppm at 600 and 1000 ppm concentration when measured at sea level and 25 degree Celsius (77 degrees F), factory calibrated or calibrated at start-up, and certified by the manufacturer to require calibration no more frequently than once every five years. A number of manufacturers now have self-calibrating sensors that either adjust to ambient levels during unoccupied times or adjust to the decrease in sensor bulb output through use of dual sources or dual sensors. For all systems, sensor manufacturers must provide a document to installers that their sensors meet these requirements. The installer must make this certification information available to the builder, building inspectors and, if specific sensors are specified on the plans, to plan checkers.

- When a sensor failure is detected, the system must provide a signal to reset the system to provide the minimum quantity of outside air levels required by Section 120.1(c)3 to the zone(s) serviced by the sensor at all times that the zone is occupied. This requirement ensures that the space is adequately ventilated in case a sensor malfunctions. A sensor that provides a high CO_2 signal on sensor failure will comply with this requirement.
- For systems that are equipped with DDC to the zone level, the CO_2 sensor(s) reading for each zone must be displayed continuously and recorded. The EMCS may be used to display and record the sensors' readings. The display(s) must be readily available to maintenance staff so they can monitor the systems performance.

Occupied Standby Zone Controls

Reference: Section 120.1(d)5, Section 120.2(e)3

The use of occupied-standby zone controls is mandated for spaces that are also required to use occupant sensing controls to meet the requirements for lighting shut-off controls per Section 130.1(c). Example spaces include offices, multipurpose rooms 1,000 sq. ft. or less, classrooms, conference rooms, and other spaces where the space ventilation is allowed to be reduced to zero in Table 120.1-A (see note F in the right-hand column of the table).

The HVAC system shall be controlled by an occupancy sensing control that resets temperature setpoints and ventilation air in accordance with Section 120.1(d)5 and Section 120.2(e)3 when a space meets both the following conditions.

- Section 130.1(c)5 and 6 specify that occupant sensing, as opposed to time-switch, is required to implement shutoff controls.
- Table 120.1-A specifies that ventilation air in the space is allowed to be reduced to zero when the space is in occupied standby mode.
- The zone and ventilation system is not served by pneumatic controls.

Table 4- 1: Occupancy Categories Qualifying for Occupied Standby Control Requirements lists all the occupancy categories that meet both conditions above and thus are required to install occupied standby controls if the ventilation zone is serving only qualifying spaces. Note that the "Corridors" category is duplicated from the general category and offices are duplicated from the office category to other building types for clarity.

Table 4-1: Occupancy Categories Qualifying for Occupied Standby Control Requirements

Occupancy Category
Offices
Multiuse assembly less than 1,000 sqft
Classrooms
Corridors
Conference Rooms
Restrooms
General

Occupancy Category
Guest rooms in hotel/motel

Source: California Energy Commission

Occupied-standby zone controls are used to implement "occupied standby control." This control is used when the HVAC is scheduled to be ON, but occupancy sensors do not detect any activity in the spaces served by the HVAC zone. During occupied standby, zone temperatures are reset (higher cooling setpoint and lower heating setpoint) and during times when there is neither a call for cooling nor heating the ventilation air is shut off to the zone. When ventilation air is shut off to the zone, the ventilation system serving the zone shall reduce the system outside air by the same amount of outside air reduced at the individual zone. For systems using DOAS units, please see the special note at the end of this section.

Where occupied-standby zone controls are employed (whether mandated or not) the controls must meet all of the following requirements:

- Sensors must meet the requirements of Section 110.9(b)4 and shall have suitable coverage to detect occupants in the entire space.
- Sensors that are used for lighting can be used for ventilation if the ventilation system is controlled directly from the occupant sensor and is not subject to daylighting control or other manual overrides.
- If a space conditioning system(s) serves several enclosed spaces, each space shall have its own occupant sensor and all sensors must indicate lack of occupancy before the zone airflow is cut off.
- The occupant sensor override of ventilation shall be disabled during preoccupancy purge (i.e., the terminal unit and central ventilation shall be active regardless of occupant status). Preoccupancy purge occurs during times that are scheduled to be unoccupied and the HVAC system is scheduled off and thus does not overlap with occupied standby periods.
- Single zone systems when "floating" between a call for heating or cooling will be shut off. For multizone systems, when a zone enters occupied standby and sets its zone airflow to zero, the system outside airflow shall be reduced to account for the reduced need for outside air. ASHRAE Guideline 36-2021, *High-Performance Sequences of Operation for HVAC Systems,* provides operating sequences that include the specific instructions for resetting air handler outside air amounts in response to a zone being placed in occupied standby while complying with the Title 24, Part 6 minimum outside air flowrates for the other zones.

The following three requirements allow a time delay up to 25 minutes (20 minutes sensor time delay + 5 minute occupied standby time delay) after no occupant activity is detected in all lighting zones served by the space conditioning zone and before the ventilation to the rooms is shut off.

The HVAC system must have the ability to modulate ventilation to each space conditioning zone that must comply with occupied standby mode.

The space conditioning zones and the lighting zones are not required to match controls operation. The illustration below (Figure 4- 8: Control Sequence Diagram of Occupied Standby Control of HVAC Thermal Zone Serving Two Lighting Zones (LZ1 and LZ2) Pre-Occupancy

Purge Flowchart) provides an example of the sequence of events for two lighting zones (LZ1 and LZ2) served by one HVAC zone and how occupant-sensing lighting controls relate to the HVAC ventilation controls. If an HVAC zone serves multiple lighting zones, then all lighting zones must be vacant for the HVAC zone to go into occupied standby. If a large lighting zone serves several small HVAC zones within the lighting zone, then all HVAC zones will go into occupied standby when the lighting zone is unoccupied.

- Occupant sensing controls shall indicate that a space or lighting zone is vacant in 20 minutes or less after no occupant activity is detected by any occupant sensors covering the space.
- When all the lighting zones served by the same space conditioning zone are vacant as indicated by the occupant sensing controls, the space conditioning zone enters occupied-standby mode.
- Once a space conditioning zone enters occupied-standby mode, in 5 minutes or less, thermostatic setpoints are reset and mechanical ventilation to the zone shall be shut off until any room served by the space conditioning zone becomes occupied or until ventilation is needed to provide space heating or conditioning. Temperature setback can be achieved either by:
    - Automatically set up the operating cooling temperature setpoint by 2°F or more and set back the operating heating temperature setpoint by 2°F or more; or
    - For multiple zone systems with Direct Digital Controls (DDC) to the zone level, set up the operating cooling temperature setpoint by 0.5°F or more and set back the operating heating temperature setpoint by 0.5°F or more.

What is ASHRAE Guideline 36?

ASHRAE Guideline 36, *High-Performance Sequences of Operation for HVAC Systems*, provides peer-reviewed sequences of operation for HVAC systems, written in a format that can be readily implemented by building controls manufacturers and control system contractors. It is continuously updated by a large committee of engineers, manufacturers, scientists, and contractors following the rigorous ASHRAE public review process. These sequences are intended to maximize energy efficiency while maintaining good indoor air quality and comfort. The sequences have been configured and tested to provide control stability and real-time fault detection and diagnostics. Specifying Guideline 36 control sequences reduces risk of Energy Management Control System programming errors and provides a common set of terms and sequences to facilitate communication between specifiers, contractors, and operators.

Example 4-7

Question:

If an HVAC zone is designed to serve an office space, conference room, and corridor, does this configuration require occupied standby capabilities to shut off ventilation?

Answer:

Yes.

Offices Spaces and Corridors all require occupancy sensing controls under Section 130.1(c) **AND** are occupancy categories that can have their ventilation air reduced to zero when the space is in occupied-standby mode.

- Small offices (250 square feet or less) require occupant sensing controls under 130.1(c)5.

- Large offices (250 square feet or greater) require occupant sensing controls under 130.1(c)6.

- Conference rooms of any size require occupant sensing controls under 130.1(c)5.

- Office Corridors require occupant sensing controls under sections 130.1(c)6.

Corridors which provide that ventilation are subject to occupied-standby mode under Table 120.1-A, as are office spaces (as indicated by the note "F" Column).

Example 4-8

Question:

If an HVAC zone is designed to serve both an office space and classrooms does this configuration require occupied standby capabilities to shut off ventilation?

Answer:

No, for Pre-K and K-12 classrooms.

Yes, for most Higher Education and commercial training classrooms.

As noted in the previous example, the occupied standby mode requirements are triggered if the space is subject to have occupant sensing controls under 130.1(c) **AND** are occupancy categories that can have their ventilation air reduced to zero when the space is in occupied-standby mode under Table 120.1-A. While all classrooms are required occupant sensing controls under Section 130.1(c)5, only certain types of classrooms can reduce ventilation flow to zero when the space is in occupied-standby mode.

In the case of classrooms, pre-K and K-12 educational facilities and some specialized classrooms such as art classrooms do not require occupied standby while those intended for college, community college, business lectures, or classrooms do require them. Note that the space types listed under other building types "Offices" and "General" would still apply to Educational Facilities, as result offices and corridors in educational buildings which both are required to have occupancy sensing and are allowed to set ventilation to 0 during occupied standby would also be required to have occupied standby controls if all the spaces in a thermal zone qualify for occupied standby.

Example 4-9

Question 1:

For thermal zones required to have occupant sensor ventilation controls, are these spaces allowed to set the ventilation rate to 0 during the preoccupancy ventilation purge period if there are no occupants sensed in the thermal zone?

Answer 1:

No. Preoccupancy controls (Section 120.1(d)), ventilate the building "during the 1-hour period immediately before the building is normally occupied." Occupant sensor control devices

(Section 120.1(d)5E), in contrast operate "When the zone is scheduled to be occupied and occupant sensing controls in all rooms and areas served by the zone indicate the spaces are unoccupied, " To be doubly clear, Section 120.1(d)5D says, "One hour prior to normal scheduled occupancy, occupant sensor ventilation control shall allow pre-occupancy purge as described in Section 120.1(d)2. See Figure 4- 8: Control Sequence Diagram of Occupied Standby Control of HVAC Thermal Zone Serving Two Lighting Zones (LZ1 and LZ2) Pre-Occupancy Purge Flowchart even though both spaces are vacant, and lights are out in these spaces, the space is being ventilated during the pre-occupancy purge period. This pre-occupancy purge period ventilated the space prior to the day's scheduled occupancy dilute site generated pollutants that have built up over night.

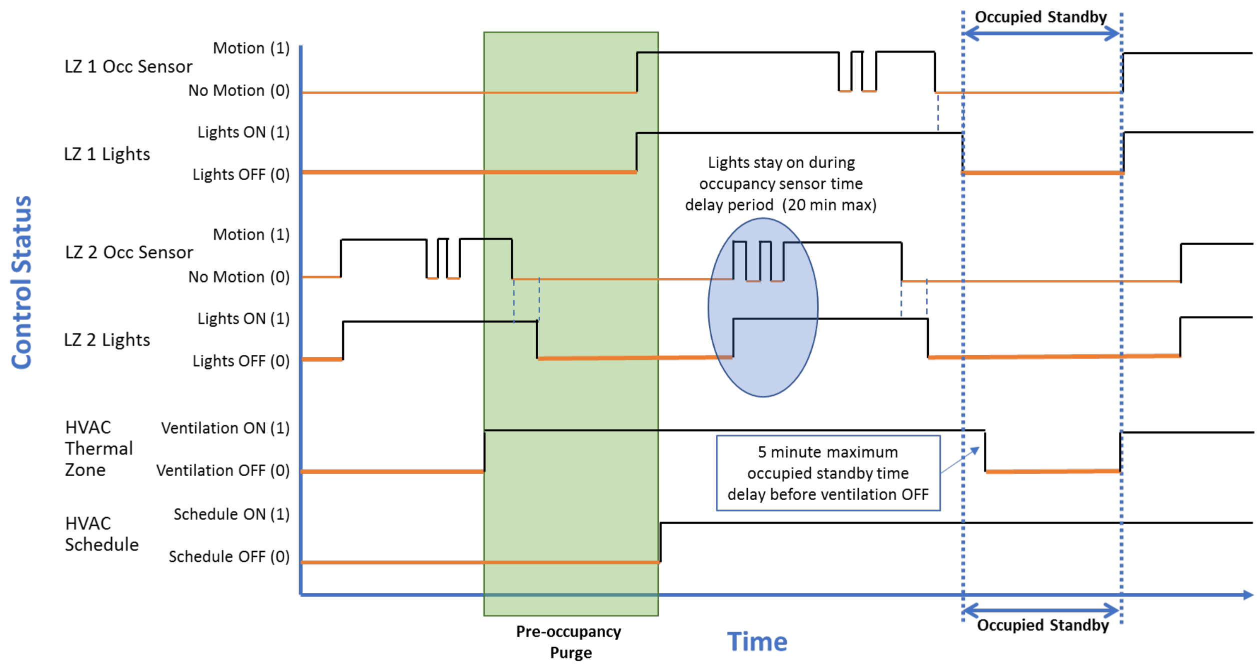
Question 2:

For a thermal zone required to have occupant sensor ventilation controls, what is the range of time delays allowed between all occupancy sensors in the zones sensing vacancy and the control shutting off ventilation air to the zone?

Answer 2:

Between 0 and 25 minutes. For the control with the shortest time delay, one could directly receive the output of the occupancy sensors and place the system in occupied standby mode whenever all the sensors do not receive a signal indicating occupancy. However, this control would have a lot of false vacancy signals as the occupant sensors are not able to detect movement continuously in occupied spaces and would be cycling the system back and forth between occupied standby and occupied. There are some HVAC designers that directly take the occupant sensor signal without the time delay built into the occupancy sensor and the program the system shut off ventilation air after a 5-minute time delay. It is also acceptable to take the lighting occupant sensor control signal that includes the lighting system time delay which is allowed to be set to as long as 20 minutes. This approach is used when the HVAC control system is taking the on/off signal from an extra set of dry contracts on the lighting occupant sensor. The HVAC system designer is allowed to take this lighting system signal which included the lighting control time delay and add on an extra 5-minute time delay before resetting the system setpoints and shutting off the ventilation air to zero.

Figure 4-8: Control Sequence Diagram of Occupied Standby Control of HVAC Thermal Zone Serving Two Lighting Zones (LZ1 and LZ2) Pre-Occupancy Purge Flowchart



Source: California Energy Commission

Special Note for Dedicated Outdoor Air Systems (DOAS)

HVAC zones utilizing DOAS units must still adhere to occupied standby control requirements.

Fan Cycling

Reference: Section 120.1(d)1

While Section 120.1(d)1 requires that ventilation be continuous during normally occupied hours when the space is usually occupied, Exception 2 allows the ventilation to be disrupted for not more than 30 minutes at a time. In this case the ventilation rate during the time the system is ventilating must be increased so the average rate over the hour is equal to the required rate.

It is important to review any related ventilation and fan cycling requirements in Title 8, which is the Division of Occupational Safety and Health (Cal/OSHA) regulations. Section 5142 specifies the operational requirements related to HVAC minimum ventilation. It states:

- The HVAC system shall be maintained and operated to provide at least the quantity of outdoor air required by the State Building Standards Code, Title 24, Part 2, California Administrative Code, in effect at the time the building permit was issued.
- The HVAC system shall be operated continuously during working hours except:
  - During scheduled maintenance and emergency repairs.
  - During periods not exceeding a total of 90 hours per calendar year when a serving electric utility by contractual arrangement requests its customers to decrease electrical power demand, or
  - During periods for which the employer can demonstrate that the quantity of outdoor air supplied by nonmechanical means meets the outdoor air supply rate. The employer must have available a record of calculations and/or measurements

substantiating that the required outdoor air supply rate is satisfied by infiltration and/or by a nonmechanically driven outdoor air supply system.

- When a space has entered occupied standby mode as permitted by Section 120.2(e)3.

Title 8 Section 5142(a)(1) refers to Title 24, Part 2 (the California Building Code) for the minimum ventilation requirements. Section 1203 in the California Building Code specifies the ventilation requirements, but simply refers to the California Mechanical Code, which is Title 24, Part 4.

Chapter 4 in the California Mechanical Code specifies the ventilation requirements. Section 402.3 states, "The system shall operate so that all rooms and spaces are continuously provided with the required ventilation rate while occupied." Section 403.5.1 states, "Ventilation systems shall be designed to be capable of providing the required ventilation rates in the breathing zone whenever the zones served by the system are occupied, including all full and part-load conditions." The required ventilation rates are thus not required whenever the zones are unoccupied. This section affirms that ventilation fans may be turned off during unoccupied periods. In addition, Section 403.6 states, "The system shall be permitted to be designed to vary the design outdoor air intake flow or the space or zone airflow as operating conditions change." This provides further validation to fan cycling as operating conditions change between occupied and unoccupied. A vacant zone has no workers present and is thus not subject to working hour's requirements until the zone is actually occupied by a worker. Finally, Title 24, Part 4, states; "Ventilation air supply requirements for occupancies regulated by the California Energy Commission are found in the California Energy Code." Thus, it refers to Title 24, Part 6 as the authority on ventilation.

Title 8 Section 5142(a)(2) states, "The HVAC system shall be operated continuously during working hours." This regulation does not indicate that the airflow, cooling, or heating needs to be continuous. If the HVAC system is designed to maintain average ventilation with a fan cycling algorithm and is active in that mode providing average ventilation air as required during working hours, it is considered to be operating continuously per its mode and sequence. During unoccupied periods, the HVAC system is turned off except for setback and it no longer operates continuously. During the occupied period, occupant sensors or CO_2 sensors in the space provide continuous monitoring and the sequence is operating, cycling the fan and dampers as needed to maintain the ventilation during the occupied period. The HVAC system is operating with the purpose of providing ventilation, heating, and cooling continuously during the working hours. The heater, air conditioner, fans, and dampers all cycle on and off subject to their system controls to meet the requirements during the working hours.

Exceptions A, B, and C to Title 8 Section 5142(a)(2) all refer to a complete system shutdown where the required ventilation is not maintained.

Example 4-10

Question:

Does a single zone air-handling unit serving a 2,000 sq. ft. auditorium with fixed seating for 240 people require DCV?

Answer:

Since the space has an occupant load factor of 8.3 sq. ft. per person (2,000 sq. ft. per 240 people), it meets the 40 sq. ft./person or less requirement triggering demand control ventilation if it has at least one of the following:

- Air economizer
- Modulating outside air control
- -Design outdoor airflow greater than 3,000 cfm

A single CO_2 sensor could be used for this space provided it is certified by the manufacturer to cover 2,000 sq. ft. of space. The sensor must be placed directly in the space.

Example 4-11

Question

If two separate units are used to condition the auditorium in the previous example, is DCV required?

Answer

Yes, for each system that meets the criteria above.

Example 4-12

Question

Does the 2,000 sq ft auditorium in the previous examples require both DCV per Section 4.3.9. and occupied-standby zone controls per Section 4.3.10?

Answer

No, only DCV is required because occupied-standby zone controls are only required for spaces such as offices 250 sq ft or less, multipurpose rooms 1,000 sq ft or less, classrooms, conference rooms, or restrooms.

Example 4-13

Question

If a central AHU supplies five zones of office space (with a design occupant density of 100 sq ft per person and two zones with conference rooms (with a design occupant density of 35 sq ft per person) is it required to have demand-controlled ventilation and if so, on which zones?

Answer

If the AHU has DDC controls to the zone and an airside economizer it is required to have DCV controls in both of the conference room zones.

The minimum OSA will be set for 0.15 cfm/ft² times the total area of all seven zones (the office and conference room zones) and the maximum required OSA does not need to exceed the sum of 0.15 cfm/ft² for the five office zones plus 15 cfm per person for the two conference rooms.

Variable Air Volume (VAV) Changeover Systems

Please refer to Chapter 4.4.12.1 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Adjustment of Ventilation Rate

Please refer to Chapter 4.4.13 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Acceptance Requirements

Please refer to Chapter 4.4.14 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Ventilation Airflow

Please refer to Chapter 4.4.14.1 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Ventilation System Time Controls and Preoccupancy Purge

Please refer to Chapter 4.4.14.2 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Demand-Controlled Ventilation System

Please refer to Chapter 4.4.14.3 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Pipe and Duct Distribution Systems

Mandatory Measures

Requirements for Pipe Insulation

Reference: Section 120.3, Table 120.3-A-1, Table 120.3-A-2

Most piping conveying mechanically heated or chilled fluids for space conditioning or service water heating must be insulated. The required thickness of piping insulation depends on the temperature of the fluid passing through the pipe, the pipe diameter, the function of the pipe within the system, and the insulation's thermal conductivity.

Table 120.3-A-1 and Table 120.3-A-2 of the Energy Code specifies the requirements in terms of inches of insulation with conductivity within a specific range. These conductivities are typical for fiberglass or foam pipe insulation. Piping within fan coil units and within other heating or cooling equipment should be insulated based on the pipe diameter and the required value in the table.

Piping that does not require insulation includes the following:

- Factory installed piping within space-conditioning equipment certified under Section 110.1 or Section 110.2, see Equipment Requirements. Nationally recognized certification programs that are accepted by the Energy Commission for certifying efficiencies of appliances and equipment are considered to meet the requirements for this exception.
- Piping that conveys fluid with a design operating temperature range between 60 degrees F and 105 degrees F, such as cooling tower piping or piping in water loop heat pump systems.
- Where the heat gain or heat loss, to or from piping without insulation, will not increase building source energy use. For example, this requirement does not apply to piping connecting fin-tube radiators within the same space, nor to liquid piping in a split system air conditioning unit. This exception does not apply to piping in solar systems. Solar systems

typically have backup devices that will operate more frequently if piping losses are not minimized.

- Piping that penetrates framing members shall not be required to have pipe insulation for the distance of the framing penetration. Metal piping that penetrates metal framing shall use grommets, plugs, wrapping or other insulating material to assure that no contact is made with the metal framing.

Conductivities and thicknesses listed in Table 120.3-A-1 and Table 120.3-A-2 are typical for fiberglass and foam. When insulating materials are used that have conductivities different from those listed here for the applicable fluid range, such as calcium silicate, the equation below for insulation thickness may be used to calculate the required insulation thickness.

When a pipe carries cold fluids, condensation of water vapor within the insulation material may impair the effectiveness of the insulation, particularly for applications in very humid environments or for fluid temperatures below 40 degrees F. Examples include refrigerant suction piping and low-temperature thermal energy storage (TES) systems. In these cases, manufacturers should be consulted, and consideration given to low permeability vapor barriers, or closed-cell foams.

The Energy Code also requires that pipe insulation be protected from damage by moisture, UV and physical abrasion including but not limited to the following:

- Insulation exposed to weather shall be installed with a cover suitable for outdoor service. The cover shall be water retardant and provides shielding from solar radiation that can cause degradation of the material. Insulation must be protected by an external covering unless the insulation has been approved for exterior use using a recognized federal test procedure. Adhesive tape shall not be used as protection for insulation exposed to weather.
- Insulation covering chilled water piping and refrigerant suction piping located outside the conditioned space shall have a Class I or Class II vapor retarder. All penetrations and joints of which shall be sealed.
- Pipe insulation buried below grade must have a waterproof, uncrushable casing or sleeve. The Energy Code does not define "uncrushability" as any material can be crushed, given enough pressure, and thus it is left to the professional judgement of the designer.

If the conductivity of the proposed insulation does not fall into the conductivity range listed in Table 120.3-A-1 and Table 120.3 -A-2, the minimum thickness must be adjusted using the following equation for insulation thickness:

$$T = PR \times [(1 + \frac{t}{PR})^{\frac{K}{k}} - 1]$$

Where,

- T = Minimum insulation thickness for material with conductivity K, inches.
- PR = Pipe actual outside radius, inches.
- t = Insulation thickness, inches (Table 120.3-A-1 and Table 120.3-A-2 for conductivity k).
- K = Conductivity of alternate material at the mean rating temperature indicated in Table 120.3-A-1 and Table 120.3-A-2 for the applicable fluid temperature range, in Btu-in./(h-ft² -°F).

- k = The lower value of the conductivity range listed in Table 120.3-A-1 and Table 120.3-A-2 for the applicable fluid temperature, Btu-in/(h-ft² -°F).

Example 4-14

Question

What is the required thickness for calcium silicate insulation on a four-inch diameter pipe carrying a 300-degree F fluid?

Answer

From Table 120.3-A-1 and Table 120.3-A-2, using data for 300-degree F fluid:

- PR = 2"
- **t = 4.5"** (from the table for a 4-inch pipe with 300-degree F fluid)
- **K = 0.40 (Btu-in.)/(h-ft²-°F)** (from calcium silicate insulation manufacturer's conductivity data at 200-degree F)
- **k = 0.29 (Btu-in.)/(h-ft²-°F)** (the lower value of the range for conductivity for 300-degree F fluid)

$T = PR[(1 + t/PR)^{K/k} - 1]$

T = 2[(1 + 4.5/2)(0.40/0.29)– 1]

T = 8.2 inches

When insulation is not available in the exact thickness calculated, the installed thickness should be the next larger available size.

Requirements for Air Distribution System Ducts and Plenums

Reference: Section 120.4

Poorly sealed or poorly insulated duct work can cause substantial losses of air volume and energy. All air distribution system ducts and plenums, including building cavities, mechanical closets, air handler boxes and support platforms used as ducts or plenums, are required to be in accordance with the California Mechanical Code Sections 601, 602, 603, 604, 605 and ANSI/SMACNA-006-*2006 HVAC Duct Construction Standards - Metal and Flexible*, 3rd Edition

The Energy Code requires all ductwork to be sealed to meet Seal Class A. Sealing means the use of adhesives, gaskets, and/or tape systems to close openings in the surface of ductwork and field erected plenums and casings through which air leakage would occur, or the use of continuous welds. Seal Class A means sealing all ductwork connections and applicable duct wall penetrations. Penetrations include pipe, tubing, rods, and wire. Rods that penetrate the duct wall must be allowed to move to function properly (such as a control rod for a volume damper) and should not be sealed in a way that prevents operation. Penetrations do not include screws and other fasteners.

Healthcare facilities are not subject to Section 120.4 and shall comply with the applicable requirements of the California Mechanical Code.

Installation and Insulation

Reference: Section 120.4(a)

Portions of supply-air and return-air ducts or ductwork conveying heated or cooled air shall be insulated to a minimum installed level of R-8 when installed:

- Outdoors
- In a space between the roof and an insulated ceiling
- In a space directly under a roof with fixed vents or openings to the outside or unconditioned spaces
- In an unconditioned crawlspace
- In other unconditioned spaces

Portions of supply-air ducts ductwork that are not in one of the above spaces shall be insulated to a minimum installed level of R-4.2 or be exposed in a directly conditioned space. For example, supply-air ducts that are inside the thermal envelope but concealed from view (such as ducts in a chase or above a hard or T-bar ceiling) are required to be insulated with at least R-4.2. However, if the ducts are exposed to directly conditioned space (i.e. ducts are visible to the occupants), then no insulation would be required.

Requirements of the California Mechanical Code

- Mechanically fasten connections between metal ducts and the inner core of flexible ducts.
- Joint and seal openings with mastic, tape, aerosol sealant or other duct closure system that meets the applicable requirements of UL 181, UL 181A, UL 181B or UL 723 (aerosol sealant).

All joints must be made airtight by use of mastic, tape, aerosol sealant, or other duct-closure system that meets the applicable requirements of UL 181, UL 181A, UL 181B, or UL 723. Duct systems shall not use cloth-back, rubber adhesive duct tape regardless of UL designation, unless it is installed in combination with mastic and clamps.

When mastic or tape is used to seal openings greater than 1/4 inch, a combination of mastic and mesh or mastic and tape must be used.

The Energy Commission has approved two cloth-backed duct tapes with special butyl or synthetic adhesives rather than rubber adhesive to seal flex duct to fittings. These tapes are:

- Polyken 558CA or Nashua 558CA, manufactured by Berry Plastics, Tapes and Coatings Division; and
- Shurtape PC 858CA, manufactured by Shurtape Technologies, Inc.

These tapes passed Lawrence Berkeley National Laboratory tests comparable to those that cloth-back rubber-adhesive duct tapes failed (the Lawrence Berkeley National Laboratory test procedure has been adopted by the American Society of Testing and Materials as ASTM E2342-03). These tapes are allowed to be used to seal flex ducts to fittings without combination with mastic. These tapes cannot be used to seal other duct system joints, such as the attachment of fittings to plenums and junction boxes. On their backing, these tapes have the phrase "CEC Approved," and a drawing of a fitting to plenum joint in a red circle with a slash through it (the international symbol of prohibition) to illustrate where they are not allowed to be used. Installation instructions in the box explains how to install the tape on duct core to fittings and a statement that the tape cannot be used to seal fitting to plenum and junction box joints.

Factory-Fabricated Duct Systems

Reference: Section 120.4(b)1

Factory-fabricated duct systems must meet the following requirements:

- All factory-fabricated duct systems shall comply with UL 181 for ducts and closure systems, including collars, connections, and splices, and be labeled as complying with UL181. UL181 testing may be performed by UL laboratories or a laboratory approved by the Executive Director.
- Pressure-sensitive tapes, heat-activated tapes, and mastics used in the manufacture of rigid fiberglass ducts comply with UL 181 and UL181A.
- Pressure-sensitive tapes and mastics used with flexible ducts comply with UL181 and UL181B.
- All ductwork and plenums with pressure class ratings shall be constructed to Seal Class A. Joints and seams of duct systems and their components shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands.

Duct located in occupied space and exposed to view is not required to meet Seal Class A.

Field-Fabricated Duct Systems

Reference: Section 120.4(b)2

Field-fabricated duct systems must meet the following requirements:

- Factory-made rigid fiberglass and flexible ducts for field-fabricated duct systems comply with UL 181. Pressure-sensitive tapes, mastics, aerosol sealants or other closure systems shall meet applicable requirements of UL 181, UL 181A and UL 181B.
- Mastic Sealants and Mesh:
    - Sealants comply with the applicable requirements of UL 181, UL 181A, and UL 181B, and shall be non-toxic and water resistant.
    - Sealants for interior applications shall pass ASTM C 731(extrudability after aging) and D 2202 (slump test on vertical surfaces), incorporated herein by reference.
    - Sealants for exterior applications shall pass ASTM C 731, C 732 (artificial weathering test) and D 2202, incorporated herein by reference.
    - Sealants and meshes shall be rated for exterior use.
- Pressure-sensitive tapes shall comply with the applicable requirements of UL 181, UL 181A and UL 181B.
- Drawbands used with flexible duct shall:
    - Be either stainless-steel worm-drive hose clamps or UV-resistant nylon duct ties.
    - Have a minimum tensile strength rating of 150 lbs.
    - Be tightened as recommended by the manufacturer with an adjustable tensioning tool.
- Aerosol-Sealant Closures:
    - Aerosol sealants meet applicable requirements of UL 723 and must be applied according to manufacturer specifications.

  - Tapes or mastics used in combination with aerosol sealing shall meet the requirements of this section.
- All ductwork and plenums with pressure class ratings shall be constructed to Seal Class A. Joints and seams of duct systems and their components shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands.

Ductwork located in occupied space and exposed to view is not required to meet Seal Class A.

Duct Insulation R-Values

Reference: Section 120.4(c), Section 120.4(d), Section 120.4(e)

Since 2001, the Energy Code has included the following requirements for the labeling, measurement, and rating of duct insulation:

- Insulation R-values shall be based on the insulation only and not include air-films or the R-values of other components of the duct system.
- Insulation R-values shall be tested C-values at 75 degrees F mean temperature at the installed thickness, in accordance with ASTM C 518 or ASTM C 177.
- The installed thickness of duct insulation for purpose of compliance shall be the nominal thickness for duct board, duct liner, factory made flexible air ducts and factory-made rigid ducts. For factory-made flexible air ducts, the installed thickness shall be determined by dividing the difference between the actual outside diameter and nominal inside diameter by two.
- The installed thickness of duct insulation for purpose of compliance shall be 75 percent of its nominal thickness for duct wrap.
- Insulated flexible air ducts must bear labels no further than three feet apart that state the installed R-value (as determined per the requirements of the Energy Code).

A typical duct wrap, nominal 1-1/2 inches and 0.75 pound per cubic foot will have an installed rating of R-4.2 with 25 percent compression.

Protection of Duct Insulation

Reference: Section 120.4(f)

The Energy Code requires that exposed duct insulation be protected from damage by moisture, UV and physical abrasion including but not limited to the following:

- Insulation exposed to weather shall be suitable for outdoor service, e.g., protected by aluminum, sheet metal, painted canvas, or plastic cover. Insulation must be protected by an external covering unless the insulation has been approved for exterior use using a recognized federal test procedure.
- Cellular foam insulation shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation that can cause degradation of the material.

Example 4-15

Question:

What are the sealing requirements in a VAV system having a static pressure setpoint of 1.25 inches water gauge and a plenum return? What are the sealing requirements for exposed ductwork in a utility closet?

Answer:

All duct work located within the return plenum must be sealed in accordance with the Seal Class A: all joints, seams, and penetrations must be sealed. A utility closet is not occupied space and therefore exposed ductwork in a utility closet must also be sealed in accordance with Seal Class A. Pressure-sensitive tape heat-seal tape and mastic may be used, if it meets the applicable requirement of UL 181, 181A, 181B, to seal joints and seams which are mechanically fastened per the California Mechanical Code.

Duct Sealing and Leakage Testing.

Reference: Section 120.4(g)

Since 2001, the Energy Code has included prescriptive duct leakage testing for ducts that are part of small single zone systems with portions of the ductwork either outdoors or in uninsulated or vented ceiling spaces. The 2019 California Mechanical Code (CMC) introduced mandatory requirements to seal and test all nonresidential air distribution systems. The prescriptive requirements for duct leakage in the Energy Code were therefore made mandatory and all systems that do not meet the criteria for testing according to the Energy Code are required to meet the requirements in the CMC.

New or replacement duct systems that meet the criteria below shall be sealed to a leakage rate not to exceed 6 percent of the nominal air handler airflow rate as confirmed through ECC acceptance testing, in accordance with Reference Nonresidential Appendix NA7.5.3.

- The duct system does not serve a healthcare facility.
- The duct system provides conditioned air to an occupiable space for a constant volume, single zone, space-conditioning system.
- The space conditioning system serves less than 5,000 square feet of conditioned floor area.
- The combined surface area of the ducts located outdoors or in unconditioned space is more than 25 percent of the total surface area of the entire duct system.

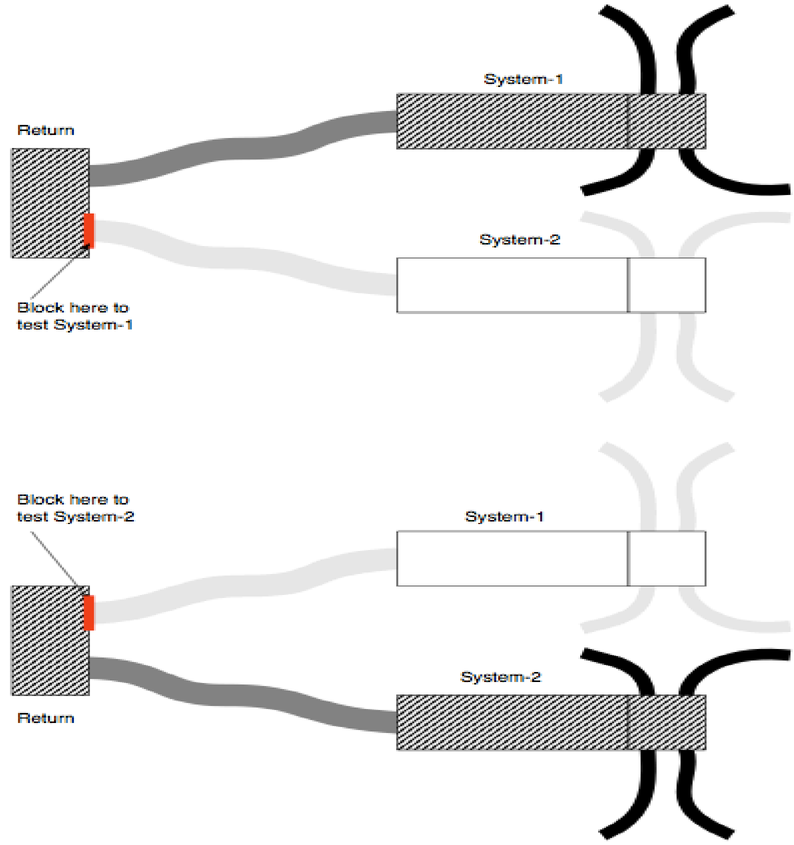
New or replacement duct systems that do not meet the criteria above shall instead meet the duct leakage testing requirements of CMC Section 603.10.1.

Alterations to an existing space conditioning system may trigger the duct sealing requirement. For more information, see Requirements for Alterations.

Duct Leakage Testing for Multiple Duct Systems with Common Return Ducts

If there are two or more duct systems in a building that are tied together at a common return duct, then each duct system should be tested separately, including the shared portion of the return duct system which should be included in each system test. Under this scenario, the portions of the second duct system that is not being tested must be completely isolated from the portions of the ducts that are being tested, so the leakage from the second duct system does not affect the leakage rate from the side that is being tested. The diagram below represents the systems that are attached to a shared return boot or remote return plenum. In this case, the point in the return system that needs to be blocked off is readily accessible through the return grille. The "duct leakage averaging" method where both systems are tested together (as though it is one large system) and the results divided by the combined tonnage to get the target leakage may not be used as it allows a duct system with more the 6 percent leakage to pass if the combined system's leakage is 6 percent or less.

Figure 4-9: Example of Two Duct Systems with a Common Return



Source: California Energy Commission

Example 4-16

Question:

A new 20-ton single zone system with new ductwork serving an auditorium is being installed. Approximately half of its ductwork is on the roof. Does it need to be leak tested in accordance with NA7.5.3 or the California Mechanical Code?

Answer:

It likely needs to be tested to the CMC Section 603.10.1. Although this system meets the criteria of being single zone and having more than 25 percent of the duct surface area on the roof, the unit probably serves more than 5,000 sq ft of space. Most 15- and 20-ton units will serve spaces that are significantly larger than 5,000 sq ft. If the space is 5,000 sq ft or less the ducts do need to be leak tested per Section 120.4(g)1 and NA7.5.3.

Example 4-17

Question:

A new 5-ton single zone system with new ductwork serving a 2,000 sq ft office is being installed. The unit is a down discharge configuration and the roof has insulation over the deck. Does the ductwork need to be leak tested in accordance with NA7.5.3 or the California Mechanical Code?

Answer:

It likely needs to be tested according to the CMC Section 603.10.1. Although this system meets the criteria of being single zone and serving less than 5,000 sq ft of space, it does not have 25 percent of its duct area outdoors or in unconditioned space. With the insulation on the roof and not on the ceiling, the plenum area likely meets the criteria of indirectly conditioned.

Acceptance Requirements

The Energy Code has acceptance requirements where duct sealing and leakage testing is required by Section 120.5(a)3.

These tests are described in the Chapter 13, Acceptance Requirements, and the Reference Nonresidential Appendix NA7.

HVAC System Control Requirements

Mandatory Measures

This section covers controls that are mandatory for all system types, including:

- Heat pump controls for the auxiliary heaters
- Zone thermostatic control including special requirements for hotel/motel guest rooms and perimeter systems
- Shut-off and setback/setup controls
- Infiltration control
- Off-hours space isolation
- A new mandatory requirement for hot water supply temperature (HWST)
- Economizer fault detection and diagnostics (FDD)
- Control equipment certification
- Direct digital controls (DDC)
- Optimum start/stop controls.

Zone Thermostatic Controls

Reference: Section 120.2(a), (b), and (c)

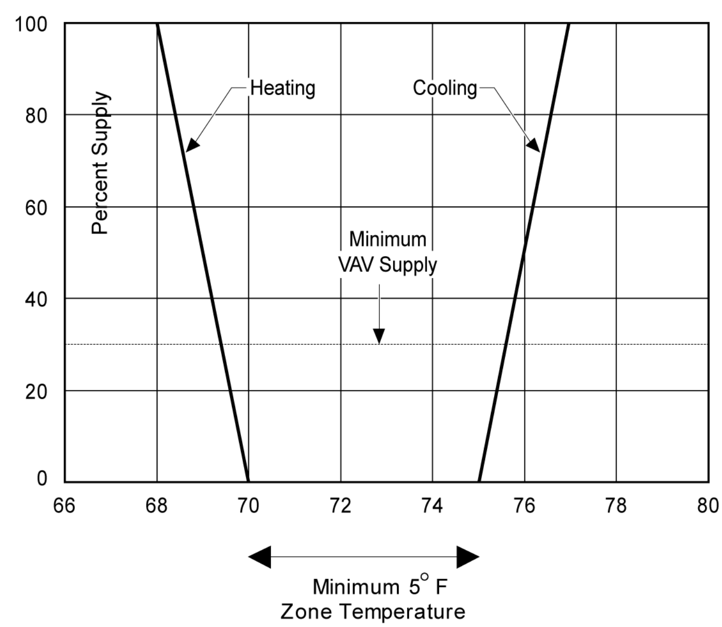
Thermostatic controls must be provided for each space-conditioning zone or dwelling unit to control the supply of heating and cooling energy within that zone. The controls must have the following characteristics:

- When used to control **heating**, the thermostatic control must be adjustable down to 55 degrees F or lower.
- When used to control **cooling**, the thermostatic control must be adjustable up to 85 degrees F or higher.

- When used to control both **heating and cooling**, the thermostatic control must be adjustable from 55 degrees F to 85 degrees F and also provide a temperature range or **dead band** of at least 5 degrees F. When the space temperature is within the dead band, heating and cooling energy must be shut off or reduced to a minimum. A dead band is not required if the thermostat requires a manual changeover between the heating and cooling modes Exception to Section 120.2(b)3.
- For all single-zone air conditioners and heat pumps, all thermostats shall have setback capabilities with a minimum of four separate setpoints per 24-hour period. Also, the thermostat must comply with the occupant controlled smart thermostat requirements in Section 110.12(a), which is capable of responding to demand response signals in the event of grid congestion and shortages during high electrical demand periods.
- Systems equipped with DDC to the zone level, rather than zone thermostats, must be equipped with automatic demand shed controls that provide demand shedding, as described later in Automatic Demand Shed Controls.

The setpoint may be adjustable either locally or remotely, by continuous adjustment or by selection of sensors.

Figure 4-10: Proportional Control Zone Thermostat



Source: California Energy Commission

Supplemental perimeter heating or cooling systems are sometimes used to augment a space-conditioning system serving both interior and perimeter zones. This is allowed provided controls are incorporated to prevent the two systems from conflicting with each other. If that were the case, then the Energy Code requires that:

- The perimeter system must be designed solely to offset envelope heat losses or gains.
- The perimeter system must have at least one thermostatic control for each building orientation of 50 ft or more.
- The perimeter system is controlled by at least one thermostat located in one of the zones served by the system.

The intent is that all major exposures are controlled by their own thermostat, and that the thermostat is located within the conditioned perimeter zone. Other temperature controls, such as outdoor temperature reset or solar compensated outdoor reset, do not meet these requirements of the Energy Code.

Thermostats with adjustable setpoints and deadband capability are not required for zones that must have constant temperatures to prevent the degradation of materials, an exempt process, plants, or animals (Exception 1 to Section 120.2(b)4). Included in this category are manufacturing facilities, hospital patient rooms, museums, and computer rooms. Chapter 13 describes mandated acceptance test requirements for thermostat control for packaged HVAC systems.

Example 4-18

Question

Can an energy management system be used to control the space temperatures?

Answer

Yes, provided the space temperature setpoints can be adjusted, either locally or remotely. This section sets requirements for "thermostatic controls" which need not be a single device like a thermostat; the control system can be a broader system like a DDC system. Some DDC systems employ a single cooling setpoint and a fixed or adjustable deadband. These systems comply if the deadband is adjustable or fixed at 5 degrees F or greater.

Hotel/Motel Guest Room Thermostats

Please refer to Chapter 4.6.1.2 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Heat Pump Controls

Please refer to Chapter 4.6.1.3 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Shut Off and Temperature Setup/Setback

Reference: Section 120.2(e)1, Section 120.2(e)2, Section 120.2(e)3

For specific occupancies and conditions, each space-conditioning system must be provided with controls that comply with the following requirements:

- The control can automatically shut off the equipment during unoccupied hours and shall have one of the following:
    - An automatic time switch device with the same characteristics that lighting devices must have, as described in Chapter 5, and a manual override accessible to the occupants that allows the system to operate up to four hours. The manual override can be included as a part of the control device, or as a separate override control.
    - An occupancy sensor. Since a building ventilation purge is required prior to normal occupancy, an occupancy sensor may be used to control the availability of heating and cooling but should not be used to control the outdoor ventilation system.

- A four-hour timer that can be manually operated to start the system. As with occupancy sensors, the same restrictions apply to controlling outdoor air ventilation systems.

Exception to Section 120.2(e)1: The mechanical system serving retail stores and associated malls, restaurants, grocery stores, churches, or theaters equipped with seven-day programmable timers do not have to comply with the above requirements.

- When shut down, the controls shall automatically restart the system to maintain:
  - A setback heating thermostat setpoint if the system provides mechanical heating. *Exception:* Thermostat setback controls are not required in nonresidential buildings in areas where the winter median of extremes outdoor air temperature is greater than 32 degrees F.
  - A setup cooling thermostat setpoint if the system provides mechanical cooling. *Exception:* Thermostat setup controls are not required in nonresidential buildings in areas where the summer design dry bulb 0.5 percent temperature is less than 100 degrees F.
- Occupant-sensing zone controls:

Space conditioning systems serving rooms that are required to have occupant sensing controls to satisfy the lighting control requirements of Section 130.1(c) and where Table 120.1-A of the Energy Code identifies the room or space is eligible to reduce the ventilation air to zero, shall incorporate this control strategy known as occupied standby mode. Occupancy sensors are required to report the room status as vacant if all sensors within that room do not detect activity for 20 minutes (building designers are allowed to set a shorter time threshold to define vacancy).

A space conditioning zone shall enter occupied standby mode when occupant sensing controls indicate that all the lighting zones within the zone are vacant for five minutes or less. After entering occupied standby mode, the cooling setpoint shall be increased by at least 2 degrees F and the heating setpoint shall be decreased by at least 2 degrees F, or for a multiple zone system with DDC to the zone level the cooling setpoint shall be increased by at least 0.5 degrees F and the heating setpoint shall be decreased by at least 0.5 degrees F. All airflow to the zone shall be shut off when in occupied standby mode. If the temperature in the zone drifts outside the deadband, then the full space conditioning system will turn on to satisfy the load in that zone.

This occupancy control must not prevent outside air ventilation of the space when the pre-occupancy ventilation purge cycle is required by Section 120.1(d)2. Pre-occupancy purge ventilates the space prior to scheduled occupancy each day to dilute and exhaust contaminants that have built up inside the building over night while the HVAC systems were off. Typically, the space is unoccupied during these periods and the occupancy control must not disable this scheduled ventilation cycle.

- Exceptions for automatic shutoff, setback and setup, and occupant sensor setback:
  - *Exception to A, B, and C:* It can be demonstrated to the satisfaction of the enforcement agency that the system serves an area that must operate continuously.

   - *Exception to A, B, and C:* Systems that have a full load demand of 2 kW or less, or 6,826 Btu/h, if they have a readily accessible manual shut off switch. Included is the energy consumed within all associated space-conditioning systems including compressors, as well as the energy consumed by any boilers or chillers that are part of the system.
   - *Exception to A and B:* Systems serve hotel/motel guest rooms, if they have a readily accessible manual shut-off switch.
- Hotel/motel guest room controls:

Reference: Section 120.2(e)4

Hotel/motel guest rooms shall have captive card key controls, occupancy sensing controls, or automatic controls such that within 30 minutes of a guest leaving the room, setpoints are set-up of at least +5 degrees F (+3 degrees Celsius) in cooling mode and set-down of at least -5 degrees F (-3 degrees Celsius) in heating mode.

Example 4-19

Question:

Can occupancy sensors be used in an office to shut off the VAV boxes during periods when the spaces are unoccupied?

Answer:

Yes, only if the ventilation is provided through operable openings. With a mechanical ventilation design the occupancy sensor could be used to reduce the VAV box airflow to the minimum allowed for ventilation. It should not shut the airflow off completely; ventilation must be supplied to each space at all times when the space is usually occupied.

Example 4-20

Question:

Must a 48,000 sq ft building with 35 fan coil units have 35-time switches?

Answer:

No. More than one space-conditioning system may be grouped on a single time switch, subject to the area limitations required by the isolation requirements (see Isolation). In this case, the building would need two isolation zones, each no larger than 25,000 sq ft, and each having its own time switch.

Example 4-21

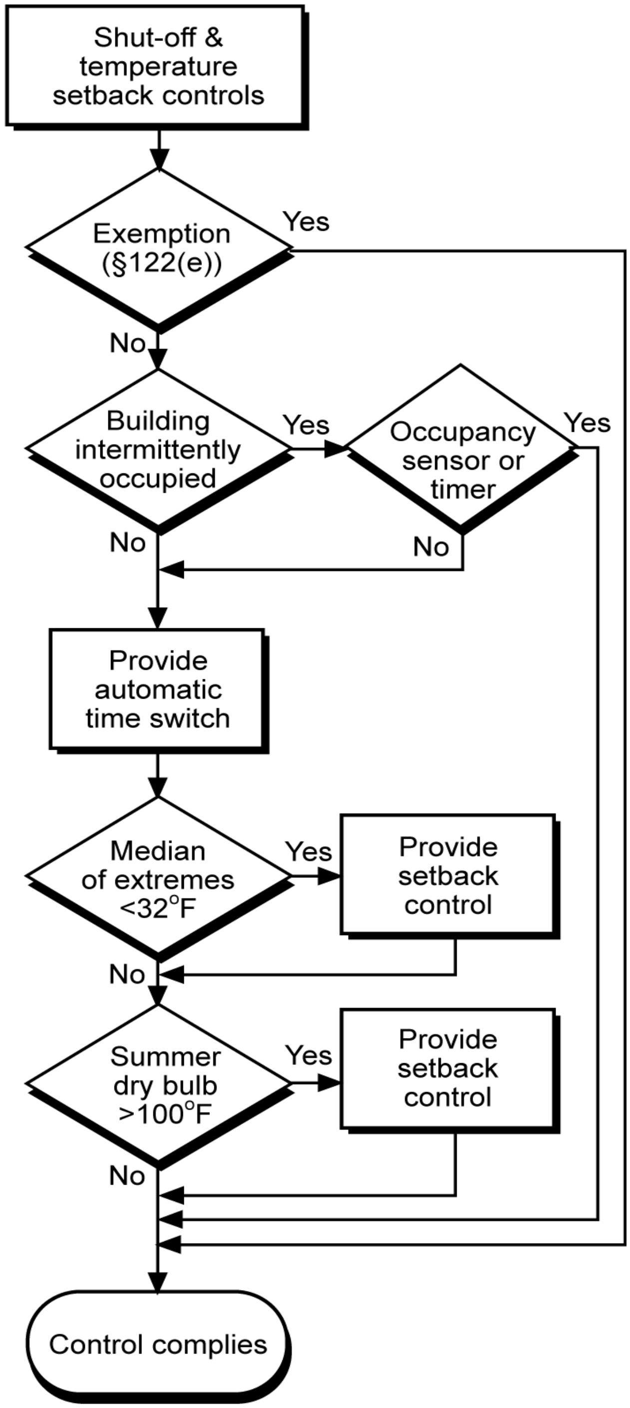
Question:

Can a thermostat with setpoints determined by sensors (such as a bi-metal sensor encased in a bulb) be used to accomplish a night setback?

Answer:

Yes. The thermostat must have two heating sensors, one each for the occupied and unoccupied temperatures. The controls must allow the setback sensor to override the system shutdown.

Figure 4-11: Shut-Off and Setback Controls Flowchart



Source: California Energy Commission

These provisions are required by the Energy Code to reduce the likelihood that shut-off controls will be circumvented to cause equipment to operate continuously during unoccupied hours.

Example 4-22

Question:

If a building has a system comprised of 30 fan coil units, each with a 300-watt fan, a 500,000 Btu/h boiler, and a 30-ton chiller, can an automatic time switch be used to control only the boiler and chiller (fan coils operate continuously)?

Answer:

No. The 2 kW criterion applies to the system as a whole and is not applied to each component independently. While each fan coil only draws 300 W, they are served by a boiler and chiller that draw much more. The consumption for the system is well in excess of 2 kW.

Assuming the units serve a total area of less than 25,000 sq ft (see Isolation), one-time switch may control the entire system.

Infiltration Control

Reference: Section 120.2(f)

Outdoor air supply and exhaust equipment must incorporate dampers that automatically close when fans shut down.

Fans shut down when ventilation or conditioned air is not necessary for the building, which only occurs when a normally scheduled unoccupied period begins (such as overnight or a weekend for office buildings) or when occupancy sensors are used for ventilation control. The dampers may either be motorized, or of the gravity type. However, only motorized dampers that remain closed when the fan turns on would be capable of accomplishing the best practice below.

Best Practice

Though the Energy Code only specifies fan shut down, as a best practice outside air dampers should also remain completely closed during the unoccupied periods, even when the fan turns on to provide setback heating or cooling. However, to avoid instances of insufficient ventilation, or sick building syndrome, the designer should specify that the outside air dampers open and provide ventilation if:

- The unoccupied period is a one-hour pre-occupancy purge ventilation, as per Section 120.1(c)2.
- The damper is enabled by an occupant sensor in the building as per Section 120.1(c)5, indicating that there are occupants that demand ventilation air.
- The damper is enabled by an override signal as per Section 120.2(e)1, which includes an occupancy sensor and an automatic time switch control device or manually operated four-hour timer.

Exception 1: Equipment that serves an area that must operate continuously.

Exception 2: Damper control required on gravity ventilators or other non-electrical equipment, provided that readily accessible manual controls are incorporated.

Exceptions 3 and 4: Damper control is not required at combustion air intakes and shaft vents or where prohibited by other provisions of law. If the designer elects to install dampers or shaft vents to help control stack-induced infiltration, the damper should be motorized and controlled to open in the event of a fire in accordance with applicable fire codes.

Isolation Area Controls

Reference: Section 120.2(g)

Large space-conditioning systems serving multiple zones may waste considerable quantities of energy by conditioning all zones when only a few are occupied. Typically, this occurs during evenings or weekends when less people are working. When the total area served by a system exceeds 25,000 sq ft, the Energy Code requires that the system be designed, installed, and controlled with area isolation devices to minimize energy consumption during these times. The requirements are:

- The building shall be divided into isolation areas, the area of each not exceeding 25,000 sq ft. An isolation area may consist of one or more zones.
- An isolation area cannot include spaces on different floors.
- Each isolation area shall be provided with isolation devices such as valves or dampers that allow the supply of heating or cooling to be setback or shut off independently of other isolation areas.
- Each isolation area shall be controlled with an automatic time switch, occupancy sensor, or manual timer. The requirements for these shut-off devices are the same as described previously in Shut Off and Temperature Setup/Setback. As discussed previously for occupancy sensors, a building purge must be incorporated into the control sequences for normally occupied spaces, so occupancy sensors and manual timers are best limited to use in those areas that are intermittently occupied.

Any zones requiring continuous operation do not have to be included in an isolation area.

Example 4-23

Question

How many isolation zones does a 55,000 sq ft building require?

Answer

At least three. Each isolation zone may not exceed 25,000 sq ft.

Isolation of Zonal Systems

Small zonal type systems such as water loop heat pumps or fan coils may be grouped on automatic time-switch devices, with control interlocks that start the central plant equipment whenever any isolation area is occupied. The isolation requirements apply to equipment supplying heating and cooling only; central ventilation systems serving zonal type systems do not require these devices.

Isolation of Central Air Systems

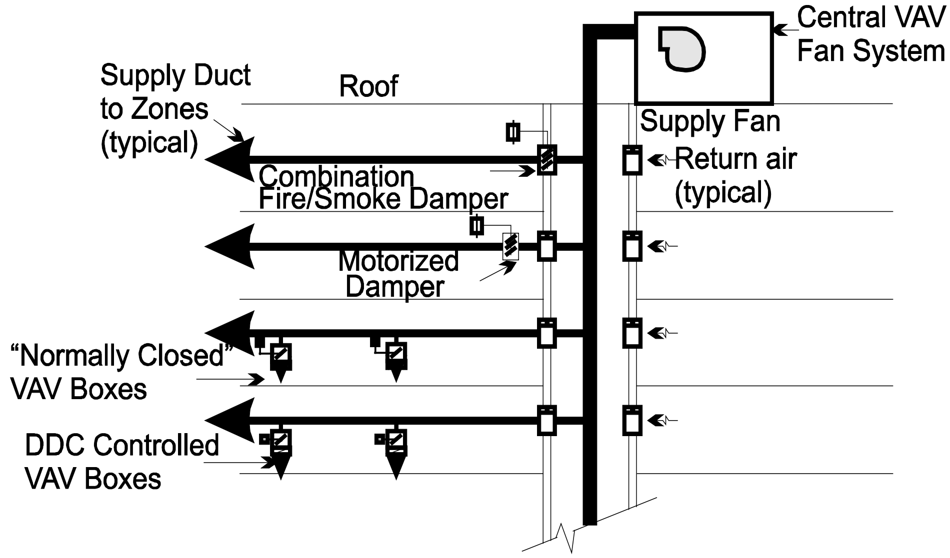
Figure 4-12 below depicts four methods of area isolation with a central VAV system:

- On the lowest floor, programmable DDC boxes can be switched on a separate time schedule for each zone or blocks of zones. When unoccupied, the boxes can be programmed to have zero minimum volume setpoints and unoccupied setback/setup setpoints. This form of isolation can be used for sections of a single floor distribution system.
- On the second floor, normally closed pneumatic or electric VAV boxes are used to isolate zones or groups of zones. In this scheme the control source (pneumatic air or control power) for each group is switched on a separate control signal from an individual time

schedule. Again, this form of isolation can be used for sections of a single floor distribution system.

- On the third floor, isolation is achieved by inserting a single motorized damper on the trunk of the distribution ductwork. With the code requirement for fire/smoke dampers (see next numbered item) this method is somewhat obsolete. When applied, this method can only control a single trunk duct. Care must be taken to integrate the motorized damper controls into the fire/life safety system.
- On the top floor, a combination fire smoke damper is controlled to provide the isolation. This control can only be used on a single trunk duct. Fire/smoke dampers required by code can be used for isolation at virtually no cost, provided that they are wired so that the fire life-safety controls take precedence over off-hour controls (local fire officials generally allow this dual usage of smoke dampers since it increases the likelihood that the dampers will be in good working order in the event of a fire). No isolation devices are required on the return.

Figure 4-12: Isolation Methods for a Central VAV System



Source: California Energy Commission

Example 4-24

Question

Does each isolation area require a ventilation purge?

Answer

Yes. Consider each isolation area as if it were a separate air-handling system, each with its own time schedule, setback, and setup control.

Turndown of Central Equipment

Where isolation areas are provided, it is critical that the designer plans the central systems (fans, pumps, boilers, and chillers) to have sufficient stages of capacity or turndown controls to operate stably, as required to serve the smallest isolation area on the system. Failure to do so may cause fans to operate in surge, excessive equipment cycling and loss of temperature control. Acceptable schemes include:

- Application of demand-based supply pressure reset for VAV fan systems. This will generally keep variable speed driven fans out of surge and can provide 10:1 turndown.
- Use of pony chillers (an additional small chiller to be used at partial load conditions) or unevenly split capacities in chilled water plants. This may already be required to serve 24/7 loads.
- Unevenly split boiler plants.

Automatic Demand Shed Controls

Please refer to Chapter 4.6.1.7 of the 2022 Nonresidential and Multifamily Compliance Manual.

Economizer Fault Detection and Diagnostics

Reference: Section 120.2(i)

Economizer Fault Detection and Diagnostics (FDD) is a mandatory requirement for all newly installed air handlers with a mechanical cooling capacity greater than 33,000 Btu/hr and an air economizer.

The FDD system can be either a stand-alone unit or integrated. A stand-alone FDD unit is added onto the air handler, while an integrated FDD system is included in the air handler system controller or is part of the DDC system.

Where required, the FDD system shall meet each of the following requirements:

- Temperature sensors shall be permanently installed to monitor system operation of outside air, supply air, and return air.
- Temperature sensors shall have an accuracy of ±2 degrees F over the range of 40 degrees F to 80 degrees F.
- The controller shall have the capability of displaying the value of each sensor.
- The controller shall provide system status by indicating the following conditions:
    - Free cooling available.
    - Economizer enabled.
    - Compressor enabled. For systems that don’t have compressors, indicating “mechanical cooling enabled” also complies.
    - Heating enabled if the system is capable of heating.
    - Mixed air low limit cycle active.
- The unit controller shall allow manual initiation of each operating mode so that the operation of cooling systems, economizers, fans, and heating system can be independently tested and verified.
- Faults shall be reported using one of the following options:
    - An EMCS that is regularly monitored by facility personnel
    - Displayed locally on one or more zone thermostats or a device within five feet of a zone thermostat, clearly visible, at eye level and meet the following requirements:

        - On the thermostat, device, or an adjacent written sign, there must be instructions displayed for how to contact the appropriate building personnel or an HVAC technician to service the fault.
        - In buildings with multiple tenants, the fault notification shall either be within property management offices or in a common space accessible by the property or building manager.
    - Reported to a fault management application that automatically provides notification of the fault to a remote HVAC service provider. This allows the service provider to coordinate with an HVAC technician to service the fault.
- The FDD system shall have the minimum capability of detecting the following faults:
    - Air temperature sensor failure/fault. This failure mode is a malfunctioning air temperature sensor, such as the outside air, discharge air, or return air. This could include loss of calibration, complete failure (either through damage to the sensor or its wiring) or failure due to disconnected wiring.
    - Not economizing when programmed to do so. In this case, the economizer should be enabled yet is not providing free cooling. This leads to an unnecessary increase in mechanical cooling energy. For example, if the economizer high limit setpoint is too low (55˚F), or the economizer is stuck in the closed position.
    - Economizing when not programmed to do so. This is the opposite malfunction from the previous problem. In this case, conditions are such that the economizer should be at minimum ventilation position but instead is open beyond the correct position. This leads to an unnecessary increase in heating and cooling energy. For example, if the economizer high limit setpoint is too high (82˚F), or the economizer is stuck in the open position.
    - Damper not modulating. This issue represents a stuck, disconnected, or otherwise inoperable damper that does not modulate. It is a combination of the previous two faults: not economizing when programmed to do so and economizing unnecessarily.
    - Excess outdoor air. This failure occurs when the economizer provides an excessive level of ventilation, usually much higher than is needed for design minimum ventilation. It causes an energy penalty during periods when the economizer should not be enabled (during cooling mode when outdoor conditions are higher than the economizer high limit setpoint). During heating mode, excess outdoor air will increase heating energy.
- The FDD system shall be certified to the Energy Commission, by the manufacturer of the FDD system, to meet the requirements one through seven, above. The manufacturer submittal package is available in Joint Appendices JA6.3, Economizer Fault Detection and Diagnostics Certification Submittal Requirements.

For air handlers controlled by DDC (including packaged systems), FDD sequences of operations must be developed to adhere with the requirements of Section 120.2(i)1 through 7. FDD systems controlled by DDC are not required to be certified to the Energy Commission, but manufacturers, controls suppliers, or other market actors can choose to apply for certification. For DDC based FDD systems, a new acceptance test has been developed to test the sequences of operations in the field to verify that they in-fact comply with the required faults of Section 120.2(i).

ASHRAE Guideline 36-2021 is a good reference for developing sequences of operations specifically for the faults listed in 120.2(i). The purpose of Guideline 36 is to provide uniform sequences of operation for heating, ventilating, and air-conditioning (HVAC) systems that are intended to maximize HVAC system energy efficiency and performance, provide control stability, and allow for real-time fault detection and diagnostics. To properly adhere to Guideline 36, all sequences of operations design elements in Sections 5.16.14 and/or 5.18.13 of that guideline must be implemented, including defining operating states, the use of an alarm delay, and the installation of an averaging mixed air temperature sensor. If a designer uses Guideline 36 to detect the required economizer faults in Title 24, Section 120.2(i), the sequences of operations should include Guideline 36 Fault Conditions numbers #2, 3, and 5 through 13, at a minimum. Other Title 24 FDD requirements in Section 120.2(i) and acceptance tests would not be met by including these fault conditions into sequences of operations and must be met through other means.

Direct Digital Controls

Reference: Section 120.2(j)

The requirement for DDC will mostly impact smaller buildings, since it is already common practice to install DDC in medium and large buildings; primarily due to the size and complexity of HVAC systems of medium and large buildings, which DDC is well suited to operate. Small buildings in the past did not require DDC and therefore could not take advantage of basic energy savings strategies.

DDC systems facilitate energy saving measures through monitoring and regulating the HVAC systems and optimizing their efficient operation. With most buildings requiring DDC, the following energy saving measures will be triggered if DDC is applied to the zone level:

- DCV (mandatory) - Demand Controlled Ventilation
- Automatic Demand Shed Controls (mandatory) - Automatic Demand Shed Controls
- Optimum Start/Stop Controls (mandatory) - Optimum Start/Stop Controls
- Setpoint Reset Controls for VAV systems (prescriptive) - Variable Air Volume (VAV) Supply Fan Controls

For further explanation, see the appropriate compliance manual sections for the measures listed above.

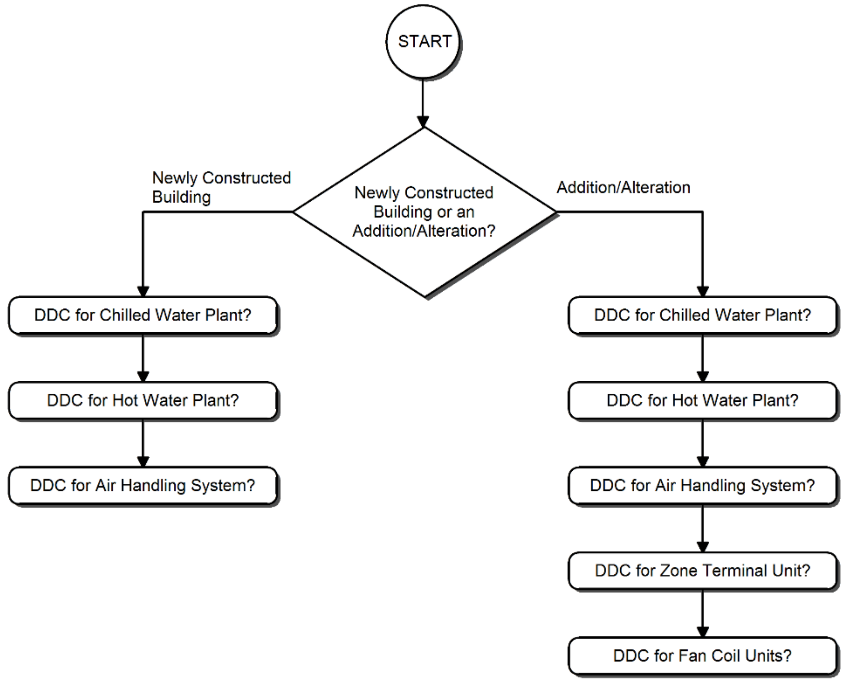
The Energy Code mandates DDC for only certain building applications with minimum qualifications or equipment capacities, as specified in Table 120.2-A of the Energy Code.

Buildings that do not meet the specified minimum qualifications are not required to install DDC.

Follow the flowchart in Figure 4-13: Building Status Flowchart to determine if a DDC system is required for newly constructed buildings, additions, or alterations. The Building Status Flowchart will indicate which equipment flowchart (Figure 4-14: Chilled Water Plant Flowchart through Figure 4-18: Fan Coil Units Flowchart) should be used for each type of HVAC equipment that will be installed in the building.

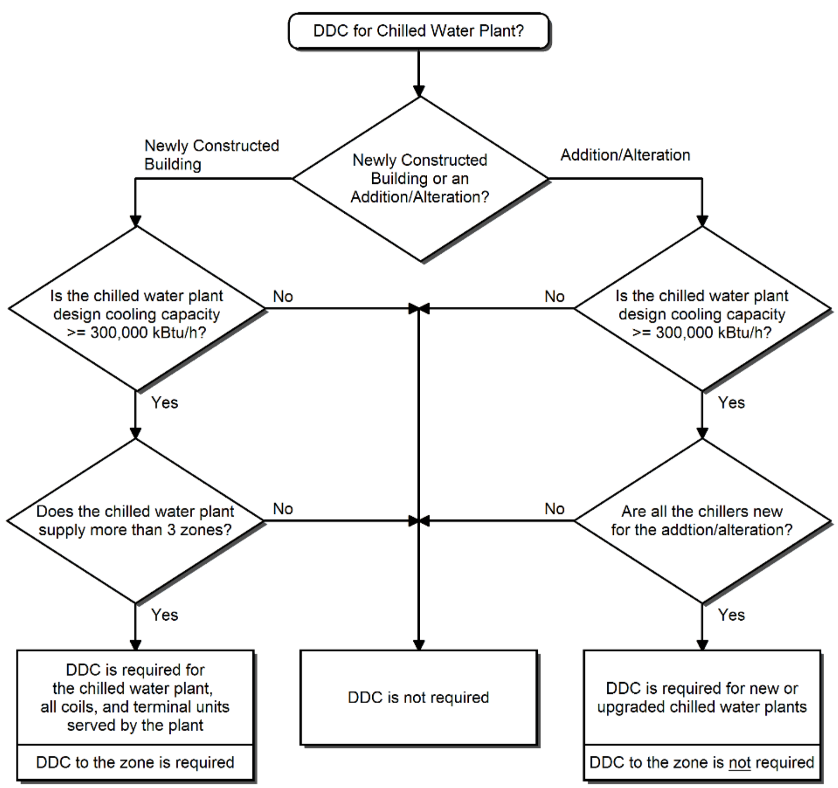
The flowcharts will indicate whether DDC is required for the building, how it should be applied to the equipment and whether it is required to be installed at the zone level.

Figure 4-13: Building Status Flowchart



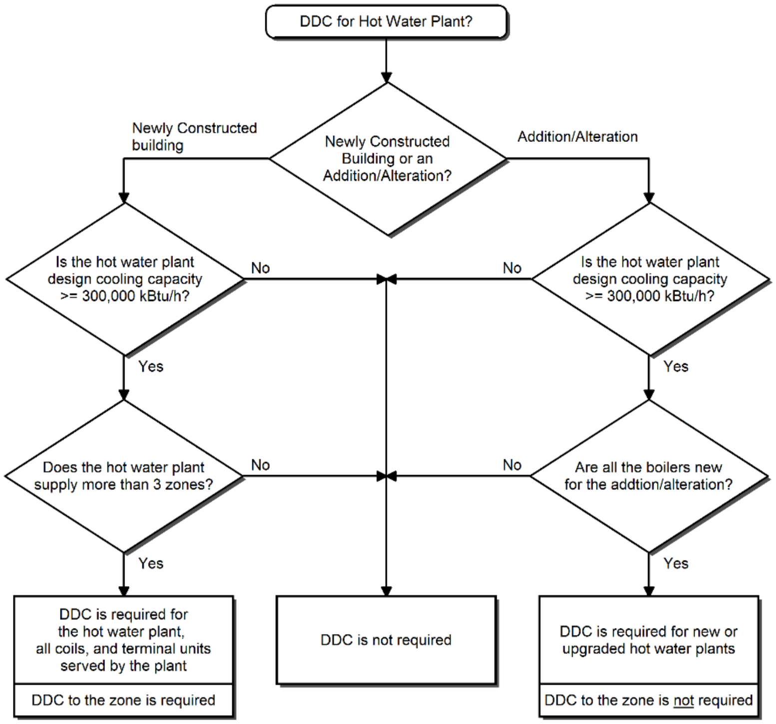
Source: California Energy Commission

Figure 4-14: Chilled Water Plant Flowchart



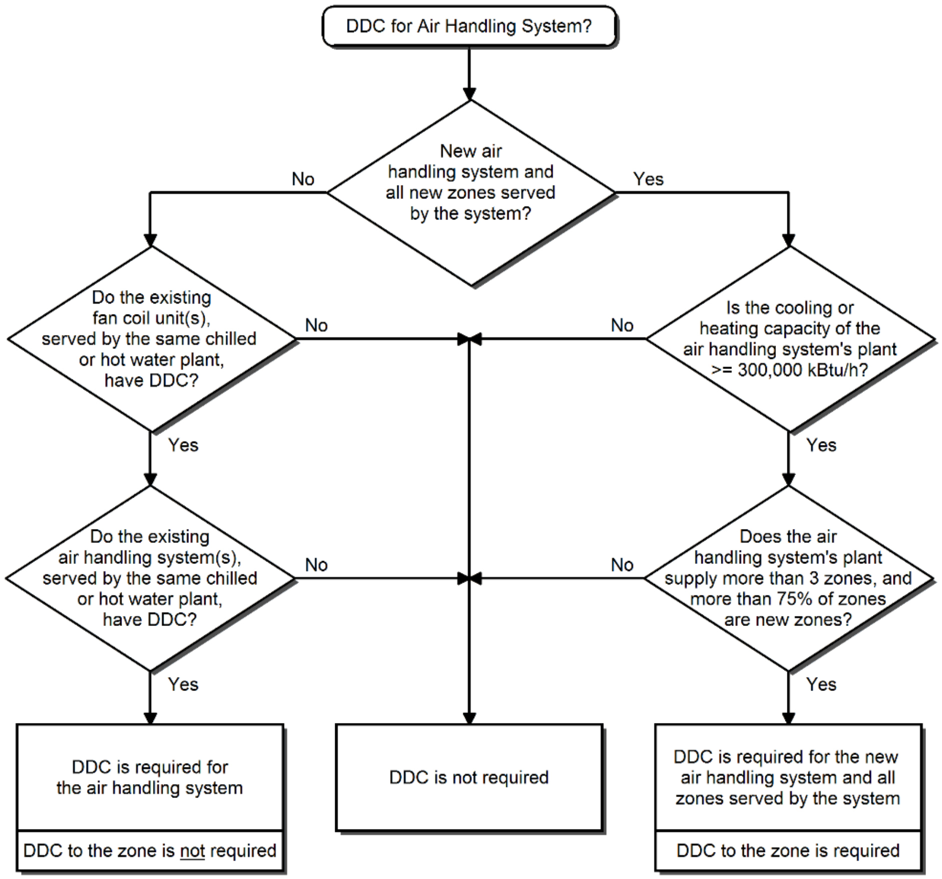
Source: California Energy Commission

Figure 4-15: Hot Water Plant Flowchart



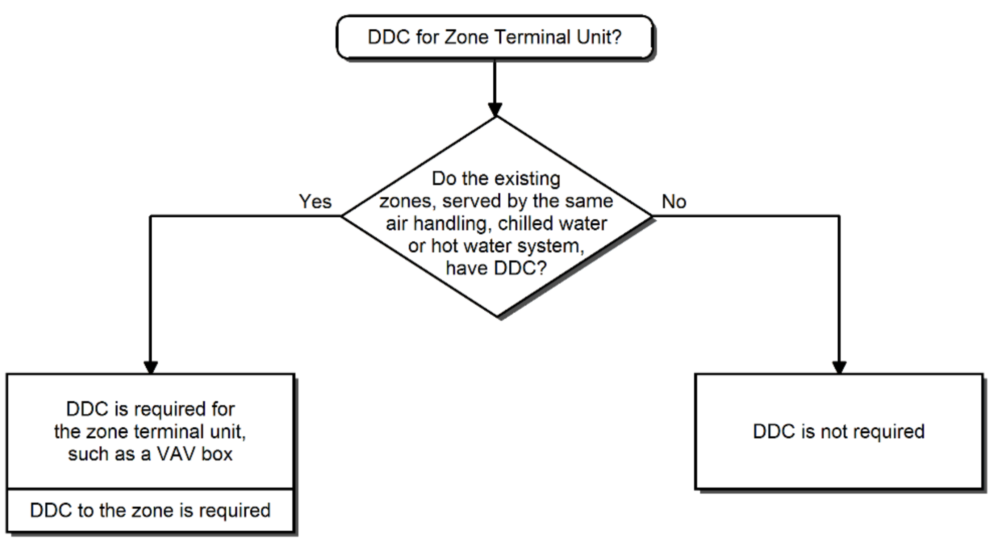
Source: California Energy Commission

Figure 4-16: Air Handling System Flowchart



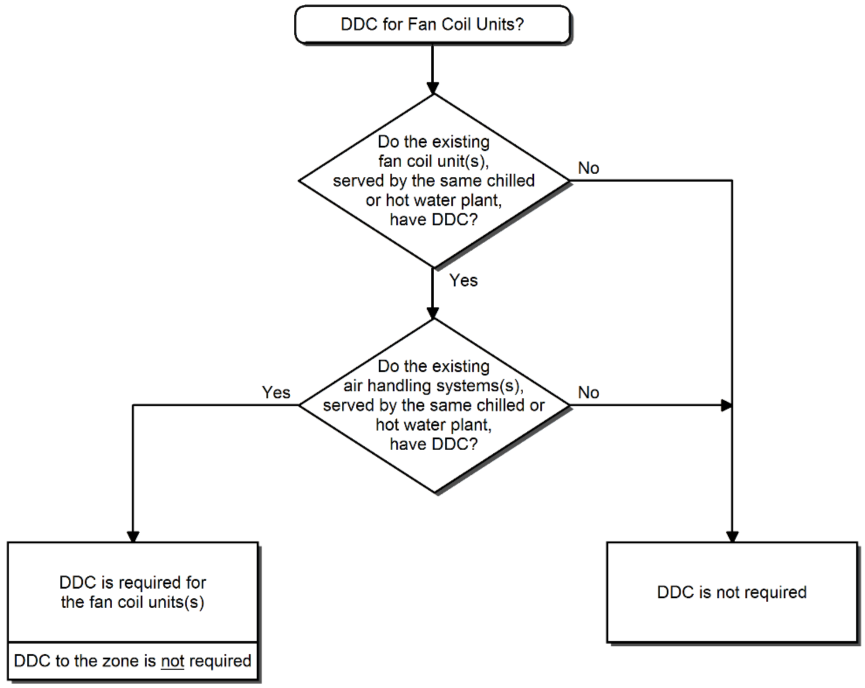
Source: California Energy Commission

Figure 4-17: **Zone Terminal Unit Flowchart**



Source: California Energy Commission

Figure 4-18: **Fan Coil Units Flowchart**



Source: California Energy Commission

For additions or alterations to buildings, zones that are not part of the addition or alteration are not required to be retrofitted with DDC to the zone. Pre-existing DDC systems in buildings are not required to be retrofitted so DDC is to the zone.

Example 4-25

Question:

If a newly constructed building has an HVAC system comprised of an air handling system, serving four zones and a chilled water plant with a design cooling capacity of 250,000 Btu/h, is DDC required?

Answer:

No. Although the HVAC system is serving more than three zones, the chilled water plant does not meet the minimum design cooling capacity of 300,000 Btu/h (300 kBtu/h). A DDC system would be required if the design cooling capacity was 300,000 Btu/h or larger.

Example 4-26

Question:

If an addition to a building requires a new VAV box, is DDC required?

Answer:

Maybe. The answer is dependent upon whether there is already a DDC system for the zones served by the same air handling, chilled water, or hot water system. Essentially this is to ensure that if a DDC system is already installed, then it must be continued throughout the building, including the addition.

Example 4-27

Question:

If a building's chilled water plant is upgraded with new chillers that have a design capacity of 500 kBtu/h and serves three zones, is DDC required?

Answer:

Yes. The criterion that triggers the DDC requirement is that the plant upgrade is installing **new** chillers with a cooling capacity greater than 300 kBtu/h. In this case, the number of zones is irrelevant for determining if DDC is required.

The Energy Code now requires the mandated DDC system to have the following capabilities to ensure the full energy saving benefits of DDC:

- Monitor zone and system demand for fan pressure, pump pressure, heating, and cooling
- Transfer zone and system demand information from zones to air distribution system controllers and from air distribution systems to heating and cooling plant controllers
- Automatically detect those zones and systems that may be excessively driving the reset logic and generate an alarm, or other indication, to the system operator
- Readily allow operator removal of zone(s) from the reset algorithm
- Trend and graphically display input and output points for new buildings
- Reset setpoints in non-critical zones, signal from a centralized contact or software point

Optimum Start/Stop Controls

Reference: Section 120.2(k)

Optimum start/stop controls are an energy saving technique where the HVAC system determines the optimum time to turn on or turn off the HVAC system. This ensures that the space reaches the appropriate temperature during occupied hours only, without wasting energy to condition the space during unoccupied hours. It applies to heating and cooling.

Optimum start controls are designed to automatically adjust the start time of a space conditioning system each day. The purpose of these controls is to bring the space temperature to the desired occupied temperature levels at the beginning of scheduled occupancy. The controls take in to account the space temperature, outside ambient temperature, occupied temperature, amount of time prior to scheduled occupancy, and if present, the floor temperatures of mass radiant floor slab systems.

Optimum stop controls are designed to automatically adjust the stop time of a space conditioning system each day with the intent of letting the space temperature coast to the unoccupied temperature levels after the end of scheduled occupancy. The controls shall take in to account the space temperature, outside ambient temperature, unoccupied temperature, and the amount of time prior to scheduled occupancy.

Systems that must operate continuously are not subject to these requirements.

Hot Water Supply Temperature

Reference: Section 120.2(l)

Hydronic space heating systems shall be designed for a hot water supply temperature (HWST) no greater than 130°F. This applies to new construction, additions, and alterations, all building types, and in all climate zones.

Historically, higher temperatures than 130°F were used, but a maximum HWST of 130°F is compatible with existing systems. This measure allows a gradual transition as noncondensing boilers are replaced in additions and alterations with condensing boilers or air-to-water heat pumps (AWHPs). This measure requires only incremental system adjustments, like potentially upsized piping and more powerful pumps, and will ensure future buildings in California are optimized for lower hot water supply and return temperatures, enhancing efficiency without sacrificing occupant comfort.

Example 4-28

Question

Does the new measure ban the use of noncondensing boilers?

Answer

No. The measure does not ban noncondensing boilers as long as there is a secondary loop that will comply with the 130°F maximum HWST limit.

Example 4-29

Question

If we are doing an alteration that includes new zoning while having a non-condensing boiler that must operate at 180°F, can the additional piping be designed for 180°F?

Answer

No. While the existing plant may need to run at 180°F to serve existing zones, the new piping must be upsized to handle the lower hot water supply temperature of 130°F. The noncondensing boiler can keep operating at 180°F, but when it gets replaced, it will likely be with a unit (such as an AWHP or condensing boiler) that would benefit from the 130°F requirement.

Prescriptive Requirements

There are two sections describing the prescriptive requirements for space conditioning systems:

- HVAC equipment requirements includes sizing, equipment selection and type, calculations, fan systems, electric resistance heating, heat rejection systems, minimum chiller efficiency, limitation of air-cooled chillers, exhaust system transfer air, dedicated outdoor air systems, exhaust heat recovery, and mechanical heat recovery covering Sections 140.4(a), (b), (c), (g), (h), (i), (j), (o), (p), (q) and (s).
- Space conditioning control requirements includes space conditioning zone controls, economizers, variable air volume supply fan controls, supply air temperature reset controls, heat rejection fan controls, window/door switches for mechanical system shutoff, and DDC controller logic covering Sections 140.4(c), (d), (e), (f), (h), (m), (n) and (r).

Note: Section 140.4(l) is reserved.

Space Conditioning Zone Controls

Reference: Section 140.4(d)

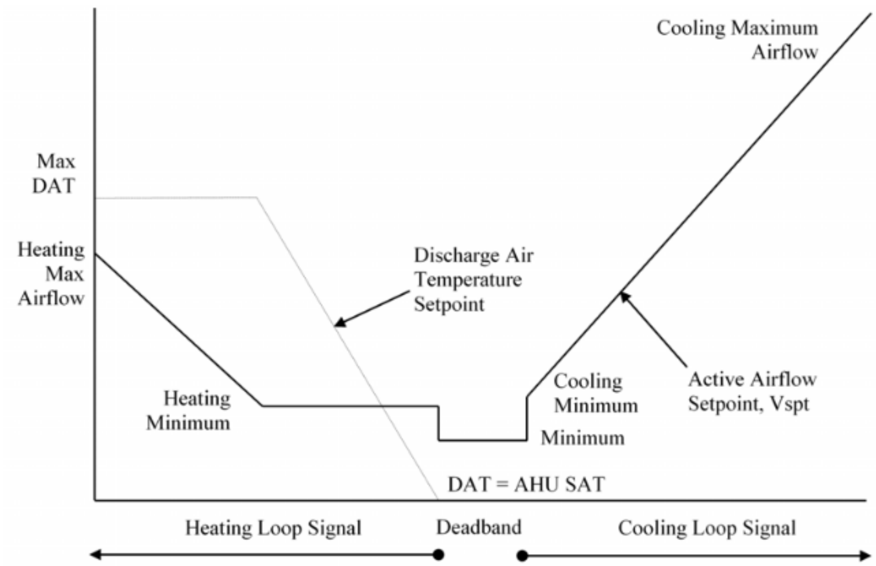
Each space-conditioning zone shall have controls designed in accordance with either of the following sets of requirements:

- Each space-conditioning zone shall have controls that prevent:
    - Reheating of air that has been previously cooled by mechanical cooling equipment or an economizer.
    - Recooling of air that has been previously heated. This does not apply to air returned from heated spaces.
    - Simultaneous heating and cooling in the same zone, such as mixing supply air that has been previously mechanically heated with air that has been previously cooled, either by mechanical cooling or by economizer systems.
- Zones served by VAV systems that are designed and controlled to reduce the volume of reheated, recooled, or mixed air to a minimum are allowed only if the controls meet all of the following requirements:
    - For each zone with DDC:
        - The volume of primary air that is reheated, re-cooled, or mixed air supply shall not exceed the larger of 50 percent of the peak primary airflow or the design zone outdoor airflow rate, per Mechanical Ventilation.
        - The volume of primary air in the deadband shall not exceed the design zone outdoor airflow rate, per Mechanical Ventilation.
        - The first stage of heating consists of modulating the zone supply air temperature setpoint up to a maximum setpoint no higher than 95 degrees F while the airflow is maintained at the deadband flow rate.
        - The second stage of heating consists of modulating the airflow rate from the deadband flow rate up to the heating maximum flow rate.
        - Control sequences of operation for reheat zones shall be in accordance with ASHRAE Guideline 36.
    - For each zone without DDC, the volume of primary air that is reheated, re-cooled, or mixed air supply shall not exceed the larger of 30 percent of the peak primary airflow or the design zone outdoor airflow rate, per Mechanical Ventilation.

For systems with DDC to the zone level, the controls must be able to support two different maximums -- one each for heating and cooling. This control is depicted in Figure 4-19: Dual-Maximum VAV Box Control Diagram with Minimum Flow in Deadband below. In cooling, this control scheme is similar to a traditional VAV reheat box control. The difference is what occurs in the deadband between heating and cooling and in heating mode. With traditional VAV control logic, the minimum airflow rate is typically set to the largest rate allowed by code. This airflow rate is supplied to the space in the deadband and heating modes. With the "dual maximum" logic, the minimum rate is the lowest allowed by code (e.g., the minimum ventilation rate) or the minimum rate the controls system can be set to (which is a function of the VAV box velocity pressure sensor amplification factor and the accuracy of the controller to convert the velocity pressure into a digital signal). As the heating demand increases, the dual maximum control first resets the discharge air temperature (typically from the design cold deck temperature up to 85 or 90 degrees F) as a first stage of heating then, if more heat is required, it increases airflow rate up to a “heating” maximum airflow setpoint, which is the same value as what traditional control logic uses as the minimum airflow setpoint. Using this control can save significant fan, reheat and cooling energy while maintaining better ventilation effectiveness as the discharge heating air is controlled to a temperature that will minimize stratification.

This control requires a discharge air sensor and may require a programmable VAV box controller. The discharge air sensor is also very useful for diagnosing control and heating system problems.

Figure 4-19: Dual-Maximum VAV Box Control Diagram with Minimum Flow in Deadband



Source: California Energy Commission

For systems without DDC to the zone (such as electric or pneumatic thermostats), the airflow that is reheated is limited to a maximum of either 30 percent of the peak primary airflow or the minimum airflow required to ventilate the space, whichever is greater.

Certain exceptions exist for space conditioned zones with one of the following:

- Special pressurization relationships or cross contamination control needs (laboratories are an example of spaces that might fall in this category)
- Site-recovered or site-solar energy providing at least 75 percent of the energy for reheating, or providing warm air in mixing systems
- Specific humidity requirements to satisfy non-covered process loads (computer rooms are explicitly not covered by this exception)
- Zones with a peak supply air quantity of 300 cfm or less
- Systems with healthcare facilities

Example 4-30

Question:

What are the limitations on VAV box minimum airflow setpoint for a 1,000 sq ft office having a design supply of 1,100 cfm and eight people?

Answer:

For a zone with pneumatic thermostats, the minimum cfm cannot exceed the larger of:

- 1,100 cfm x 30 percent = 330 cfm; or
- the minimum ventilation rate: which is the larger of:
    - 1,000 ft² x 0.15 cfm/ft² = 150 cfm; and
    - 8 people x 15 cfm/person = 120 cfm

Thus, the minimum airflow setpoint can be no larger than 330 cfm.

For a zone with DDC to the zone, the minimum cfm in the deadband cannot exceed the minimum ventilation rate. which is the larger of:

- 1,000 ft² x 0.15 cfm/ft² = 150 cfm; and
- 8 people x 15 cfm/person = 120 cfm

Thus, the minimum airflow setpoint in the dead band can be no larger than 150 cfm. And this can rise to 1100 cfm X 50 percent or 550 cfm at peak heating.

For either control system, based on ventilation requirements, the lowest minimum airflow setpoint must be at least 150 cfm, or transfer air must be provided in this amount.

Economizers

Reference: Section 140.4(e)

Airside economizers are required on air handler systems with a mechanical cooling capacity greater than 33,000 Btu/h (2.75 tons) and must be fully integrated (capable of modulating outside air and return air dampers to supply all the design supply air as outside air, even when additional mechanical cooling is required to meet the remainder of the cooling load). Under certain conditions an applicable economizer exception can be taken.

Waterside economizers are required for chilled-water systems without a fan or that induce airflow (such as chilled beams) based on the total chilled water system capacity and climate zone as described under Table 140.4-E. Additionally, waterside economizers must be capable of providing 100 percent of the expected system cooling load at an outside air temperature of 50 degrees F dry-bulb and 45 degrees F wet-bulb and below.

A schematic of an air-side economizer is depicted below in Figure 4-20: Air-Side Economizer Schematic. All air-side economizers have modulating dampers on the return and outdoor air streams.

Best Practice:

To provide 100 percent of the design supply air, designers will need to specify an economizer with a nominal capacity sufficient to deliver the design air flow rate when the economizer’s outdoor air damper is in the fully open position, and the return air damper is completely closed.

An appropriately sized economizer can also be estimated by determining the face velocity passing through the economizer, using the design airflow and the area of the economizer damper/duct opening.

The design airflow (cfm) should be available from the mechanical drawings or air handler cutsheet. The minimum area (sq ft) through which air is flowing from the outside to the fan can be measured in the field, or it can be found on the economizer damper cutsheet if the economizer damper is the smallest area. Dividing the design airflow by the smallest area will give the velocity of the air in ft per min.

Appropriately sized economizers that can supply 100 percent of the supply airflow without large pressure drops typically have face velocities of less than 2,000 ft per min.

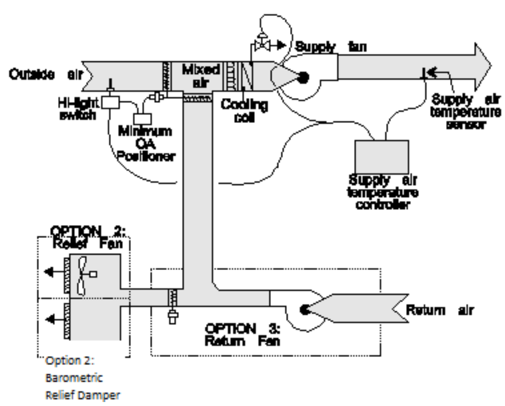
To maintain acceptable building pressure, systems with an airside economizer must have provisions to relieve or exhaust air from the building. In Figure 4-20: Air-Side Economizer Schematic, three common forms of building pressure control are depicted:

- Option 1: barometric relief
- Option 2: a relief fan generally controlled by building static pressure
- Option 3: a return fan often controlled by tracking the supply

On first call for cooling the outdoor air damper is modulated from minimum position to 100 percent open while the return air damper remains 100 percent open. As additional cooling is required, the outdoor air damper remains 100 percent open while the return air damper is modulated from 100 percent open to 0 percent open (fully-closed, 100 percent outdoor air). As more cooling is required, the outdoor air damper remains at 100 percent open and the return air damper remains at 0 percent open as the cooling coil is sequenced on. Slightly different approaches may apply depending on whether relief or return fans are involved and what minimum outdoor air control strategy applies.

Graphics of water-side economizers are presented in Water Economizers at the end of this chapter.

Figure 4-20: Air-Side Economizer Schematic



Source: California Energy Commission

Economizers are not required where:

Reference: Exceptions to Section 140.4(e)1

- Outside air filtration and treatment for the reduction of unusual outdoor contaminants make compliance unfeasible.
- Increased overall building TDV energy use results. This may occur where economizers adversely impact other systems, such as humidification, dehumidification, or supermarket refrigeration systems.
- Systems serving hotel/motel guest rooms.
- Cooling systems have the cooling efficiency that meets or exceeds the cooling efficiency improvement requirements in Table 140.4-F (typically used for VRF systems).
- Fan systems primarily serving computer room(s). See Section 140.9(a) for computer room economizer requirements.
- Systems utilizing dedicated outside air systems (DOAS) for ventilation capable of providing at least 0.3 cfm/sf and exhaust air heat recovery can take an economizer exception for their independent space-cooling air handlers (typically VRF or WSHP), if those systems are less than 54,000 Btu/h (4.5 tons).
- Where the use of an air economizer in controlled environment horticulture spaces will affect carbon dioxide enrichment systems.
- Systems complying with sections 140.4(a)3Ai or 140.4(a)3Aii.

If an economizer is required, it must be:

Reference: Section 140.4(e)2

- Designed and equipped with controls that do not increase the building heating energy use during normal operation. This prohibits the application of single-fan dual-duct systems and traditional multizone systems using the Prescriptive Approach of compliance. With these systems, the operation of the economizer to pre-cool the air entering the cold deck also precools the air entering the hot deck and thereby increases the heating energy. *Exception:* when at least 75 percent of the annual heating is provided by site-recovered or site-solar energy.
- Fully integrated into the cooling system controls so that the economizer can provide partial cooling even when mechanical cooling is required to meet the remainder of the cooling load. On packaged units with stand-alone economizers, a two-stage thermostat is necessary to meet this requirement.
- Designed and equipped with a device capable of turning off the economizer under various conditions, see Air-side economizer high limit switches.
- If controlled by a DDC system, configured with control sequences of operation in accordance with ASHRAE Guideline 36.

The requirement that economizers be designed for concurrent operation is not met by some popular water economizer systems, such as those that use the chilled water system to convey evaporatively-cooled condenser water for “free” cooling. Such systems can provide all of the cooling load, but when the point is reached where condenser water temperatures cannot be sufficiently cooled by evaporation; the system controls throw the entire load to the mechanical chillers. Because this design cannot allow simultaneous economizer and refrigeration system operation, it does not meet the requirements of this section. An integrated water-side economizer which uses condenser water to precool the Chilled Water Return (CHWR) before it reaches the chillers (typically using a plate-and-frame heat exchanger) can meet this integrated operation requirement.

The requirement that DDC controllers be configured with ASHRAE Guideline 36 control sequences will avoid challenges with legacy control logic while ensuring effective implementation of the following key features:

- Pressure drop through air handling equipment will be minimized, as the economizer and return air dampers are sequenced such that they will not simultaneously restrict airflow.
- Economizer outdoor air and return air dampers are controlled to ensure that the supply air temperature control scheme does not yield an outdoor air flowrate that is less than the minimum outdoor airflow setpoint, as could occur in cold weather as the incoming outdoor air drives the supply air temperature down.
- Control loop conflicts, i.e., "fighting," between the economizer dampers and the cooling/heating coils is avoided. This conflict-avoidance prevents simultaneous heating and cooling and ensures that the economizer is maximized before enabling mechanical cooling.
- Building pressure is controlled to ensure that the building does not become over-pressurized.

Refer to the *Advanced Building Automation System Best Practices Guide*, referenced in DDC Controller Logic Using ASHRAE Guideline 36, for guidance with the selection and installation of building pressure sensors and economizer temperature sensors.

Refer to ASHRAE Guideline 16, *Selecting Outdoor, Return, and Relief Dampers for Air-Side Economizer Systems,* for guidance with the selection and sizing of economizer control dampers.

Refer to DDC Controller Logic Using ASHRAE Guideline 36 for additional guidance regarding the specification and implementation of ASHRAE Guideline 36 control sequences.

Air-side economizer high limit switches:

Reference: Section 140.4(e)2C

If an economizer is required by Section 140.4(e)1 and an air economizer is used to meet the requirement, the air side economizer is required to have high-limit shut-off controls that comply with Table 140.4-G.

- The first column identifies the high limit control category. There are three categories allowed in this prescriptive requirement: fixed dry bulb; differential dry bulb; and fixed enthalpy plus fixed dry bulb.
- The second column represents the California climate zone. "All" indicates that this control type complies in every California climate.
- The third and fourth columns present the high-limit control setpoints required.

The Energy Code eliminated the use of fixed enthalpy, differential enthalpy, and electronic enthalpy controls. Research on the accuracy and stability of enthalpy controls led to their elimination (with the exception of use when combined with a fixed dry-bulb sensor). The enthalpy-based controls can be employed if the project uses the performance approach. However, the performance model will show a penalty due to the inaccuracy of the enthalpy sensors.

Air Economizer Construction

Reference: Section 140.4(e)2E

If an economizer is required by Section 140.4(e)1, and an air economizer is used to meet the requirement, then the air economizer, and all air dampers shall have the following features:

- A five-year factory warranty for the economizer assembly.
- Certification by the manufacturer that equipment has been tested and is able to open and close against the rated airflow and pressure of the system for at least 60,000 damper opening and closing cycles. Required equipment includes, but is not limited to, outdoor air dampers, return air dampers, drive linkages and actuators.
- Economizer outside air and return air dampers shall have a maximum leakage rate of 10 cfm/sq ft at 250 Pascals (1.0 in. w.g) when tested in accordance with AMCA Standard 500-D. The leakage rates for the outside and return dampers shall be certified to the Energy Commission in accordance with Section 110.0.
- If the high-limit control uses either a fixed dry-bulb, or fixed enthalpy plus fixed dry-bulb control, the control shall have an adjustable setpoint.
- Economizer sensors shall be calibrated within the following accuracies:
    - Dry bulb (db) and wet bulb (wb) temperatures accurate to plus or minus 2 degrees F over the range of 40 degrees F to 80 degrees F.
    - Enthalpy accurate to plus or minus 3 Btu/lb over the range of 20 Btu/lb to 36 Btu/lb.
    - Relative humidity (RH) accurate to plus or minus 5 percent over the range of 20 percent to 80 percent
- Data from sensors used for control of the economizer shall be plotted on a sensor performance curve.
- Sensors used for the high limit control shall be located to prevent false readings, including but not limited to, being properly shielded from direct sunlight.
- Relief air systems shall be capable of providing 100 percent outside air without over-pressurizing the building.

Compressor unloading:

Reference: Section 140.4(e)2F

Systems that include an air economizer must comply with the following requirements:

- Unit controls shall have mechanical capacity controls interlocked with economizer controls such that the economizer is at 100 percent open position when mechanical cooling is on and does not begin to close until the leaving air temperature is less than 45 degrees F.
- Direct Expansion (DX) units greater than 65,000 Btu/hr that control the capacity of the mechanical cooling directly based on occupied space temperature shall have a minimum of two stages of mechanical cooling capacity.
- DX units not within the scope of number two (above), shall comply with the requirements in Table 140.4-H, and have controls that do not false load the mechanical cooling system by limiting or disabling the economizer or by any other means, except at the lowest stage of mechanical cooling capacity.

Chapter 14 of this manual describes mandated acceptance test requirements for economizers.

If the economizer is factory-calibrated the economizer acceptance test is not required at installation. A calibration certificate of economizer control sensors (outdoor air temperature, return air temperature, etc.) must be submitted to the local code enforcement agency in the permit application.

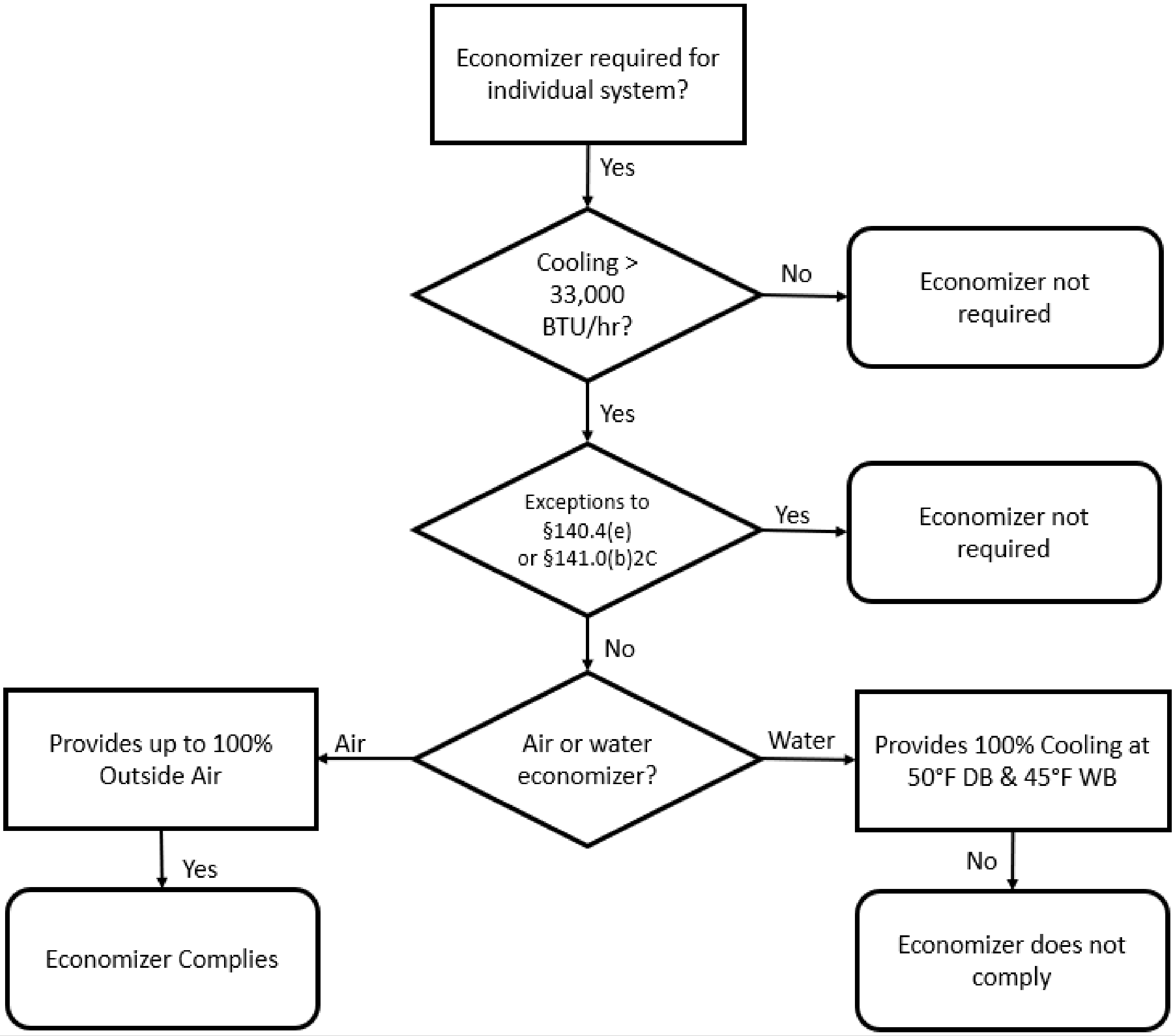
Water Economizer Specific Requirements

Reference: Section 140.4(e)3

Unlike air-side economizers, water economizers have parasitic energy losses that reduce the cooling energy savings. One of these losses comes from increases in pumping energy. To limit the losses, the Energy Code requires that precooling coils and water-to-water heat exchangers used as part of a water economizer system have either 1) a water-side pressure drop of less than 15 feet of water, or 2) a secondary loop so that the coil or heat exchanger pressure drop is not seen by the circulating pumps when the system is in the normal cooling (non-economizer) mode.

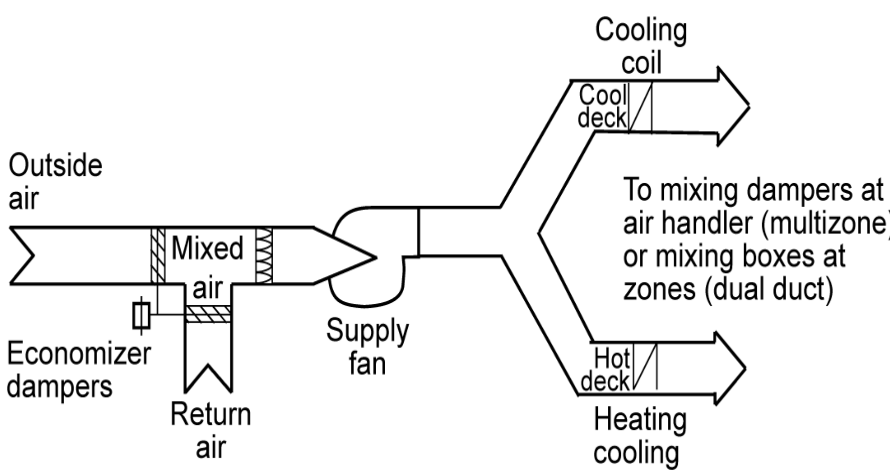
Water economizer systems must also be integrated with the mechanical cooling system so that they are capable of providing partial cooling--even when additional mechanical cooling is required to meet the remainder of the cooling load. This includes controls that do not false load the mechanical cooling system by limiting or disabling the economizer, or by any other means--such as hot gas bypass--except at the lowest stage of mechanical cooling.

Figure 4-21: Economizer Flowchart



Source: California Energy Commission

Figure 4-22: Single-Fan Dual-Duct System



Source: California Energy Commission

Example 4-31

Question:

If the design conditions are 94 degrees F db/82 degrees F wb can the design cooling loads be used to size a water-side economizer?

Answer:

No. The design cooling load calculations must be rerun with the outdoor air temperature set to 50 degrees F db/45 degrees F wb. The specified tower, as well as cooling coils and other devices, must be checked to determine if it has adequate capacity at this lower load and wet-bulb condition.

Example 4-32

Question:

Will a strainer cycle water-side economizer meet the prescriptive economizer requirements?

Answer:

No. It cannot be integrated to cool simultaneously with the chillers.

Example 4-33

Question:

Does a 12-ton packaged AC unit in climate zone 10 need an economizer?

Answer:

Yes. In addition, the economizer must be equipped with a fault detection and diagnostic system. However, the requirement for an economizer can be waived if the AC unit's efficiency is is at least 30% more efficient than the minimum cooling efficiency requirement. Refer to Table 140.4-F.

Variable Air Volume (VAV) Supply Fan Controls

Reference: Section 140.4(c), Section 140.4(m)

The VAV requirements for supply fans are as follows:

- Single zone systems (where the fans are controlled directly by the space thermostat) shall have a minimum of two stages of fan speed with no more than 66 percent speed when operating on stage one while drawing no more than 40 percent full fan power when running at 66 percent speed.
- All systems with air-side economizers to satisfy Economizers are required to have a minimum of 2 speeds of fan control during economizer operation.
- Multiple zone systems shall limit the fan motor demand to no more than 30 percent of design wattage at 50 percent design air volume.

Variable speed drives can be used to meet any of these three requirements.

VAV fan systems that do not have DDC to the zone level are required to have the static pressure sensor located in a position such that the control setpoint is less than or equal to 1/3 of the design static pressure of the fan. For systems without static pressure reset, the further the sensor is from the fan the more energy will be saved. For systems with multiple duct branches in the distribution separate sensors in each branch must be provided to control the fan and to satisfy the sensor with the greatest demand. When locating sensors, care should be taken to have at least one sensor between the fan and all operable dampers (e.g., at the bottom of a supply shaft riser before the floor fire/smoke damper) to prevent loss of fan static pressure control.

For systems with DDC to the zone level the sensor(s) may be anywhere in the distribution system and the duct static pressure setpoint must be reset utilizing control sequences of operation in accordance with ASHRAE Guideline 36. Guideline 36 applies a zone level demand-based trim and respond algorithm. For example, each zone will generate "requests" for increased static pressure as the damper approaches its full-open position. The AHU controller will respond by increasing its duct static pressure setpoint as requests are generated. Once the number of requests has reduced sufficiently (based on setpoint parameters), the AHU controller will trim its duct static pressure setpoint downward to reduce fan power.

Reset of supply pressure by demand not only saves energy but it also protects fans from operation in surge at low loads. Chapter 13, Acceptance Requirements, describes mandated acceptance test requirements for VAV system fan control.

The requirement that systems with zone level DDC controls utilize Guideline 36 control sequences ensures effective implementation of the following key features:

- System response (i.e., static pressure setpoint adjustments) can be tuned to ensure that critical zones are not starved of airflow and nuisance zones may be deprioritized by adjusting the zone level "Importance Multiplier."
- Rogue zones are automatically tracked and clearly identified. "Rogue zones" are zones that continuously drive the reset strategy in the direction of increased energy use. Automatic rogue zone detection offers an effective mechanism to diagnose and remedy an ineffective reset strategy, both during and post-implementation. Early rogue zone tracking can help to identify problems such as undersized VAV terminals, which presents the opportunity to remedy these problems before the owner takes occupancy.
- SAT setpoint and static pressure setpoint will be reset independently, using entirely separate loops. Both reset strategies react to zone demand, but each uses a distinct type of request. Note that zones requesting additional static pressure do not necessarily need colder air, and vice versa. For example, a zone that is in heating status may be starved for air as the heating airflow setpoint increases, hence it will generate static pressure requests without generating cold air requests. Alternatively, a zone that is located relatively close to the AHU may experience a climbing space temperature during a period of high cooling demand, despite having no issues achieving its design supply airflow rate. In this case, the zone controller will generate cold air requests without generating static pressure requests.

Refer to the *Advanced Building Automation System Best Practices Guide*, referenced in DDC Controller Logic Using ASHRAE Guideline 36, for additional guidance and information regarding trim and respond reset strategies.

Refer to DDC Controller Logic Using ASHRAE Guideline 36 for additional guidance regarding the specification and implementation of ASHRAE Guideline 36 control sequences.

Fan power consumption for laboratory exhaust systems must meet requirements in Section 140.9(c).

Supply Air Temperature Reset Control

Reference: Section 140.4(f)

Mechanical space-conditioning systems supplying heated or cooled air to multiple zones must include controls that automatically reset the supply air temperature in response to representative building loads or to outdoor air temperature. The controls must be capable of resetting the supply air temperature by at least 25 percent of the difference between the design supply-air temperature and the design room air temperature. The controls must also be configured with control sequences of operation in accordance with ASHRAE Guideline 36.

For example, if the design supply temperature is 55 degrees F and the design room temperature is 75 degrees F, then the difference is 20 degrees F, of which 25 percent is 5 degrees F. Therefore, the controls must be capable of resetting the supply temperature from 55 degrees F to 60 degrees F.

Air distribution zones that are likely to have constant loads, such as interior zones, shall have airflow rates designed to meet the load at the fully reset temperature. Otherwise, these zones may prevent the controls from fully resetting the temperature or will unnecessarily limit the hours when the reset can be used.

Control sequences of operation for supply air temperature (SAT) setpoint reset shall be in accordance with ASHRAE Guideline 36. Guideline 36 applies a two-factor SAT reset based on both zone level demand and outside air temperature (OAT), as follows:

- The demand-based SAT reset strategy utilizes a trim and respond algorithm. For example, each zone will generate "requests" for colder air as the zone controller approaches full-cooling operation, as indicated by the controller's cooling control loop approaching an output of 100 percent. For a VAV controller, a cooling control loop output that is approaching 100 percent typically correlates to an airflow setpoint that is approaching the design maximum cooling airflow. Each zone will generate additional requests for colder air as the zone temperature drifts further above the active cooling setpoint. The AHU controller will respond by reducing its SAT setpoint as requests are generated. Once the number of requests has reduced sufficiently (based on setpoint parameters), the AHU controller will trim its SAT setpoint in the direction of lower energy use.
- The OAT-based SAT reset strategy imposes an upper setpoint limit that is linearly-scaled with OAT (see Figure 4- 23: Energy Efficient Supply Air Temperature Reset Control for VAV Systems).

  For example, consider a single-duct VAV system that is configured with:
    - Maximum Cooling SAT Setpoint = 65 degrees F
    - Minimum Cooling SAT Setpoint = 55 degrees F
    - OAT Maximum Threshold = 70 degrees F
    - OAT Minimum Threshold = 60 degrees F

  In this case, the AHU controller will limit the SAT setpoint as follows:
    - If OAT < 60 degrees F, SAT may be reset to a maximum of 65 degrees as dictated by the zone level trim and respond logic.

    - If OAT > 60 degrees F and < 70 degrees F, SAT may be reset to a maximum that is linearly-scaled between 65 degrees F and 55 degrees F as a function of OAT, and as dictated by the zone level trim and respond logic.
    - If OAT > 70 degrees F, SAT is limited to 55 degrees F regardless of the zone level trim and respond logic.

  The OAT thresholds shown here offer a starting point but should be manipulated for the specific application. For instance, a building that has a relatively low envelope load (i.e. low window-to-wall ratio, low exterior-to-interior space area ratio) or a building that has inherently high air change rates may achieve greater energy performance by raising the OAT thresholds such that SAT reset is extended further into the cooling season.

The two-factor Guideline 36 SAT reset strategy is intended to conserve fan energy as the outside air temperature rises and the building cooling demand increases. The requirement that systems with zone level DDC controls utilize Guideline 36 control sequences ensures effective implementation through many key features. See Variable Air Volume (VAV) Supply Fan Controls for related discussion about setpoint reset strategies.

SAT reset is required for VAV reheat systems even if they have variable-speed drive (VSD) fan controls and static pressure setpoint reset logic.

Supply temperature reset is also required for constant volume systems with reheat justified on the basis of special zone pressurization relationships or cross-contamination control needs.

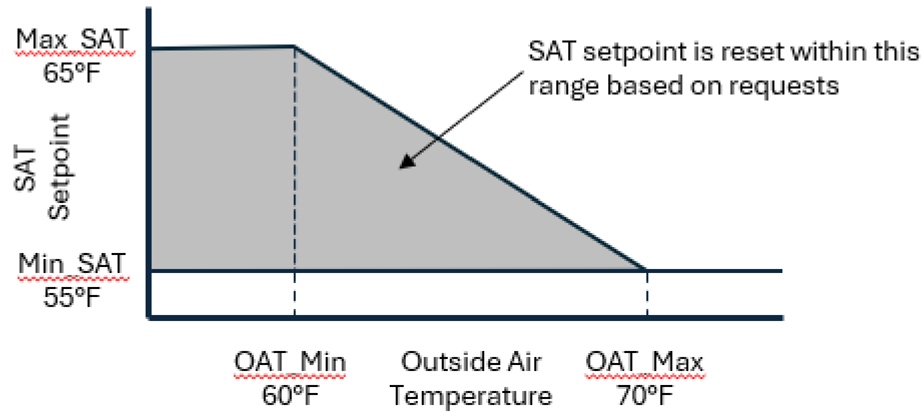
Refer to the *Advanced Building Automation System Best Practices Guide*, referenced in DDC Controller Logic Using ASHRAE Guideline 36, for additional guidance and information regarding trim and respond reset strategies.

Refer to DDC Controller Logic Using ASHRAE Guideline 36 for additional guidance regarding the specification and implementation of ASHRAE Guideline 36 control sequences.

Supply-air temperature reset is not required when:

- The zone(s) must have specific humidity levels required to meet exempt process needs. Computer rooms cannot use this exception.
- Where it can be demonstrated (to the satisfaction of the enforcement agency) that supply air reset would increase overall building energy use.
- The space-conditioning zone has controls that prevent reheating and recooling and simultaneously provide heating and cooling to the same zone.
- Systems serving healthcare facilities.

Figure 4-23: Energy Efficient Supply Air Temperature Reset Control for VAV Systems



Source: California Energy Commission

Heat Rejection Fan Control

Reference: Section 140.4(h)

When the fans on open cooling towers, closed-circuit fluid coolers, air-cooled condensers, and evaporative condensers are powered by a fan motor of 7.5 hp or larger, the system must be capable of operating at two-thirds speed, or less. In addition, the system must have controls that automatically change the fan speed to control the leaving fluid temperature or condensing temperature or pressure of the heat rejection device. Fan speed controls are not subject to these requirements when:

- Fans are powered by motors smaller than 7.5 hp.
- Heat rejection devices are included as an integral part of the equipment listed in Section 110.2(a).
- Condenser fans are serving multiple refrigerant circuits or flooded condensers.
- Up to one third of the fans on a condenser or tower with multiple fans have lead fans that comply with the speed control requirement.

Example 4-34

Question

A chilled water plant has a three-cell tower with 10 hp motors on each cell. Are speed controls required?

Answer

Yes. At minimum the designer must provide 2-speed motors, pony motors or variable speed drives on two of the three fans for this tower.

Hydronic System Measures

Reference: Section 140.4(k)

Hydronic Variable Flow Systems

Reference: Section 140.4(k)1

Hot water and chilled-water systems are required to be designed for variable flow. Variable flow is provided by using 2-way control valves. The Energy Code only require that flow is reduced to whichever value is greater: 50 percent or less of design flow or the minimum flow required by the equipment manufacturer for operation of the central plant equipment.

There are two exceptions for this requirement:

- Systems that include no more than three control valves.
- Systems having a total pump system power less than or equal to 1.5 hp.

It is not necessary for each individual pump to meet the variable flow requirement. These requirements can be met by varying the total flow for the entire pumping system in the plant. Strategies that can be used to meet these requirements include but are not limited to variable frequency drives on pumps and staging of the pumps.

The primary loop on a primary/secondary or primary/secondary/tertiary system could be designed for constant flow even if the secondary or tertiary loop serves more than three control valves. This is allowed because the primary loop does not directly serve any coil control valves. However, the secondary and tertiary loops of these systems must be designed for variable flow if they have four or more control valves.

The flow limitations are provided for primary-only variable flow chilled-water systems where a minimum flow is typically required to keep a chiller on-line. In these systems minimum flow can be provided with either a bypass with a control valve or some three-way valves to ensure minimum flow at all times. The system with a bypass valve is more efficient as it only provides bypass when absolutely required to keep the plant online.

For hot water systems, application of slant-tube or bent tube boilers will provide the greatest flow turndown. Typically, copper fin tube boilers require a higher minimum flow.

Example 4-35

Question

A plant is trying to meet the variable flow requirements of Section 140.4(k). Must each individual pump meet these requirements for the plant to comply with the Energy Code?

Answer

No. Individual pumps do not need to meet the variable flow requirements of this section. As long as the entire plant meets the variable flow requirements, the plant is in compliance. For example, the larger pumps may be equipped with variable frequency drives, or the pumps can be staged in a way that can meet these requirements.

Isolation for Chillers and Boilers
Reference: Section 140.4(k)2 and 3

Plants with multiple chillers or boilers are required to provide either isolation valves or dedicated pumps. In addition, they must check valves to ensure that flow will only go through the chillers or boilers that are staged on. Chillers that are piped-in series for the purpose of increased temperature differential shall be considered as one chiller.

Chilled and Hot Water Reset
Reference: Section 140.4(k)4

Similar to the requirements for supply air temperature reset, chilled and hot water systems that have a design capacity greater than 500,000 Btu/h are required to provide controls to reset the hot or cold-water temperature setpoints as a function of building loads or the outdoor air temperature. This reset can be achieved either using a direct indication of demand (usually cooling or heating valve position) or an indirect indication of demand (typically outdoor air temperature). On systems with DDC controls reset using valve position is recommended.

Exceptions for this requirement:

- Hydronic systems that are designed for variable flow complying with Section 140.4(k)1
- Systems serving healthcare facilities

Isolation Valves for Water-Loop Heat Pump Systems

Reference: Section 140.4(k)5

Water-circulation systems serving water-cooled air conditioner and hydronic heat pump systems with a design circulation pump brake horsepower greater than five bhp are required to be provided with 2-way isolation valves that close whenever the compressor is off. These systems are also required to be provided with the variable speed drives and pressure controls described in the following section.

Although not required on central tenant condenser water systems (for water-cooled AC units and HPs) it is beneficial to provide the 2-way isolation valves on these systems as well. In addition to providing pump energy savings, these two-way valves can double as head-pressure control valves allowing aggressive condenser water to reset for energy savings in chilled water plants that are also cooled by the towers.

Variable-Speed Drive for Pumps Serving Variable-Flow Systems

Reference: Section 140.4(k)6

Pumps on variable flow systems that have a design circulation pump brake horsepower greater than 5 bhp are required to have variable-speed drives. Alternatively, they may have a different control that will result in pump motor demand of no more than 30 percent of design wattage, at 50 percent of design water flow.

Pressure Sensor Location and Setpoint:

- For systems without direct-digital control of individual coils reporting to the central control panel, differential pressure must be measured at the most remote heat exchanger or the heat exchanger requiring the most pressure. This includes chilled-water systems, condenser water systems serving water-cooled air conditioning loads and water-loop heat pump systems.
- For systems with direct digital control of individual coils with a central control panel, the static pressure setpoint must be reset based on the valve requiring the most pressure and the setpoint shall be no less than 80 percent open. The pressure sensor(s) may be mounted anywhere.

Exceptions are provided for hot-water systems and condenser water systems that only serve water-cooled chillers. The hot water systems are not subject to these requirements because the heat from the added energy of the pump riding the curve provides a beneficial heat that reduces the boiler use. This diminishes the benefit from the reduced pumping energy.

Hydronic Heat Pump (WLHP) Controls

Reference: Section 140.4(k)7

Hydronic heat pumps connected to a common heat pump water loop with central devices for heat rejection and heat addition must have controls that are capable of providing a heat pump water supply temperature dead band of at least 20 degrees F between initiation of heat rejection and heat addition by the central devices. Exceptions are provided where a system loop temperature optimization controller is used to determine the most efficient operating temperature based on real-time conditions of demand and capacity, dead bands of less than 20 degrees F shall be allowed.

Window/Door Switches for Mechanical System Shutoff

Reference: Section 140.4(n)

If a directly conditioned zone has a thermostat and one or more manually operable wall or roof openings to the outdoors, then the openings must all have sensors that communicate to the HVAC system. The HVAC controller must be capable of shutting off the heating or cooling to that zone if the sensor detects that the opening has remained open for more than five minutes. This can be accomplished by resetting the heating setpoint to 55 degrees F or the heating can be disabled altogether. If the HVAC system is in cooling mode, then similarly this requirement can be satisfied by resetting the cooling setpoint to 90 degrees F unless the outside air temperature is less than the space temperature, in which case the cooling setpoint can be reset, or not. If the zone is in cooling and the outside air temperature is less than the space temperature, then additional infiltration from the opening provides economizer-free cooling and is not an additional cooling load on the mechanical system.

This requirement does not require any openings to the outdoors to.be operable. However, if operable openings are present, then they must comply with this requirement.

Mechanical ventilation as required by Mechanical Ventilation must still be provided. The mechanical system shut off pertains to the space conditioning equipment only. Mechanical ventilation must still be provided if the space does not fall under the natural ventilation criteria. Systems that meet the ventilation requirements with natural ventilation, rather than mechanical ventilation, are still subject to the window/door switch requirement. Thus, in the same way that most homeowners typically choose between opening the windows and running the heating/cooling, window/door switches will now cause occupants to choose between opening windows/doors and allowing full heating/cooling.

Manually operable openings to the outdoors include manually operable windows, skylights, and doors that do not have automatic closing devices (e.g., sliding balcony doors). Motorized openings (e.g., motorized skylights) are still considered manually operable if occupants can move the openings as desired and they will stay open until manually closed.

If a zone serves more than one room, then only the openings in the room with the thermostat are required to be interlocked. For example, if three perimeter private offices are served by a single VAV box then only the operable openings in the office with the thermostat need to be interlocked. The windows in the offices that do not have a thermostat do not need to be interlocked.

If there is a large room with more than one zone, then only the zones with operable windows in them need to be interlocked. For example, if a large open office has a perimeter zone and an interior zone in the same room and there are operable windows in the perimeter zone but not the interior zone then only the perimeter zone thermostat needs to be interlocked to the windows.

Exceptions to this requirement:

- Interlocks are not required on doors with automatic closing devices
- Any space without a thermostatic control
- Healthcare facilities

Alterations to existing buildings are not subject to this requirement. Additions to existing buildings only have to comply if the operable opening(s) and associated zone are new.

DDC Controller Logic Using ASHRAE Guideline 36

Reference: Section 140.4(r)

HVAC systems with DDC controllers shall use controller logic originating from a programming library based on sequences of operation from ASHRAE Guideline 36 in accordance with the following:

- Requirement applies to all controllers that are capable of being programmed in the field; and
- Requirement applies to the entirety or all applicable portions of equipment control for configurations included in the programming library; and
- The programming library shall be certified to the Energy Commission as meeting the requirements of Reference Joint Appendix JA18.
  Note: Non-programmable (configurable-only) controllers for zone terminal units shall follow applicable ASHRAE Guideline 36 zone sequences referenced in JA18 Table 18.3-1 but are not subject to certification requirements.

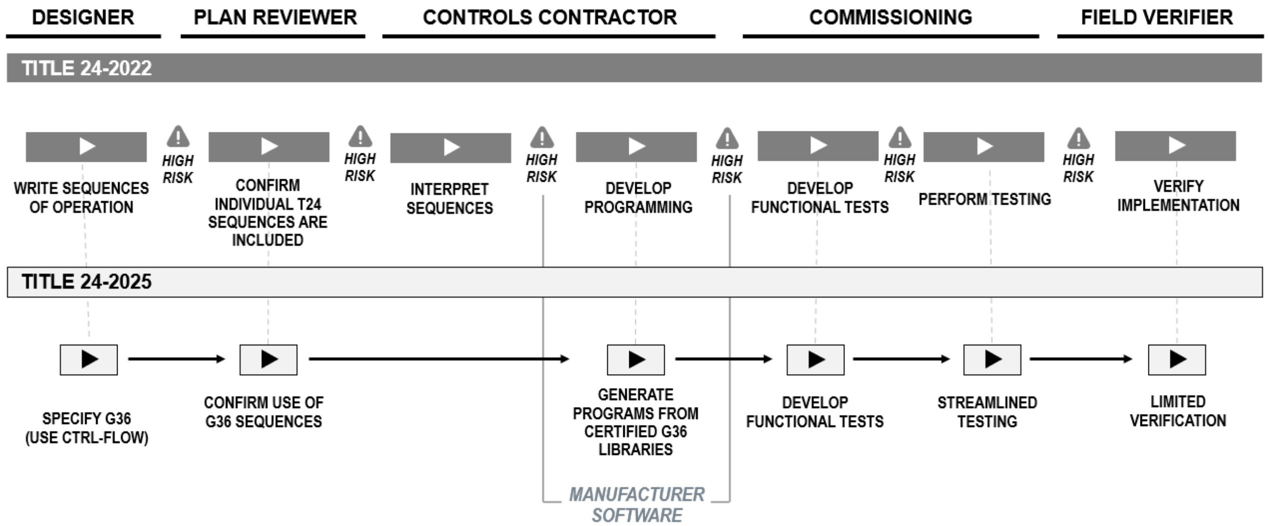
There are two exceptions to these requirements:

Exception 1: Logic from the certified programming library modified to suit application-specific operation that are not included in Guideline 36 sequences.

Exception 2: Systems serving healthcare facilities.

Figure 4-24: Industry delivery process for control logic for Title 24-2022 and Title 24-2025, depicts the process from designer to field verifier under the 2022 Energy Code (dark bars) and under the 2025 Energy Code (light bars). The new process references ASHRAE Guideline 36, which provides standardized, high-performance sequence logic for the control of select HVAC systems and equipment. The 2022 Energy Code has multiple steps that are manual and customized per project and is highly dependent on the expertise of individual engineers, controls technicians, and commissioning providers. Under the 2025 Energy Code, with the introduction of references to Guideline 36, designers specify sequences based on Guideline 36 and controls contractors follow the guideline using programming from certified programming libraries. A common workflow may be a BAS manufacturer that develops a Guideline 36 programming library, certifies it with the Energy Commission according to Reference Joint Appendix JA18, and then makes the library available to its installers. For applicable projects, the installers start with logic from the Guideline 36 programming libraries and then adapt and supplement the logic as needed to meet site specific needs. The 2025 Energy Code process reduces effort and improves quality over the 2022 Energy Code product delivery chain.

Figure 4- 24: Industry delivery process for control logic for Title 24-2022 and Title 24-2025



Source: California Statewide CASE Team

Guideline 36 consists of several parts to be used by the controls designer (with Parts 1 and 2 covering the purpose and scope of the guideline, respectively):

- Part 3: Setpoints, Design and Field Determined describes the setpoints and other parameters that must be specified by the design engineer, or determined during construction by the testing, adjusting, and balancing (TAB) or controls contractor.
- Part 4: List of Hardwired Points includes points lists for all system types addressed by the Guideline.
- Part 5: Sequences of Operations contains the control logic itself, organized by the type of equipment.
- Informative Appendix A has control diagrams that correspond to a subset of the Part 4 points lists.

Parts 3, 4, and 5 of the Guideline are intended to be edited and issued together as part of a specification under Division 23 or Division 25 and are formatted accordingly.

The requirements in Section 140.4(r) apply to controller logic that is used in field-programmable controllers. It does not apply to packaged controls that come integrated with some mechanical equipment, such as DX rooftop units (RTU).

Non-programmable (configurable) zone controllers are a special case addressed by Exception to Section 140.4(r)3. This exception expands applicability of this section to configurable-only zone controllers so that they are required to follow applicable Guideline 36 zone sequences. Because the configurable controllers do not have field-programmable logic, they are not subject to the certification requirements in JA18.

Guideline 36 provides high performance sequences of operation for many common HVAC system types but there may be some system types and unique circumstances that are not directly supported. Section 140.4(r) requires the use of a certified programming library for applications that are supported by Guideline 36. That may mean that a particular project has a mix of programming that originates from a certified programming library and custom programming that does not. The certified programming library requirements in JA18 do not include chilled water and hot water plants, so although these types of equipment are supported by Guideline 36, the requirement for the use of logic from certified programming libraries does not apply.

Example 4-36

Question:

A project will include packaged DX rooftop units (RTU). The packaged unit includes factory-built controls that control the fans, dampers, and compressors. The packaged unit controls are technically programmable but are fully programmed at the factory and not intended to be programmed in the field. Does the controller logic need to come from a programming library certified according to JA18?

Answer:

No, the controller logic provided with the packaged unit would not be subject to JA18. Often there is a DDC system that controls the zone-level equipment (e.g., VAV boxes) and communicates with a packaged DX RTU controller. In that situation, projects following the prescriptive compliance approach would be required to follow Section 140.4(r) for applicable portions of Guideline 36, including dual maximum VAV logic, supply air temperature setpoint reset, and duct static pressure setpoint reset. The setpoint reset logic in the DDC system would communicate setpoints to the packaged controller, and the packaged controller would be responsible for modulating dampers, compressor staging, and fan speed control to meet those setpoints with its own internal logic. In this case, the actual SAT control logic within the packaged controls would not be subject to this requirement because it is not field-programmed and because Guideline 36 does not directly address the control of DX cooling coils.

Compliance and Certification

The programming library shall be certified to the Energy Commission. The submittal package is available in Joint Appendices JA18, Guideline 36 Programming Library Certification. A controls manufacturer, controls contractor, or other controls company may certify their Guideline 36 programming library to the Energy Commission.

For an individual job, the controls designer must specify sequences of operation based on Guideline 36 where applicable and must indicate it on the construction documents (drawings and specifications) and relevant NRCC forms (specifically forms MCH-E and PRF-01-E). The plans examiner must review the construction documents and NRCC forms and verify that where Guideline 36 is applicable, that it is referenced. The installer must start controls programs from a certified Guideline 36 programming library and must make this certification information available to the building inspector. The inspector must verify that the installer used a certified Guideline 36 programming library where applicable.

Guideline 36 is intended to be specified by editing the control sequences in the Guideline to only include applicable sections. Guideline 36 is available as an editable document to facilitate this approach. The *Advanced Building Automation System Best Practices Guide,* at https://tayloreng.egnyte.com/dl/phXTDfFQb8/2022-06-

13_BAS_Best_Practices_Guide_v1.0.pdf, provides additional support and guidance on applying Guideline 36 to project-specific needs.

Portions of the native Guideline 36 control sequences must be tailored for the project. For example, the intended building pressure relief strategy for a Multiple-Zone VAV Air Handling Unit (AHU) will require some designer input. If the AHU includes a return fan, then the designer must determine whether the return fan and relief damper will be controlled based on a Direct Building Pressure control strategy or an Airflow Tracking strategy. The setpoints for either strategy must also be communicated.

Where Guideline 36 sequences are not required by Title 24, the designer may still decide to implement available Guideline 36 sequences, or they may elect to specify another control sequence that is specific to the application. For systems, equipment, and components where Guideline 36 sequences have not been published, the designer must specify an application-specific sequence. Where control sequences are specified that do not originate from Guideline 36, or where deviations are made from native Guideline 36 text, it is recommended that the alternate and/or deviated sequence language is clearly differentiated from the native Guideline 36 text to ensure scope clarification and avoid ambiguity during project delivery, such as through the use of different font colors.

Applications that require modification of native Guideline 36 sequences will also require modifications from Guideline 36 Certified Programming Libraries. Installing contractors, during programming, will start out with the Certified Programming Libraries and will modify or add additional logic as required to meet the specified sequence of operation. Modifications from the Certified Programming Libraries should only be made where needed to comply with the specified sequence.

Example 4-37

Question:

A project will include a Multiple-Zone VAV AHU that will incorporate an integral steam humidifier. The current publication of Guideline 36 does not include any sequence logic for humidification. How do I ensure that this project is compliant with this code requirement?

Answer:

It is recommended that the base AHU control sequence is created by editing the Guideline directly. In this case, any sections that do not apply to the project will be deleted such that only the applicable sections remain. Note that there are tools and resources available to support this first step. As mentioned prior, Guideline 36 is available as an editable document that can be used as a starting point. Alternatively, base control sequences for some system components can be generated using a free tool called "ctrl-flow" (see references that follow). The current version of ctrl-flow has the capability to generate draft control sequences for VAV terminals and Multiple-Zone VAV AHUs such that only the applicable sections of Guideline 36 remain.

Each base control sequence should be edited for the project-specific application. The control sequence for the steam humidifier should be added to the native Guideline 36 AHU sequence. It is recommended that the steam humidifier control sequence be clearly differentiated such that it stands out from the surrounding native Guideline 36 AHU sequence. For example, the steam humidifier sequence language should reside in a dedicated paragraph, and the text should be modified to appear differently from the native Guideline 36 text. One possible method is to assign the steam humidifier text an alternate font with a heavier weight and a different font color.

From here, the installing contractor should be positioned to clearly identify the project-specific sequence language that will not otherwise be available from the Guideline 36 Certified Programming Libraries. The contractor may then apply the base AHU sequence based on what is available from the Certified Programming Libraries, before implementing the additional programming that's necessary to incorporate the steam humidifier control sequence.

Acceptance Requirements

Please refer to Chapter 4.6.3 of the *2022 Nonresidential and Multifamily Compliance Manual*.

HVAC Equipment Requirements

Mandatory Requirements

Water-Conservation Measures for Cooling Towers

Reference: Section 110.2(e)

There are mandatory requirements (Section 110.2(e)) for the efficient use of water in the operation of open (direct) and closed (indirect) cooling towers. The building standard applies to the new construction and retrofit of commercial, industrial, and institutional cooling towers with a rated capacity of 150 tons or greater. For these towers all of the following are required:

- The towers shall be equipped with conductivity controls to manage cycles of concentration based on local water quality conditions. The controls shall automate system bleed and chemical feed (if applicable) based on conductivity. Conductivity controllers shall be installed in accordance with manufacturer's specifications.
- Design documents have to document target maximum achievable cycles of concentration based on local water supply as reported by the local water supplier using the equations documented in Section 110.2(e)2. The calculations shall determine maximum cycles based on the parameters identified in Table 110.2-A-1. Building owner shall document maximum cycles of concentration on the mechanical compliance form which shall be reviewed and signed by the Professional Engineer (P.E.) of Record.
- Cooling towers shall not allow blowdown until one or more of the parameters in Table 110.2-A-1 reaches the maximum value specified.
- The towers shall be equipped with a flow meter with an analog output for flow. This can be connected to the water treatment control system using either a hardwired connection or gateway.
- The towers shall be equipped with an overflow alarm to prevent overflow of the sump in case of makeup water valve failure. This requires either a water level sensor or a moisture detector in the overflow drain. The alarm contact should be connected to the building Energy Management Control System to initiate an alarm to alert the operators.
- The towers shall be equipped with drift eliminators that achieve a maximum rated drift of 0.002 percent of the circulated water volume for counter-flow towers and 0.005 percent for crossflow towers.
- Conductivity controls and overflow alarm shall be verified according to NA 7.5.18.

As water is evaporated off the tower, the concentration of dissolved solids, like calcium carbonate and silica, will increase. The pH of the water will also change. With high levels of silica, or dissolved solids, deposits will form on the tower fill or clog the tower nozzles, which will reduce the tower's heat rejection capacity. High pH is a concern for metal tower basins and structural members. As the thresholds of these contaminants of concern are approached the automated controls should bleed some of the concentrated water out and dilute it with make-up water. The bleed is best controlled through conductivity (a measurement of the dissolved solids). The term "*cycles of concentration*" is the metric of how concentrated the contaminants are at the controlled level. The right value depends on the characteristics of the supply water, the rate of tower drift, the weather characteristics, and the load on the tower. Good practice involves maintaining the levels below those listed in Table 110.2-A-1.

The Langelier Saturation Index predicts scaling. It indicates whether water will precipitate, dissolve, or be in equilibrium with calcium carbonate. The index is a function of hardness, alkalinity, conductivity, pH, and temperature expressed as the difference between the actual system pH and the saturation pH.

Additionally, the pH in new cooling towers using galvanized metal should be maintained at less than or equal to 8.3 until metal is passivated, which occurs after three-six months of operation.

To meet compliance, the design documents must document the target maximum achievable cycles of concentration and install conductivity controls that prevent blowdown from occurring until one or more of the parameters in Table 110.2-A-1 reaches the maximum value specified. These values are available from the local water supplier in the most recent annual Consumer Confidence Report or Water Quality Report. These reports are generally posted on the water supplier's website, or by contacting the local water supplier by telephone. Many water districts have multiple sources of water which often are changed seasonally. For example, many water districts use a reservoir in the winter and spring then switch to well water in the summer and fall. Each supply will typically have different characteristics; the water treatment and control cycles of concentration should be seasonally shifted as well.

After entering the required water quality data, the user must also enter skin temperature; the default value of 110 degrees F is acceptable. The resulting cycles of concentration are considered by the Energy Commission to be the Achievable Cycles of Concentration and must be recorded on the mechanical compliance document (NRCC-MCH-06-E), to which a copy of the Consumer Confidence Report or Water Quality Report must be attached. The professional engineer of record must sign the compliance document (NRCC-MCH-06-E) attesting to the calculated maximum cycles of concentration.

Example 4-38

Question:

Where is the data for makeup water quality?

Answer:

Water agencies are required to make their annual water quality data available to the public. Water quality data is generally organized into an annual Consumer Confidence Report or Water Quality Report, which can often be found posted on the water agency's website by searching for the key words “water quality”. Since many water districts have more than one water supply ask for a report for each source.

Example 4-39

Question:

What if all, or some, of the water quality data is not provided in the Consumer Confidence Report or Water Quality Report?

Answer:

Some data may be available by calling the local water agency’s Water Quality Division. For example, agencies are not required to test for and report alkalinity. However, they often do test for it and will provide data over the phone or in an email. Also check with water treatment firms that are doing business in the area. They often have test data that they will share. Finally, it is possible to hire a water treatment firm to take samples of the water to test.

Sizing and Equipment Selection

Reference: Section 140.4(a)1

The Energy Code requires mechanical heating and cooling equipment (including electric heaters and boilers) serving common use areas in multifamily buildings, hotel/motel buildings, and nonresidential buildings other than healthcare facilities to be the smallest size available, while still meeting the design heating and cooling loads of the building or spaces being served. Depending on the equipment, oversizing can be either a penalty or benefit to energy usage. For vapor compression equipment, gross oversizing can drastically increase the energy usage and in some cases cause premature failure from short cycling of compressors. Boilers and water-heaters generally suffer lower efficiencies and higher standby losses if they are oversized. On the other hand, cooling towers, cooling coils, and variable speed driven cooling tower fans can actually improve in efficiency if oversized. Oversized distribution ductwork and piping can reduce system pressure losses and reduce fan and pump energy.

When equipment is offered in size increments, such that one size is too small and the next is too large, the larger size may be selected.

Mechanical heating and mechanical cooling equipment serving healthcare facilities shall be sized to meet the design heating and cooling loads of the building or facility being served. Packaged HVAC equipment may serve a space with substantially different heating and cooling loads. The unit size should be selected on the larger of the loads, based on either capacity or airflow. The capacity for the other load should be selected as required to meet the load, or if very small, should be the smallest capacity available in the selected unit. For example, packaged air-conditioning units with gas heat are usually sized on the basis of cooling loads. The furnace is sized on the basis of airflow and is almost always larger than the design heating load.

Equipment may be oversized provided one or more of the following conditions are met:

- It can be demonstrated (to the satisfaction of the enforcing agency) that oversizing will not increase building source energy use

- Oversizing is the result of standby equipment that will operate only when the primary equipment is not operating. Controls must be provided that prevent the standby equipment from operating simultaneously with the primary equipment
- Multiple units of the same equipment type are used, each having a capacity less than the design load. In combination, however, the units have a capacity greater than the design load. Controls must be provided to sequence or otherwise optimally control the operation of each unit based on load.

Single Zone Space Conditioning System Type

Reference: Section 140.4(a)2

For prescriptive compliance, the Energy Code requires single zone space-conditioning systems with direct expansion cooling with rated cooling capacity 240,000 Btu/hr or less serving the following spaces to meet the following requirements.

- Retail and Grocery Building Spaces in climate zones 2 through 15. The space-conditioning system shall be a heat pump.
- Retail and Grocery Building Spaces in climate zones 1 and 16 with cooling capacity less than 65,000 Btu/hr. The space-conditioning system shall be an air conditioner with furnace.
- Retail and Grocery Building Spaces in climate zones 1 and 16 with cooling capacity 65,000 Btu/hr or greater. The-space conditioning system shall be a dual-fuel heat pump.
- School Building Spaces. For climate zones 2 – 15, the space conditioning system shall be a heat pump. For climate zones 1 and 16, the space-conditioning system shall be a dual-fuel heat pump.
- Office, Financial Institution, and Library Building Spaces in climate zones 1 – 15. The space-conditioning system shall be a heat pump.
- Office, Financial Institution, and Library Building Spaces in climate zone 16 with cooling capacity less than 65,000 Btu/hr. The space-conditioning system shall be an air conditioner with furnace.
- Office, Financial Institution, and Library Building Spaces in climate zone 16 with cooling capacity 65,000 Btu/hr or greater. The space-conditioning system shall be a dual-fuel heat pump.
- Office Spaces in Warehouses. The space-conditioning system shall be a heat pump in all climate zones.

For performance compliance, the prescriptive requirements in Section 140.4(a)2 set the standard design space conditioning budget. Under the performance compliance approach the building can comply using any supported space conditioning system type as long as it meets the standard design source energy and LSC budgets for the building.

Multi-Zone Space Conditioning System Type

Reference: Section 140.4(a)3

For prescriptive compliance, the Energy Code requires multi-zone space-conditioning system types in some office buildings and school buildings not covered by Section 140.4(a)2 to include certain characteristics and system types, as described below.

There are two exceptions to these requirements. The first exception is for school buildings and office buildings greater than 150,000 square feet or greater than five habitable stories. The second exception is for school buildings in climate zones 6 and 7.

Allowable System Types

Applicable office buildings and school buildings with multi-zone space-conditioning systems shall use one of the following four HVAC system types:

- Variable refrigerant flow (VRF) heat pump with a dedicated outdoor air system (DOAS) providing ventilation to all zones served by the VRF system. The VRF system must include a refrigerant heat recovery loop. Additional requirements for the indoor fans and DOAS are outlined in Additional Indoor Fan Requirements and Additional DOAS Requirements, respectively.
- Four-pipe fan coil (FPFC) terminal units with heating supplied by an air-to-water heat pump (AWHP) with DOAS providing ventilation to all zones served by the FPFC terminal units. Additional requirements for the AWHP, indoor fans, and DOAS are outlined in Additional AWHP Requirements, Additional Indoor Fan Requirements, and Additional DOAS Requirements, respectively.
- A variable air volume (VAV) system with heating supplied by an AWHP that meets the requirements of Additional AWHP Requirements. Additional restrictions and requirements for school buildings and office buildings are described below.
    - For office buildings:
        - In climate zones 1 – 6 and 16, parallel fan-powered boxes shall be used to meet 100% of the perimeter zone terminal unit heating capacity. In climate zones 7 – 15, parallel fan-powered boxes shall be used to meet 25% of the perimeter zone terminal unit heating capacity. Parallel fan-powered boxes must meet the requirements in Additional Parallel Fan-Powered Box Requirements.
        - In climate zones 1, 3, and 5, the system shall include a heat recovery ventilation system that complies with Exhaust Air Heat Recovery (EAHR) Requirements.
        - In climate zones 3 and 5, the ventilation system's fan power allowance shall be 15% lower than the value specified by Fan Power Consumption.
    - For school buildings:
        - This system type is only allowed in climate zones 2, 4, and 8 through 16.
        - All perimeter zone terminal units shall be parallel fan-powered boxes that comply with Additional Parallel Fan-Powered Box Requirements.
        - In climate zones 2, 4, and 11 – 16, the system shall include a heat recovery ventilation system that complies with Exhaust Air Heat Recovery (EAHR) Requirements.
        - In climate zone 2:
            - The ventilation system's fan power allowance shall be 15% lower than the value specified by Fan Power Consumption.

    - The design leaving water temperature of the heating loop shall be no greater than 120 °F.

- A dual fan dual duct system (DFDD) with hot and cold decks served by separate fan systems. Additionally, when Economizers are required, economizers shall be located on the cold deck. The hot deck shall supply 100% return air, except when outdoor air is needed to supplement the cold deck to maintain the design minimum outdoor air flow rate. The heating source for the hot deck shall be a heat pump. All control sequences related to the DFDD system (both the central and terminal units) shall comply with ASHRAE Guideline 36.

In addition to the four options listed above, other systems that demonstrate equal or greater energy efficiency performance can comply prescriptively if approved by the Executive Director.

This requirement only applies to systems within the buildings, not necessarily the entire building. For example, if a given office includes a combination of single zone space-conditioning systems with a rated cooling capacity of 240 kBtu/hr (20 tons) or less and a multi-zone space-conditioning system, then only the multi-zone system must meet these requirements. The single zone system must meet the requirements as described in Single Zone Space Conditioning System Type.

Additional AWHP Requirements

The AWHP must meet the following requirements:

- The AWHP must meet the minimum efficiency requirements listed in Equipment Efficiency.
- If chilled water produced by an AWHP is used for space-cooling, then the heat recovery system shall comply with the Mechanical Heat Recovery Requirements.
- Supplemental heating shall be provided by an electric resistance (ER) boiler with a capacity that does not exceed 50% of the design hot water loop capacity. As a supplemental boiler, it should be configured such that it never activates unless the AWHP cannot satisfy the building’s hot water demand on its own.

Additional Indoor Fan Requirements

The indoor fans must meet the following requirements:

- The fan shall have a maximum fan power of 0.35 W/cfm at design airflow
- Shall have no less than three speeds
- Shall turn off when there is no demand for heating or cooling in the space
- At 66 percent air flow the power draw shall be no more than 51 percent of the fan power at full fan speed
- At 33 percent air flow the power draw shall be no more than 12 percent of the fan power at full fan speed

Additional DOAS Requirements

The DOAS system must meet the following requirements:

- The DOAS system must comply with the prescriptive DOAS requirements located in Dedicated Outdoor Air System (DOAS).
- The DOAS system must include a heat recovery system that meets the Exhaust Air Heat Recovery (EAHR) Requirements.

- The maximum fan power consumption shall not exceed 0.77 W/cfm at design airflow.
- DOAS units that provide active heating and cooling shall meet one of the following requirements:
    - Heating coils served by the AWHP system and cooling coils served by a chilled water loop.
    - Heating and cooling provided by a heat pump without an electric resistance heating element.

Additional Parallel Fan-Powered Box Requirements

Parallel fan-powered boxes used to comply with the third option in Allowable System Types shall meet the following requirements:

- The system shall use only recirculated air from the zone or plenum when in heating mode.
- Fans shall cycle on only when there is a demand for heating.
- The maximum fan power shall not be greater than 0.3 W/cfm at design airflow.
- Terminal units providing ventilation air shall be set to no greater than the minimum ventilation rate when the zone is in deadband or in heating mode.

Load Calculations

Reference: Section 140.4(b)

For the purposes of sizing HVAC equipment, the designer shall use all of the following criteria for load calculations:

- The heating and cooling system design loads must be calculated in accordance with the procedures described in the ASHRAE Handbook, Fundamentals Volume, Chapter 30, Table 1. Other load calculation methods (e.g., ACCA, SMACNA) are acceptable provided that the method is ASHRAE-based. When submitting load calculations of this type, the designer must accompany the load calculations with a written affidavit certifying that the method used is ASHRAE-based. If the designer is unclear as to whether or not the calculation method is ASHRAE-based, the vendor or organization providing the calculation method should be contacted to verify that the method is derived from ASHRAE.
    - For systems serving healthcare facilities, the method in the California Mechanical Code shall be used.
- Indoor design conditions of temperature and relative humidity for general comfort applications are not explicitly defined. Designers are allowed to use any temperature conditions within the "comfort envelope" defined by ANSI/ASHRAE 55-1992 or the 2017 ASHRAE Handbook, Fundamentals Volume. Winter humidification or summer dehumidification is not required.
    - For systems serving healthcare facilities, the method in Section 320.0 of the California Mechanical Code shall be used.
- Outdoor design conditions shall be selected from Reference Joint Appendix JA2, which is based on data from the ASHRAE Climatic Data for Region X or from the ASHRAE Handbook, Equipment Volume, Applications Volume and Fundamentals Volume, for the following design conditions:

    - Heating design temperatures shall be no lower than 99.0 percent Heating Dry Bulb or the temperature listed in the Heating Winter Median of Extremes value.
    - Cooling design temperatures shall be no greater than the 0.5 percent Cooling Dry Bulb and Mean Coincident Wet Bulb values.
    - Cooling design temperatures for cooling towers shall be no greater than the 0.5 percent cooling design wet bulb values.

  For systems serving healthcare facilities, the method in Section 320.0 of the California Mechanical Code shall be used.
- Outdoor air ventilation loads must be calculated using the ventilation rates required in Ventilation and Indoor Air Quality Requirements.
- Envelope heating and cooling loads must be calculated using envelope characteristics including square footage, thermal conductance, solar heat gain coefficient or shading coefficient and air leakage, consistent with the proposed design.
- Lighting heating and cooling loads shall be based on actual design lighting levels or power densities consistent with Chapter 5.
- Sensible and latent gains from people must be based on the expected occupant density of the building and occupant activities as determined under Ventilation and Indoor Air Quality Requirements. If ventilation requirements are based on a cfm/person basis, then loads from people must be based on the same number of people used to calculate ventilation requirements. Sensible and latent gains must be selected for the expected activities as listed in 2017 ASHRAE Handbook, Fundamentals Volume, Chapter 18.
- Loads caused by a process shall be based on actual information on the intended use of the building.
- Miscellaneous equipment loads include duct losses, process loads and infiltration and shall be calculated using design data compiled from one or more of the following sources:
    - Actual information based on the intended use of the building
    - Published data from manufacturer's technical publications or from technical societies (such as the ASHRAE Handbook, HVAC Applications Volume)
    - Other data based on the designer's experience of expected loads and occupancy patterns
- Internal heat gains may be ignored for heating load calculations.
- A safety factor of up to 10 percent may be applied to design loads to account for unexpected loads or changes in space usage.
- Other loads such as warm-up or cool-down shall be calculated using one of the following methods:
    - A method using principles based on the heat capacity of the building and its contents, the degree of setback, and desired recovery time
    - The steady state design loads may be increased by no more than 30 percent for heating and 10 percent for cooling. The steady state load may include a safety factor of up to 10 percent as discussed above in Item 11.

- The combination of safety factor and other loads allows design cooling loads to be increased by up to 21 percent (1.10 safety x 1.10 other), and heating loads by up to 43 percent (1.10 safety x 1.30 other).

Example 4-40

Question:

Do the sizing requirements restrict the size of duct work, coils, filter banks, etc. in a built-up system?

Answer:

No. The intent of the Energy Code is to limit the size of equipment, which if oversized will consume more energy on an annual basis. Coils with larger face areas will usually have lower pressure drops than otherwise and may also allow the chilled water temperature to be higher, both of which may result in a decrease in energy usage. Larger filter banks will also usually save energy. Larger duct work will have lower static pressure losses, which may save energy, depending on the duct's location, length, and degree of insulation.

Oversizing fans, on the other hand, may or may not improve energy performance. An oversized airfoil fan with inlet vanes will not usually save energy, as the part-load characteristics of this device are poor. But the same fan with a variable frequency drive may save energy. Controls are also an important part of any system design.

The relationship between various energy consuming components may be complex and is left to the designer's professional judgment. When components are oversized, it must be demonstrated to the satisfaction of the enforcement agency that energy usage will not increase.

Fan Power Consumption

Reference: Section 140.4(c)

Maximum fan power is regulated in individual fan systems where the power of at least one fan or fan array in the fan system is greater than or equal to 1kW of fan electrical input power at design conditions. A system consists of only the components that must function together to deliver air to a given area; fans that can operate independently of each other comprise separate systems. Included are all fans associated with moving air from a given space-conditioning system to the conditioned spaces and back to the source, or to exhaust air to the outdoors.

The 1kW total criteria apply to:

- All supply and return fans within the space-conditioning system that operate at peak load conditions.
- All exhaust fans at the system level that operate at peak load conditions. Exhaust fans associated with economizers are not counted, provided they do not operate at peak conditions, including fans that circulate air for the purpose of conditioning air within the space.
- Fan-powered VAV boxes if these fans run during the cooling peak. This is always the case for fans in series type boxes. Fans in parallel boxes may be ignored if they are controlled to

operate only when zone heating is required, are normally off during the cooling peak, and there is no design heating load, or they are not used during design heating operation.
- Elevator equipment room exhausts (or other exhausts that draw air from a conditioned space) through an otherwise unconditioned space, to the outdoors.

The criteria are applied individually to each space-conditioning system. In buildings having multiple space-conditioning systems, the criteria apply only to the systems having a fan or fan array whose demand exceeds 1 kW of fan electrical input power.

Fans not directly associated with moving conditioned air to or from the space-conditioning system, or fans associated with a process within the building.

Meeting the fan power limit is accomplished in two parts. First, the designer calculates the allowable fan input power for their fan systems (Fan kWbudget). Second, the designer calculates the actual electrical input power (Fan kWdesign, system) values of the fans in the system by summing up the Fan kWdesign value of each fan in the fan system. The total power input must be less than the allowable power input for the fan system to comply.

To calculate the fan kW budget, the designer must know the following pieces of information:

- The type of fan system (described below)
- The fan system control type (i.e., either Multi-Zone VAV or all other fan systems) and airflow passing through each component of the fan system
- Knowledge of the status of all components (e.g., presence or absence of DX cooling coils, gas furnace, energy recovery wheel, economizer return damper, etc.) in the fan system. This determines which allowances from the given allowance table (e.g., Table 140.4-A, Table 140.4-B, etc.) apply to the fan system when calculating Fan kWbudget.
- The altitude of the building to account for reduced air density (if greater than 3,000 feet).

The fan system type contributes to the determination of how the fan power budget is calculated. The fan system types are listed and described below.

- **Single-cabinet fan system.** This is a fan system where a single fan, single fan array, a single set of fans operating in parallel, or fans or fan arrays in series and embedded in the same cabinet that both supply air to a space and recirculate the air. Designers of this type of system will use the applicable allowances from the given supply fan power allowance table (e.g., Table 140.4-A) and exhaust/return/relief/transfer fan power allowance table (e.g., Table 140.4-B) at the fan system design airflow. Examples include:
    - A rooftop unit with a single fan that both supplies air to the space and recirculates air.
    - An air handler with a supply and return fan in the same cabinet.
    - A rooftop unit with a relief fan that only runs during economizer operation.
- **Supply-only fan system.** This is a fan system that provides supply air to interior spaces and does not recirculate the air. Designers of this type of system will use the applicable allowances from the given supply table (e.g., Table 140.4-A) at the fan system design supply airflow. Examples include:
    - An air handler with only a supply fan where the return fan is not in the same cabinet.

  - The supply fan of an ERV, even if there is an exhaust fan in the same cabinet.
  - The fan of a make-up air unit where air is exhausted from the building by a different fan.
- **Relief fan system.** This is a fan system dedicated to the removal of air from interior spaces to the outdoors that operates only during economizer operation. Designers of this type of system will use the applicable allowances from the given exhaust/return/relief/transfer fan power allowance table (e.g., Table 140.4-B) at the fan system design relief airflow.
- **Exhaust, return, and transfer fan systems.** An exhaust fan system is a fan system dedicated to the removal of air from interior spaces to the outdoors that may operate at times other than economizer operation. A return fan system is a fan system dedicated to removing air from interior where some or all the air is to be recirculated except during economizer operation. A transfer fan system is a fan system that exclusively moves air from one occupied space to another. Designers of any of these three system types will use the applicable allowances from the given exhaust/return/relief/transfer fan power allowance table (e.g., Table 140.4-B) at the fan system design airflow.
- **Complex fan system.** This is a fan system that combines a single-cabinet fan system with other supply fans, exhaust fans, or both. The designer will separately calculate the fan power allowance for the supply component and the return/exhaust component and then arrive at a total fan power allowance. This approach differs from a single-cabinet fan system in that for the single-cabinet fan system, the individual allowances from the supply and exhaust/return/relief/transfer tables are added before arriving at a Fan kW budget value, whereas for complex fan systems, a supply power allowance value is calculated using its allowances, a return/exhaust power value is calculated using its allowances, and then the two are added together to determine the overall Fan kW budget value.

Once the required information and fan system classification has been determined, the designer will apply the appropriate allowances from the appropriate budget table before calculating the overall Fan kWbudget value. All fan systems should use the base allowance from the applicable table, as well as other allowances that apply to their individual fan system. For fan system components that only receive a fraction of the airflow passing through the rest of the system, the adjusted fan power allowance should be calculated according to the following formula.

$$FPA_{adj} = \frac{Q_{comp}}{Q_{sys}} \times FPA_{comp}$$

Where,

- FPA_{adj} = The corrected fan power allowance for the component in w/cfm
- Q_{comp} = The airflow through component in cfm
- Q_{sys} = The fan system airflow in cfm
- FPA_{comp} = The fan power allowance of the component from the applicable table (e.g., Table 140.4-A or Table 140.4-B)

If the site is at an altitude of 3,000 feet above sea level or greater, the designer should apply the appropriate correction factor from Table 140.4-C to the resulting Fan kWbudget value.

Fan electrical input power (Fan kWdesign) is the electrical input power in kilowatts required to operate an individual fan or fan array at design conditions. It includes the power consumption of motor controllers, if present. This value encompasses all wire-to-air losses, including motor controller, motor, and belt losses.

There are four methods available to determine Fan kWdesign for an individual fan in a fan system. There is no requirement to use the same method for different fans in the fan system. For all methods, fan input power shall be calculated with twice the clean filter pressure drop.

- Use the default values for Fan kWdesign (Table 140.4-D in the standard) based on minimum U.S. DOE motor efficiencies. There are values for input power with and without a motor controller. This method can be used if only the motor nameplate horsepower is known. This table will likely provide a conservative estimate of fan input electrical power. This method cannot be used for complex fan systems.
- Use the fan input power at fan system design conditions provided by the manufacturer of the fan, fan array, or equipment that includes the fan or fan array calculated per a test procedure included in USDOE 10 CFR 430, USDOE 10 CFR 431, ANSI/AMCA Standard 208, ANSI/AMCA Standard 210, AHRI Standard 430:2020, AHR Standard 440:2019 and ISO 5801:2017.
- Use one of the options listed in Section 5.3 of ANSI/AMCA Standard 208 at design conditions. This method can be used in cases where the fan shaft input power is provided by the manufacturer, and the designer needs to calculate the input power to the motor or motor controller.
- Use the maximum electrical input power included on the fan motor nameplate. Note that this value does not account for the loading of the fan in question (which will usually be lower than this value) and thus is likely to be a conservative method.

Once the designer has calculated the fan power budget value (Fan kWbudget) and their fan system's input electrical power at design conditions (Fan kWdesign, system), the two values are compared against each other to determine if the fan system complies.

$$Fan\ kW_{design,system} \leq Fan\ kW_{budget}$$

If the above inequality is valid, then the fan system complies with the fan power budget.

Selected Fan Power Budget Allowance

Please refer to Chapter 4.7.2.5 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Fractional HVAC Motors for Fans

Reference: Section 140.4(c)3

HVAC fan motors that are one hp or less and 1/12 hp or greater shall be electronically commutated motors or shall have a minimum motor efficiency of 70 percent when rated in accordance with the National Electric Manufacturers Association (NEMA) Standard MG 1-2006 at full-load rating conditions. These motors shall also have the means to adjust motor speed for either balancing or remote control. Belt-driven fans may use sheave adjustments for airflow balancing in lieu of a varying motor speed.

This requirement can be met with either electronically commutated motors or brushless direct current (DC) motors. These motors have higher efficiency than permanent split capacitor

(PSC) motors and inherently have speed control that can be used for VAV operation or balancing.

This requirement includes fan-powered terminal units, fan-coil units, exhaust fans, transfer fans, and supply fans. There are three exceptions to this requirement:

- Motors in fan-coil units and terminal units that operate only when providing heating to the space served. This includes parallel style fan-powered VAV boxes and heating only fan-coils.
- Motors that are part of space conditioning equipment certified under Section 110.1 or Section 110.2. This includes supply fans, condenser fans, ventilation fans for boilers, and other fans that are part of equipment that is rated as a whole.
- Motors that are part of space conditioning serving healthcare facilities.

Electric-Resistance Heating

Reference: Section 140.4(g), Section 141.0

The Energy Code strongly discourages the use of electric-resistance space heat. Electric-resistance space heat is not allowed in the prescriptive approach except where:

- Site-recovered or site-solar energy provides at least 60 percent of the annual heating energy requirements.
- A heat pump is supplemented by an electric-resistance heating system, and the heating capacity of the heat pump is more than 75 percent of the design heating load at the design outdoor temperature (determined in accordance with the Energy Code).
- The total capacity of all electric-resistance heating systems serving the entire building is less than 10 percent of the total design output capacity of all heating equipment serving the entire building.
- The total capacity of all electric-resistance heating systems serving the building, excluding those that supplement a heat pump, is no more than 3 kW.
- An electric-resistance heating system serves an entire building that:
    - Is not a hotel/motel building.
    - Has a conditioned floor area no greater than 5,000 sq ft.
    - Has no mechanical cooling.
    - Is in an area where natural gas is not currently available and an extension of a natural gas system is impractical, as determined by the natural gas utility.
- The existing mechanical systems use electric reheat (when adding VAV boxes) added capacity cannot exceed 20 percent of the existing installed electric capacity, under any one permit application in an alteration.
- The existing VAV system with electric reheat is being expanded, the added capacity cannot exceed 50 percent of the existing installed electric reheat capacity under any one permit in an addition.
- Heating systems serve as emergency backup to gas heating equipment.
- Supplemental electric resistance heating systems complying with the prescriptive requirement for multi-zone space-conditioning system types.

The Energy Code allows a small amount of electric-resistance heat to be used for local space heating or reheating (provided reheat is in accordance with these regulations).

Example 4-40

Question:

If a heat pump is used to condition a building having a design heating load of 100,000 Btu/h at 35 degrees F, what are the sizing requirements for the compressor and heating coils?

Answer:

The compressor must be sized to provide at least 75 percent of the heating load at the design heating conditions, or 75,000 Btu/h at 35 degrees F. The Energy Code does not address the size of the resistance heating coils. Normally, they will be sized based on heating requirements during defrost.

Cooling Tower Flow Turndown

Reference: Section 140.4(h)2

The Energy Code requires that open cooling towers with multiple condenser water pumps be designed so that all cells can be run in parallel with the larger of the flow that is produced by the smallest pump or 50 percent of the design flow for the cell.

In a large plant at low load operation, not all the cells are typically run at once. This is allowed in the Energy Code.

Cooling towers are very efficient at unloading the fan energy drops off as the cube of the airflow. It is always more efficient to run the water through as many cells as possible- two fans at half speed use less than one third of the energy of one fan at full speed for the same load. Unfortunately, there is a limitation with flow on towers. The flow must be sufficient to provide full coverage of the fill. If the nozzles do not fully wet the fill, air will go through the dry spots providing no cooling benefit and cause the water at the edge of the dry spot to flash evaporate, depositing dissolved solids on the fill.

Fortunately, the cooling tower manufacturers do offer low-flow nozzles (and weirs on basin type towers) to provide better flow turndown. This typically only costs $100 to $150 per tower cell. As low-flow nozzles can eliminate the need for a tower isolation control point, this option provides energy savings at a reduced first cost.

Example 4-41

Question:

If a large central plant has five equally sized chillers and five equally sized cooling tower cells do all of the cooling tower cells need to operate when only one chiller is on-line?

Answer:

No. You would probably only run three cells with one chiller. The cooling tower cells must be designed to run at 33 percent of their nominal design flow. With two to five chillers running, you would run all of the cells of the cooling tower. With only one chiller running you would run three cells. In each case, you would need to keep the tower flow above the minimum that it was designed for.

Centrifugal Fan Limitation

Reference: Section 140.4(h)3

Open cooling towers with a combined rated capacity of 900 gpm and greater are prohibited from using centrifugal fans. The 95-degree F condenser water return, 85-degree F condenser water supply and 75-degree F outdoor wet-bulb temperature are test conditions for determining the rated flow capacity in gpm. Centrifugal fans use approximately twice the energy as propeller fans for the same duty. There are a couple of exceptions to this requirement:

- Cooling towers that are ducted (inlet or discharge) or have an external sound trap that requires external static pressure capability.
- Cooling towers that meet the energy efficiency requirement for propeller fan towers in Table 110.2-E.

Centrifugal fans may be used on closed circuit fluid coolers.

As with all prescriptive requirements centrifugal fan cooling towers may be used when complying with the performance method. The budget building will be modeled using propeller towers.

Cooling Tower Efficiency

Reference: Section 140.4(h)5

For prescriptive compliance, axial fan open-circuit cooling towers with a combined rated capacity of 900 gpm or greater must achieve a rated efficiency between 42.1-80 gpm/hp depending on the climate zone - climate zones 1 and 16 are 42.1 GPM/HP; climate zones 3, 11, and 14 are 60 GPM/HP; Climate Zones 2, 4, 5, and 12 are 70 GPM/HP; and Climate Zones 6, - 10, 13 and 15 are 80 GPM/HP. This efficiency is rated at 95-degree F condenser water return; 85-degree F condenser water supply; and 75-degree F outdoor wet-bulb temperature. These conditions are specified in the Cooling Technology Institute's (CTI) standards, CTI ATC-105 and CTI STD-201 RS. These test conditions are used for code compliance purposes and do not have to align with the conditions a designer may want to use for selecting a given cooling tower for a given project. There is one exception to this requirement:

- Cooling towers that are installed as a replacement to an existing chilled water plant if the tower is located on an existing roof or inside an existing building.

Axial-fan open-circuit cooling towers with a capacity of 900 gpm or larger and less than 60 gpm/hp may be used when complying with the performance method if the towers comply with the mandatory minimum efficiency rating of 42.1 gpm/hp as listed in Table 110.2-E.

Chiller Efficiency

Reference: Section 140.4(i)

In Table 110.2-D, there are two sets of efficiency for almost every size and type of chiller. Path A represents fixed speed compressors and Path B represents variable speed compressors. For each path, there are two efficiency requirements: a full load efficiency and an integrated part-load efficiency. Path A typically has a higher full load efficiency and a lower part-load efficiency than Path B. In all California climates, the cooling load varies enough to justify the added cost for a Path B chiller. This is a prescriptive requirement, so Path B is used in the base case model in the performance method.

There are a number of exceptions to this requirement:

- Chillers with an electrical service of greater than 600 volts. The cost of a VSD is much higher on medium voltage service.
- Chillers attached to a heat recovery system with a design heat recovery capacity greater than 40 percent of the chiller's design cooling capacity. Heat recovery typically requires operation at higher lifts and compressor speeds.
- Chillers used to charge thermal energy storage systems with a charging temperature of less than 40 degrees F. This performance again requires a high lift operation for chillers.
- In a building with more than three chillers only three of the chillers are required to meet the Path B efficiencies.

Limitation on Air Cooled Chillers

Reference: Section 140.4(j), Section 141.0

New central cooling plants and cooling plant expansions will be limited on the use of air-cooled chillers. For both types the limit is 300 tons per plant.

In the studies provided to support this requirement, air cooled chillers always provided a higher life cycle cost than water-cooled chillers even accounting for the water and chemical treatment costs.

Exceptions to this requirement:

- Where the water quality at the building site fails to meet manufacturer's specifications for the use of water-cooled chillers. This exception recognizes that some parts of the state have exceptionally high quantities of dissolved solids that could foul systems or cause excessive chemical treatment or blow down.
- Chillers that are used to charge a thermal energy storage system with a design temperature of less than 40 degrees F. This addresses the fact that air-cooled chillers can operate very efficiently at low ambient air temperatures. Since thermal energy storage systems operate for long hours at night, these systems may be as efficient as a water-cooled plant. The chiller must be provided with head pressure controls to achieve these savings.
- Systems serving healthcare facilities.

Exhaust System Transfer Air

Reference: Section 140.4(o)

The Energy Code prescriptively requires the use of transfer air for exhaust air makeup in most cases. The purpose is to avoid supply air that requires increased outdoor air intake, which would require conditioning, for exhaust makeup when return or relief air from neighboring spaces can be used instead. The requirement limits the supply of conditioned air to not exceed the larger of: (1) the supply flow required for space heating or space cooling, (2) the required ventilation rate, or (3) the exhaust flow, minus the available transfer air from conditioned spaces or plenums on the same floor and within 15 ft and not in different smoke or fire compartments. Available transfer air does not include air required to maintain pressurization and air that cannot be transferred based on-air class as defined by in Section 120.1.

There are a few exceptions to this requirement:

- Biosafety laboratories classified Level 3 or higher

- Vivarium spaces
- Spaces that are required by applicable codes and standards to be maintained at positive pressure relative to adjacent spaces. For spaces taking this exception, any transferable air that is not directly transferred shall be made available to the associated air-handling unit and shall be used whenever economizer or other options do not save more energy.
- Spaces where the demand for transfer air may exceed the available transfer airflow rate and where the spaces have a required negative pressure relationship. For spaces taking this exception, any transferable air that is not directly transferred shall be made available to the associated air-handling unit and shall be used whenever economizer or other options do not save more energy.
- Healthcare facilities

A compliant example would be a space with a restroom with 300 cfm of exhaust. The makeup air would consist of 60 cfm of supply air and 240 cfm of transfer air from an adjacent ceiling return air plenum. The amount of air required for the space is 60 cfm for heating and cooling and the rest of the makeup air is transferred from the return air plenum.

A non-compliant example would be if the same space had a constant air volume box with reheat supplying all of the makeup air. The reheat would be needed to prevent the space from being overcooled. Since there is transfer air available in the adjacent plenum, the maximum allowed supply air would be only what's required for space heating or cooling, which would be 60 cfm.

Dedicated Outdoor Air System (DOAS)

Reference: Section 140.4(p)

Systems specifying DOAS units must comply with the following requirements to ensure a compliant system:

- DOAS fan efficiency: If the DOAS unit fan power is less than 1 kW, then the fan efficiency of that fan must be less than or equal to 1.0 watt per cubic foot per minute. If the fan power is greater than or equal to 1 kW, it is subject to the fan power budgets requirements under Section 140.4(c).
- DOAS complying with requirements under Section 140.4(a)3E are not subject to this requirementReducing terminal unit fan power: in order to ensure that adequate ventilation air can be provided to the space without severely impacting the ability of independent terminal unit fans to shut off when not needed, the following scenarios are compliant:
    - Ventilation air provided by the DOAS unit must be provided directly to the space
    - Ventilation air is provided to the outlet of the terminal heating or cooling coils (such as a VRF).
    - A system using active-chilled beam systems
    - Sensible-only cooling terminal units with pressure independent variable airflow devices that limit DOAS supply air to the greater of latent load or minimum ventilation requirements.
    - Any configuration where the downstream terminal fans use no greater than 0.12 watts per cubic foot per minute.

- Airflow Balance: supply and exhaust fans for the DOAS shall have a minimum of three speeds for system balancing
- Limiting reheat: if a DOAS utilizes mechanical cooling, then the DOAS ventilation air shall not use supply air above 60°F when the majority of zones require cooling.

Under certain climate zones and air handler design scenarios, DOAS units may also require Exhaust Air Heat Recovery requirements under section 140.4(q).

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Exhaust Air Heat Recovery (EAHR)

Reference: Section140.4(q)

HVAC systems (including DOAS) must comply with EAHR requirements if their air handling systems meet design specifications that trigger compliance. For most HVAC systems these requirements are triggered if the full design airflow meets the criteria in Table 140.4-J or Table 140.4-K or where required by Section 140.4(a)3.

These requirements are also triggered if a decoupled DOAS system is utilizing Exhaust Air Heat Recovery instead of meeting economizer requirements for the independent space-conditioning indoor units using the DOAS-Economizer exception (Exception 6 to 140.4(e)).

- The HVAC System must utilize an exhaust air heat recovery device with an energy recovery ratio of 60 percent or an enthalpy recovery ratio of 50 percent for both heating and cooling (note: climate zone 1 only needs to comply with heating requirements and climate zone 15 only needs to comply with cooling requirements).
- The HVAC System must utilize energy recovery or bypass controls to disable exhaust air heat recovery and directly economizer with ventilation air. Economizing with ventilation air is dependent on the outside air temperature as described in Table 140.4-G of the Energy Code. Where energy transfer cannot be stopped, a bypass shall be included which prevents the airflow rate of either the outdoor air or exhaust air through the energy recovery exchanger from exceeding 10 percent of the full design airflow rate.

Reference: Exceptions to Section 140.4(q)

- Laboratory and factory exhaust systems (those meeting Section 140.9c)
- Systems designed to condition to 60 degrees F or less
- Systems within heating-dominated Climate Zone 16 (only) where 60% of heating energy is recovered on site.
- Systems where the usable[2] exhaust air is too distributed to utilize for heat recovery (systems where a quantity of less than 75 percent of the outdoor airflow rate can be gathered within 20 linear feet).
- Systems with low operating hours (20 hours or less per week)

Example 4-42

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[2] (1) Unusable exhaust air includes air used for another energy recovery system; (2) air not allowed for energy recovery under the CMC; (3) Class 4 air as specified under Section 120.1(g)

Question:

If a building has some areas that need continuous operation (24 hours per day & 7 days a week) and some which has lower hours, which table of Exhaust Air Heat Recovery requirements do you need to follow?

Answer:

These requirements are system-based and **not** building-based. If any part of an air handling system serves an area that need to operate 24/7, they will need to comply with the requirements under the greater than 8,000 hours per year table or else take a relevant exception.

Mechanical Heat Recovery

Reference: Section 140.4(s)

This requirement exists to ensure heat recovery occurs for sites with a meaningful amount of simultaneous cooling and heating loads. The code language is geared toward detecting whether the site's cooling and heating loads are likely to be overlapping or not. The benefit of a heat recovery system is that instead of concurrently rejecting waste heat from the cooling system and separately generating heat with a boiler or air to water heat pump, the waste heat from the cooling system provides the heating energy. However, this is only beneficial to the site when both end uses are present simultaneously.

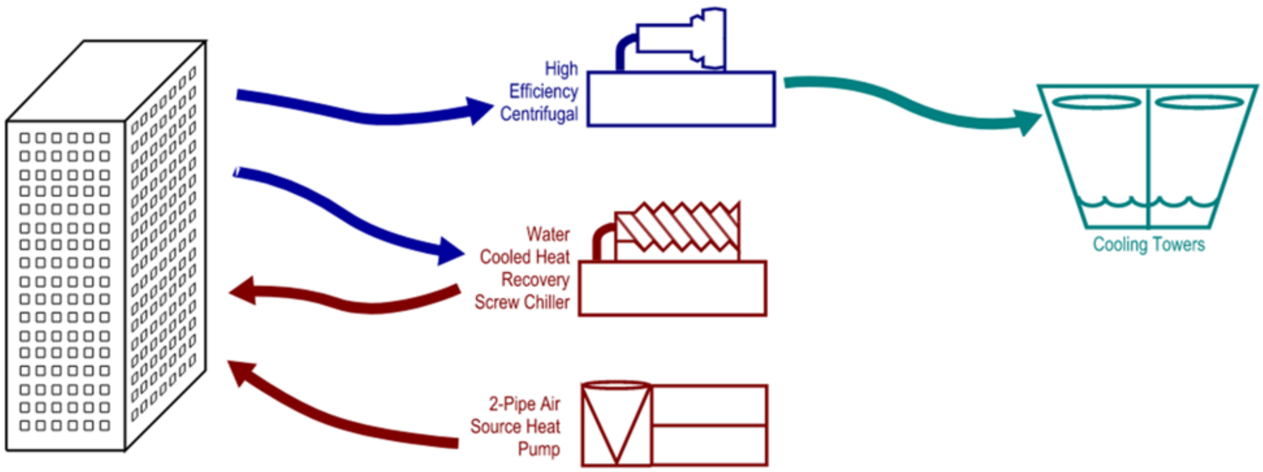
Typical building types that are expected to be triggered by this requirement include hospitals, mixed-use buildings that include functions such as commercial kitchens or laundromats, offices with data centers, or any medium to large sized building with a process cooling or heating load.

Laboratory buildings with exhaust air heat recovery systems meeting Section 140.9(c)6 and buildings in climate zone 15 with service water heating design capacity less than 600 kBtu/h are not subject to the simultaneous mechanical heat recovery requirement.

The purpose of the formulas in 140.4(s)1Ai and 140.4(s)1Aii is to estimate the approximate coincident cooling and heating loads for the building without having to run a full year hourly energy model for the building. Since this is a prescriptive code requirement, it cannot be assumed that a whole building energy model is being conducted. Simultaneous cooling and heating loads are more likely to occur during mild weather conditions or when the building contains a process cooling or heating load. This is what drives the 10% multiplier next to CLL in the first equation and HCAP in the second one. This adjusts the design capacities to a more appropriate estimated value for mild weather conditions (e.g., temperatures in the 50s or 60s Fahrenheit). The distinction between "low density" cooling and "high density" cooling in the first equation is intended to estimate the component to the cooling load that is likely present during mild or colder ambient conditions, e.g., for a data center. In the second equation, the service hot water (i.e., the aspect with the potential for significant process loads) aspect is similarly broken out from the ambient temperature-driven space heating loads. It is expected that sites with larger process heating loads will maintain those loads into higher ambient temperatures, when significant cooling loads occur.

Section 140.4(s)B describes the equipment capable of meeting this requirement for mechanical heat recovery. The most common unit is expected to be a 4-pipe heat recovery chiller or water-to-water heat pump (WWHP) whose evaporator is connected to the chilled water loop and condenser is connected to the hot water loop (see Figure 4-25: Pipe Heat Recovery Chiller (configured to reject heat from the CHW to HW loop)).

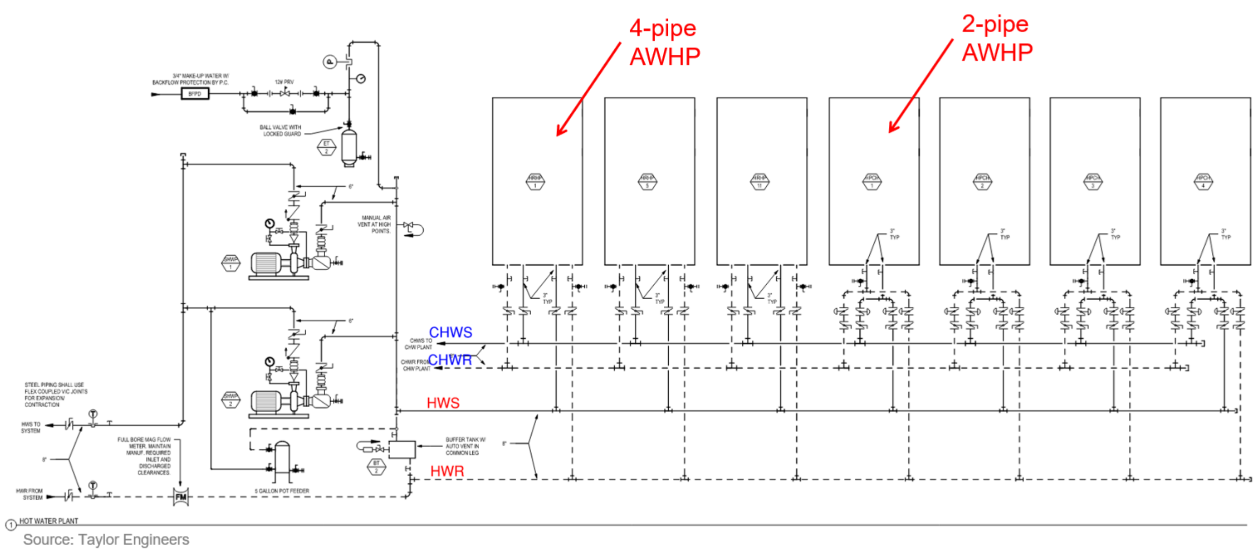
Figure 4-25: Pipe Heat Recovery Chiller (configured to reject heat from the CHW to HW loop)



Source: California Statewide CASE Team

4-pipe air-to-water heat pumps (AWHPs) that have the ability to operate like a WWHP, absorbing heat from the CHW loop and rejecting it to the HW loop, can also meet this requirement (see Figure 4-26: 4-Pipe Air-to-Water Heat Pumps with Heat Recovery Capability). It is important to recognize, however, that some 4-pipe AWHPs are not capable of heat recovery. They may be capable of simultaneous heating and cooling but only by rejecting heat to the air with one circuit and absorbing heat from the air with an independent circuit. Furthermore, there may be other requirements in the Energy Code that preclude this system (e.g., the 300 ton air-cooled chiller limitation).

Figure 4-26: 4-Pipe Air-to-Water Heat Pumps with Heat Recovery Capability



Source: California Statewide CASE Team

Other types of thermal storage heat recovery systems that could potentially satisfy the requirement include chilled water storage, hot water storage, ice storage, water-cooled VRF with condenser water storage, and water-to-air heat pumps (water-source heat pumps) with condenser water storage.

The requirement to size the heat recovery equipment to the lesser of 25% of the peak heat rejection of the cooling system or the combined capacity of the space and service water heating systems is intended to help ensure that the system is cost-effective and not oversized relative to the magnitude of the overlapping loads.

140.4(s)2 is intended to further specify the type of heat recovery system that a site with a large service water heating load should install, namely one that serves the service water heating load with the cooling heat of rejection. Similar to 140.4(s)1B, this requirement specifies the smaller of 30% of the heat rejection of the cooling system or the service water heating capacity be used to size the heat recovery system.

Buildings with a computer room heat recovery system or wastewater heat recovery system capable of providing not less than 25% of the sum of the service water heating design capacity and space heating design capacity are not subject to the service water heating heat recovery requirement.

Example 4-43

Question:

A 75,000 sf mixed-use building in climate zone 9 with office space (including a portion devoted to a server room) and commercial kitchen is under construction. The building's low density cooling load is 150 tons and its space heating capacity is 1,000 kBtuh. The building's high density cooling load is 175 tons and the commercial kitchen's service water heating load is 650 kBtuh. Would the building be required to comply with 140.4(s), and if so, what should the capacity of the heat recovery system be?

Answer:

First, test the conditions against 140.4(s)1Ai:

- CHL + 0.1*CLL ≥ 200 tons and SWHCAP + HCAP ≥ 2200 kBtuh

Replacing the terms with the values specific to this building produces:

- 175 + 15 = 190 which is not ≥ 200 tons and 650 + 1,000 = 1,650 which is not ≥ 2,200 kBtuh, so therefore the first equation is not satisfied.

Next, test the conditions against 140.4(s)1Aii:

- CCAP ≥ 300 tons and SWHCAP + 0.1 * HCAP ≥ 700 kBtuh

Again, replacing the variables with values produces:

- 150 + 175 = 325 which is ≥ 300 tons and 650 + 100 which is ≥ 700 kBtuh, so therefore the second equation is satisfied and the building must install a heat recovery system.

In order to size the heat recovery system, assume that the cooling system requires 400 tons of heat rejection capacity. 25% of this value is 100 tons or 1,200 kBtuh. 25% of the sum of SWHCAP and HCAP is 538 kBtuh, making this the required value for the heat recovery system based on 140.4(s)1B. Note that since 140.4(s)2 is also triggered (since at 650 kBtuh, SWHCAP is ≥ 500 kBtuh), then the heat recovery system must be setup to heat or preheat the service hot water. Based on 140.4(s)2B, the service hot water system would have to be sized to 30%

of SWHCAP or 195 kBtuh (since at 1,200 kBtuh, 30% of the peak heat rejection of the cooling system is greater). This does not exempt the building's overall heat recovery requirement of 538 kBtuh based on the value calculated from 140.4(s)1Bii.

Water Heating Requirements

Please refer to Chapter 4.8 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Service Water Systems Mandatory Requirements

Efficiency and Control

Please refer to Chapter 4.8.1.1 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Multiple Temperature Usage

Please refer to Chapter 4.8.1.2 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Controls for Hot Water Distribution Systems

Reference: Section 110.3(c)2

Service hot water systems with a circulating pump or with electrical heat trace shall include a control capable of automatically turning off the system when hot water is not required. Such controls include automatic time switches, interlocks with HVAC time switches, occupancy sensors, and other controls that accomplish the intended purpose.

Systems serving healthcare facilities are not subject to this requirement.

Storage Tank Insulation

Please refer to Chapter 4.8.1.4 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Systems with Recirculation Loops

Reference: Section 110.3(c)4

Service water systems with central recirculation distribution must include all of the following mandatory features. The intent of these measures is to optimize performance and allow for lower cost of maintenance. These requirements are applicable to nonresidential occupancies as well as multifamily and hotel/motel systems.

Air Release Valves

Reference: Section 110.3(c)4A

The constant supply of new water and leaks in system piping or components during normal operation of the pump may introduce air into the circulating water. Entrained air in the water may also contribute to increased cavitation, the formation of vapor bubbles in liquid on the low pressure (suction) side of the pump. The vapor bubbles generally condense back to the liquid state after they pass into the higher-pressure side of the pump. Cavitation contributes to a loss of head pressure and pumping capacity, may produce noise and vibration in the pump, and may result in pump impeller corrosion, all of which impacts the pumps' efficiency and life expectancy.

Entrained air and cavitation should be minimized by the installation of an air release valve. The air release valve must be located no more than 4 feet from the inlet of the pump and must be mounted on a vertical riser with a length of at least 12 inches. Alternatively, the pump shall be mounted on a vertical section of the return piping.

Recirculation Loop Backflow Prevention

Reference: Section 110.3(c)4B

Temperature and pressure differences in the water throughout a recirculation system can create potentials for backflows, resulting in cooler water from the bottom of the water heater tank and water near the end of the recirculation loop flowing backwards towards the hot water load and reducing the delivered water temperature.

To prevent this from occurring, the Energy Code requires that a check valve or similar device be located between the recirculation pump and the water heating equipment.

Equipment for Pump Priming/Pump Isolation Valves

Reference: Section 110.3(c)4C, Section 110.3(c)4D

Many systems are allowed to operate to complete failure due to the difficulty of repair or servicing. Repair labor costs can be reduced significantly by planning ahead and designing for easy pump replacement. Provisions for pump priming and pump isolation valves help reduces maintenance costs.

To meet the pump priming equipment requirement, a hose bibb must be installed between the pump and the water heater. In addition, an isolation valve shall be installed between the hose bibb and the water heating equipment. This configuration will allow the flow from the water heater to be shut off, allowing the hose bibb to be used for bleeding air out of the pump after replacement.

The requirement for the pump isolation valves will allow replacement of the pump without draining a large portion of the system. The isolation valves shall be installed on both sides of the pump. These valves may be part of the flange that attaches the pump to the pipe. One of the isolation valves may be the same isolation valve as in Section 110.3(c)5C.

Connection of Recirculation Lines

Reference: Section 110.3(c)4E

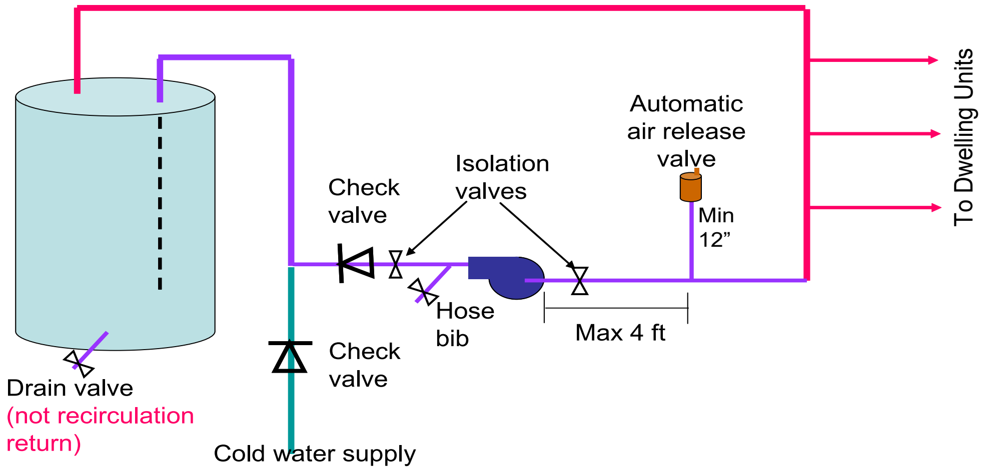
Manufacturer specifications should always be followed to assure optimal system performance. The cold-water piping and the recirculation loop piping should never be connected to the hot water storage tank drain port.

Backflow Prevention in Cold Water Supply

Reference: Section 110.3(c)4F

The dynamic between the water in the heater and the cold-water supply are similar to those in the recirculation loop. Thermosyphoning can occur on this side of the loop just as it does on the recirculation side of the system. To prevent this, the Energy Code requires a check valve to be installed on the cold-water supply line. The valve should be located between the hot water system and the next closest tee on the cold-water supply line. The system shall comply with the expansion tank requirements of California Plumbing Code, Section 608.3.

Figure 4-27: Backflow Prevention



Source: California Energy Commission

Service Water Heaters in State Buildings

Please refer to Chapter 4.8.1.6 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Isolation Valves for Instantaneous Water Heaters

Reference: Section 110.3(c)6

All newly installed instantaneous water heaters with an input greater than 6.8 kBtu/h or 2 kW shall have isolation valves on both the incoming cold water supply and the hot water pipe leaving the water heater, to assist in the flushing of the heat exchanger and help prolong the life the water heaters. Instantaneous water heaters with integrated drain ports for servicing are acceptable to meet the requirement and will not require additional isolation valves.

Pipe Insulation

Reference: Section 120.3

All requirements of Section 120.3 also apply to service water heating in nonresidential, hotel and motel buildings. See Mandatory Measures for full details.

For pipes with conductivity ranges within those specified in Table 120.3-A-1 and Table 120.3-A-2, the nominal pipe diameters grouping ranges have changed, as well as the thickness of insulation required for each pipe diameter range.

Mandatory Requirements Applicable to Hotel/Motel

In addition to the mandatory requirements listed above, there are mandatory requirements that will apply to water heating systems for hotels and motels only. The applicability of the mandatory features listed above will change depending on whether the water heating system has a central system or uses individual water heaters.

Systems with Recirculation Loops

See Systems with Recirculation Loops.

Commercial Boilers

See Commercial Boilers.

Water Piping Insulation

Reference: Section 120.3

Nonresidential and hotel/motel domestic hot water system piping must be insulated per Table 120.3-A-1 and Table 120.3-A-2. The Energy Code also requires that pipe insulation be protected from damage by moisture, UV and physical abrasion including but not limited to the following:

- Insulation exposed to weather shall be installed with a cover suitable for outdoor service. The cover shall be water retardant and provides shielding from solar radiation that can cause degradation of the material. Insulation must be protected by an external covering unless the insulation has been approved for exterior use using a recognized federal test procedure. Adhesive tape shall not be used as protection for insulation exposed to weather.
- Insulation covering chilled water piping and refrigerant suction piping located outside the conditioned space shall have a Class I or Class II vapor retarder. All penetrations and joints of which shall be sealed.
- Pipe insulation buried below grade must have a waterproof, uncrushable casing or sleeve. The Energy Code does not define uncrushability, as any material can be crushed, given enough pressure, and thus it is left to the professional judgement of the designer The internal cross-section or diameter of the casing or sleeve shall be large enough to allow for insulation of the hot water piping. Pre-insulated pipe with an integrated protection sleeve will also meet this requirement.

There are exceptions to the requirements for pipe insulation, as described below:

- Pipes completely surrounded with at least four inches of attic insulation, 2 inches of crawlspace insulation, or 1 inch of wall insulation; any section of pipe not meeting this criterion must be insulated.
- Piping in walls meeting Quality Insulation Installation (QII) requirements as specified in the Reference Residential Appendix RA3.5. Otherwise, the section of pipe not meeting the QII specifications must be insulated.
- Factory-installed piping within space-conditioning equipment certified under 110.1 or 110.2.
- Piping that penetrates framing members shall not be required to have pipe insulation for the distance of the framing penetration. Piping that penetrates metal framing shall use grommets, plugs, wrapping or other insulating material to assure that no contact is made with the metal framing. Insulation shall butt securely against all framing members.
- Certain process equipment including fluid pumps, steam traps, blow-off valves, and piping within process equipment.
- Valves, strainers, coil u-bends, air separators with at least 0.5 inches of insulation, and piping within process equipment.

Prescriptive Requirements Applicable to Nonresidential Occupancies

Please refer to Chapter 4.8.3 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Prescriptive Requirements Applicable to Hotel/Motel Buildings

Reference: Section 140.5(b)

For water heating systems for hotel/motel buildings, the code references to the multifamily prescriptive requirements under Section 170.2. The executive director can also approve another water heating system that uses no more energy than one described in Water Heating

Systems Serving Single Dwelling Units Solar Water Heating or Water Heating Systems Serving Multiple Dwelling Units below. The following paragraphs recap these requirements.

Water Heating Systems Serving Single Dwelling Units Solar Water Heating

Reference: Section 170.2(d)1

Systems for individual dwelling units with recirculation distribution systems must use Demand Recirculation with a manual on/off control meeting RA4.4.9.

There are two options for water heating systems serving single dwelling units:

- One 240V heat pump water heater (HPWH); a compact hot water distribution system (CHWDS) meeting RA4.4.6 is also required in climate zones s 1 & 16. A drain water heat recovery (DWHR) device meeting RA3.6.9 is also required in climate zone 16. Note that a 120 V HPWH may be installed for new dwelling units with one bedroom or less.
- One HPWH meeting NEEA Tier 3 or higher specifications. A DWHR device meeting RA3.6.9 is also required in climate zone 16.

Water Heating Systems Serving Multiple Dwelling Units

Reference: Section 170.2(d)2, Section 170.2(d)3

Systems serving multiple dwelling units must be central water heating systems with recirculation distribution systems meeting Section 110.3(c)2&5 (please see Controls for Hot Water Distribution Systems and Systems with Recirculation Loops for details), able to automatically control the pump based on hot water demand and water return temperature. Water heating systems serving buildings with 8 or fewer dwelling units do not require recirculation systems.

There are two water heating system options:

- HPWH with the following:
    - Recirculation loop return connected to a recirculation loop tank
    - If auxiliary heating is needed, the recirculation loop tank heater must be electric
    - Main tank must be set to 135°F
    - Recirculation loop tank temperature must be 10°F lower than that of the main tank; the recirculation loop tank water must be used to maintain the temperature before using recirculation loop tank heater
    - The compressor must shut off when the ambient temperature is 40°F or below.
- A gas or propane central water heater meeting the following:
    - In climate zones 1 – 9, if the input is 1MM Btu/h or greater, then any water heating equipment must have a thermal efficiency of 90% or greater. Multiple units can be used if their input capacity-weighted average of 90% or more. Water heaters of 100k Btu/h or less are not included in this calculation. There is an Exception for systems deriving 25% or more of their annual energy from site-solar or site-recovered energy.
    - Solar water heating

Solar Water Heating

Please refer to Chapter 4.8.4.3 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Dual Recirculation Loop Design

Please refer to Chapter 4.8.4.4 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Demand Recirculation Control

Please refer to Chapter 4.8.4.5 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Pool and Spa Heating Systems

Mandatory Requirements for Pools and Spas

Certification and Labeling Requirements

Reference: Section 110.4(a)

Electric and gas pool heaters for a pool, spa, or a pool and spa combination must be certified by the manufacturer and listed by the California Energy Commission as having:

- For equipment subject to state or federal appliance efficiency regulations, must meet Section 110.1 requirements including a listing in MAEDbS
- An on/off switch mounted on the outside of the heater in a readily accessible location that allows the heater to be shut off without adjusting the thermostat setting
- A permanent, easily readable, and weatherproof plate or card that gives the energy efficiency rating, and instructions for the energy efficient operation of the pool and/or spa heater

Installation Requirements

Reference: Section 110.4(b)

Heating equipment installed to heat pool and/or spa water shall be selected from equipment meeting the standards shown in Table 110.4-A.

If a pool and/or spa does not currently use solar heating collectors for heating the water, piping must be installed to accommodate any future installation. Contractors can choose one of three options to allow for the future addition of solar heating equipment:

- Leave at least 18 inches of vertical or horizontal pipe between the filter and heater to allow for the future addition of solar heating equipment
- Plumb separate suction and return lines to the pool dedicated to future solar heating
- Install built-up or built-in connections for future piping to solar water heating, (e.g., a built-in connection could be a capped off tee fitting between the filter and heater)

Pool and/or spa heating systems with gas or electric heaters for outdoor use shall be installed with a pool cover. The pool cover must be fitted and installed during the final inspection.

All pool systems must be installed with the following:

- Directional inlets must be provided for all pools that adequately mix the pool water.
- A time switch or similar control mechanism shall be permanently installed for pools to control the operation of the circulation control system, to allow the pump to be set or

programmed to run in the off-peak demand period, and for the minimum time necessary to maintain the water in the condition required by applicable public health standards.

Heating Source Sizing Requirements

Reference: Section 110.4(c)

Pool and/or spa heating systems or equipment must meet one of the following sizing requirements:

- For nonresidential buildings, a solar pool heating system with a solar collector surface area that is equivalent to at least 65 percent of the pool and/or spa surface area;
- A heat pump pool heater as the primary heating system that meets the HPPH manufacturer's sizing specifications, as specified in Reference Joint Appendix JA16.3. The supplementary heater can be of any energy source;
- A heating system that derives at least 60 percent of the annual heating energy from on-site renewable energy or on-site recovered energy.;
- A combination of a solar pool heating system and heat pump pool heater without any additional supplementary heater; or
- A pool heating system determined by the Executive Director to use no more energy that the systems specified in options above.

There are five allowable exceptions to the heating source sizing requirements as listed below:

- Exception 1 - Portable electric spas compliant with California's Appliance Efficiency Regulations (Title 20).
- Exception 2 - Alterations to existing pools and/or spas with existing heating systems or equipment.
- Exception 3 - A pool and/or spa that is heated solely by a solar pool heating system without any backup heater.
- Exception 4 - Heating systems which are used exclusively for permanent spa applications in existing buildings with gas availability.
- Exception 5 - Heating systems which are used exclusively for permanent spa applications where there is inadequate Solar Access Roof Area (SARA) as specified in Section 150.1(c)14 for a solar pool heating system to be installed.

Solar Pool Heating Systems

Reference: JA16.2

Solar pool heating systems shall be certified and rated by the Solar Rating and Certification Corporation (ICC-SRCC), the International Association of Plumbing and Mechanical Officials, Research and Testing (IAPMO R&T), or by a listing agency that is approved by the Executive Director.

Solar thermal collectors shall be listed and labeled in accordance with Table 110.4-A. The installed system shall meet the following eligibility criteria:

- The system shall be installed according to manufacturer's instructions.

- The system shall be installed in the exact configuration for which it was rated. The system shall have the same collector(s), piping, pump, vacuum relief valve, controls, and other components used to establish the rated condition.

Heat Pump Pool Heater Sizing

Reference: JA16.3

If the heat pump pool heater manufacturer's specifications do not include information on HPPH sizing, follow these steps:

- Determine desired pool temperature in °F.
- Determine average temperature for the coldest month of pool use in °F.
- Determine temperature rise in °F by subtracting the average temperature for the coldest month from the desired pool temperature.
- Calculate the pool volume in gallons.
- Calculate the time needed for the HPPH to achieve the 10 °F degree rise in hours. This shall not exceed 17.5 hours.
- Use the following equation to determine the Btu/h output requirement of the HPPH.

$$Q_{out} = \frac{(V_n \times 8.33 \times \Delta T)}{t}$$

Where,

- Q_{out} is the output heating capacity of the HPPH
- V_p is the pool volume in gallons
- 8.33 is the weight of a gallon of water at 62°F in pounds per gallon
- ΔT is the pool temperature rise in °F, and shall not exceed 10°F
- t is the time needed for the HPPH to achieve the 10 °F degree rise in hours and shall not exceed 17.5 hours

SARA for Solar Collectors

Reference: Section 150.1(c)14

The solar access roof area defines how much of the roof area is both capable of supporting a PV and/or solar thermal and has sufficient annual exposure to generate energy.

SARA includes:

- The area of the building's roof space capable of structurally supporting a PV or a solar pool heating system, and
- The area of all roof space on covered parking areas, carports, and any other newly constructed structures on the site that are compatible with supporting a PV and/or solar pool heating system, per Title 24, Part 2, Section 1511.2.

SARA does NOT include:

- Any roof area that has less than 70% annual solar access: Annual solar access is calculated by dividing the total annual solar insolation (sunlight exposure), considering shading obstructions, by the total annual solar insolation if there were no shading obstructions. For steep slope roofs, only shading from permanent obstructions outside the dwelling (such as trees, hills, and adjacent structures) is considered. For low slope roofs, all obstructions, including those part of the building design, are considered.

- Occupied roof areas as specified by CBC Section 503.1.4.
- Roof areas that are otherwise unavailable due to compliance with other state building code requirements or local building code requirements if local building code requirements are confirmed by the CEC Executive Director.

Example 4-44

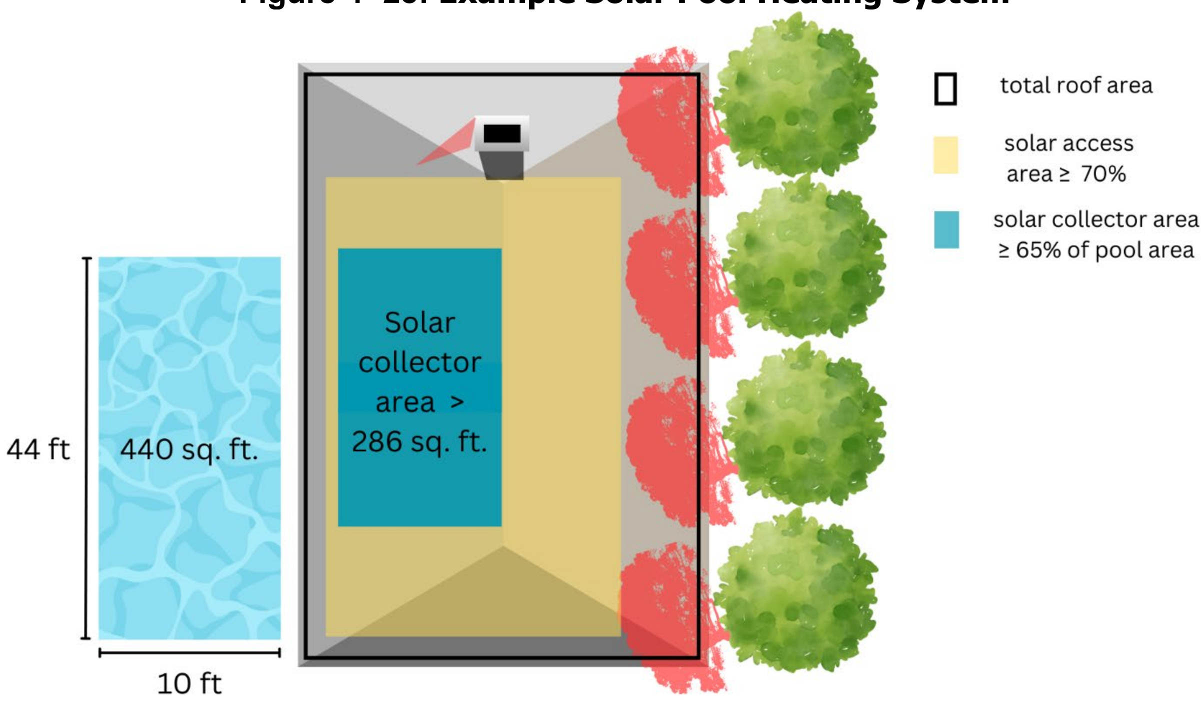
I am designing a commercial swimming pool with a surface area of 440 square feet. If I want to use a gas heater as a backup to solar, what would be the sizing requirements of my solar pool heating system?

Answer:

If you plan to use a gas heater as a backup, the solar pool heating system must have a solar collector surface area that is at least 65% of the pool's surface area. For a pool with a surface area of 440 square feet, the calculation is as follows: $440\ ft^2 \times 0.65 = 286\ ft^2$

You need to install a solar pool heating system with a collector surface area of at least 286 square feet.

Figure 4- 28: Example Solar Pool Heating System



Source: California Statewide CASE Team

Additionally, you will need to determine the SARA for your building to ensure you have sufficient space for the solar collectors. This includes:

- Assessing Planned Obstructions: Identify any trees, structures, or other potential obstructions that could shade the solar collectors and reduce their efficiency. This assessment should cover the current situation as well as future landscaping plans. For steep slope roofs, only shading from permanent obstructions outside the dwelling (such as trees, hills, and adjacent structures) is considered. For low slope roofs, all obstructions, including those part of the building design, are considered.

- Determining Annual Solar Roof Access: Calculate the annual solar access for the roof area where the solar collectors will be installed. This involves considering shading patterns throughout the year to ensure that the collectors receive adequate sunlight.

If the roof area has less than 70% annual solar access due to shading or other obstructions, it may not be suitable for a solar pool heating system as per the regulations.

Approved solar assessment tools can be found at the Energy Commission website at, https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/solar-assessment-tools

Example 4-45

Question:

I don’t have sufficient solar access for a solar swimming pool heater, how do I calculate the required size of the HPPH?

Answer:

If you don't have sufficient solar access, Exception 5 applies. Per Title 24, you are not required to size the pool heating system per requirements in 110.4(c) and may choose among all pool heating system options.

Example 4-46

Question:

A gym pool with a gas heater just broke and needs to be replaced. Could the replacement be like the existing gas heater?

Answer:

Yes, the gas heater may be replaced with a similar gas heater that meets the certification requirement of 110.4(a) and equipment requirements of 110.4(b). The sizing and source requirements of 110.4(c) do not apply since alterations to existing pools with existing heating systems qualify for Exception 2 to Section 110.4(c).

Controls for Heat Pump Pool Heaters with Supplementary Heating

Reference: Section 110.4(d)

Heat pump pool heaters with supplementary heaters shall have controls:

- That prevent supplementary heater operation when the heating load can be met by the heat pump pool heater alone; and
- In which the cut-on temperature for compression heating is higher than the cut-on temperature for supplementary heating, and the cut-off temperature for compression heating is higher than the cut-off temperature for supplementary heating.

Pool and Spa Heaters: Pilot Lights Prohibited

Reference: Section 110.5

Pool and spa heaters are not allowed to have pilot lights.

Performance Approach

Please refer to Chapter 4.9 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Additions and Alterations

Overview

Please refer to Chapter 4.10.1 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Relocation of Equipment

Please refer to Chapter 4.10.1.1 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Mandatory Measures – Additions and Alterations

New mechanical equipment or systems in additions and/or alterations must comply with the mandatory measures as listed below. Additional information on these requirements is provided in earlier sections of this Chapter.

Section 110.1 – Mandatory requirements for Appliances (see Equipment Requirements)

Reference: Section 110.1

The California Appliance Efficiency Regulations apply to small to medium sized heating equipment, cooling equipment and water heaters. These requirements are enforced for all equipment sold in California and therefore apply to all equipment used in additions or alterations.

Mandatory Requirements for Space-Conditioning Equipment (see Equipment Requirements)

Reference: Section 110.2

This section sets minimum efficiency requirements for equipment not covered by Section 110.1. Any equipment used in additions or alterations must meet these efficiency requirements.

Mandatory Requirements for Service Water-Heating Systems and Equipment (see Equipment Requirements)

Reference: Section 110.3

This section sets minimum efficiency and control requirements for water heating equipment. It also sets requirements for recirculating hot water distribution systems. All new equipment installed in additions and/or alterations shall meet the requirements. The recirculation loop requirements of Section 110.3(c)5 apply when water heating equipment and/or plumbing is changed.

Mandatory Requirements for Pool and Spa Heating Systems and Equipment (see Pool and Spa Heating Systems)

Reference: Section 110.4

The pool requirements of Section 110.4 do not apply for maintenance or repairs of existing pool heating or filtration systems.

Natural Gas Central Furnaces, Cooking Equipment, and Pool and Spa Heaters: Pilot Lights Prohibited (see Equipment Requirements)

Reference: Section 110.5

Any new gas appliances installed in additions or alterations shall not have a standing pilot light, unless one of the exceptions in Section 110.5 is satisfied.

Requirements for Ventilation (see Ventilation and Indoor Air Quality Requirements)

Reference: Section 120.1

Systems that are altered or new systems serving an addition shall meet the outside air ventilation and control requirements, as applicable.

When existing systems are extending to serve additions or when occupancy changes in an existing building (such as the conversion of office space to a large conference room), the outside air settings at the existing air handler may need to be modified and, in some cases, new controls may be necessary.

Required Controls for Space-Conditioning Systems (see HVAC System Control Requirements)

Reference: Section 120.2

Section 120.2(a) requires a thermostat for any new zones in additions or new zones created in an alteration.

Section 120.2(b) requires that new thermostats required by Section 120.2(a) meet the minimum requirements.

Section 120.2(c) applies to hotel/motel guest rooms only when the system level controls are replaced; replacement of individual thermostats are considered a repair.

Section 120.2(d) requires that new heat pumps used in either alterations or additions have controls to limit the use of electric resistance heat, per Section 110.2(b). This applies to any new heat pump installed in conjunction with an addition and/or alteration.

Section 120.2(e) requires that new systems in alterations and additions have scheduling and setback controls.

Section 120.2(f) requires that outside air dampers automatically close when the fan is not operating or during unoccupied periods and remain closed during setback heating and cooling. This applies when a new system or air handling unit is replaced in conjunction with an addition or alteration.

Section 120.2(g) requires that areas served by large systems be divided into isolation areas so that heating, cooling and/or the supply of air can be provided to only the isolation areas that need it and other isolation areas can be shut off. This applies to additions larger than 25,000 sq ft and to the replacement of existing systems when the total area served is greater than 25,000 sq ft.

Section 120.2(h) requires that direct digital controls (DDC) that operate at the zone level be programmed to enable non-critical loads to be shed during electricity emergencies. This requirement applies to additions and/or alterations anytime DDC are installed that operate at the zone level.

Section 120.2(i) requires a Fault Detection and Diagnostic System for all newly added air handler units equipped with an economizer and mechanical cooling capacity equal to or greater than 54,000 Btu/hr in accordance with Section 120.2(i)2. through Section 120.2(i)8.

Section 120.2(j) requires DDC in newly constructed buildings additions or alterations for certain applications and qualifications. It also requires certain capabilities for mandated DDC systems.

Section 120.2(k) requires optimum start/stop when DDC is to the zone level.

Requirements for Pipe Insulation (see Pipe and Duct Distribution Systems)

Reference: Section 120.3

The pipe insulation requirements apply to any new piping installed in additions or alterations.

Requirements for Air Distribution System Ducts and Plenums (see Pipe and Duct Distribution Systems)

Reference: Section 120.4

The duct insulation, construction and sealing requirements apply to any new ductwork installed in additions or alterations.

Required Nonresidential Mechanical System Acceptance (See Chapter 14)

Reference: Section 120.5

Acceptance requirements are triggered for systems or equipment installed in additions and alterations the same way they are for new buildings or systems.

Mandatory Requirements for Commercial Boilers (see Commercial Boilers)

Reference: Section 120.9

The requirements apply to any new commercial boilers installed in additions or alterations.

New or Replacement Space-Condition Systems or Components

Reference: Section 140.4

The requirements comply to systems and components other than new or replacement ducts.

Requirements for Additions

Prescriptive Approach

All new additions must comply with the following prescriptive requirements:

- Section 140.4 – Prescriptive Requirements for Space Conditioning Systems, except the condensing boiler system requirements of Section 140.4(k)8.
- Section 140.5 – Prescriptive Requirements for Service Water-Heating Systems, except the requirements of 140.5(c).

For more detailed information about the prescriptive requirements, refer to following sections of this chapter:

- HVAC System Control Requirements
- HVAC Requirements

Performance Approach

The performance approach may also be used to demonstrate compliance for new additions. When using the performance approach for additions Section 141.0(a)2B defines the characteristics of the standard design building.

For more detailed information, see Chapter 12.

Acceptance Tests

Acceptance tests must be conducted on the new equipment or systems when installed in new additions. For more detailed information, see Chapter 14.

Requirements for Alterations

Prescriptive Requirements – New or Replacement Equipment

New space conditioning systems or components other than space conditioning ducts must meet applicable prescriptive requirements of HVAC System Control Requirements and HVAC Requirements (Section 140.4).

Minor equipment maintenance (such as replacement of filters or belts) does not trigger the prescriptive requirements. Equipment replacement (such as the installation of a new air handler or cooling tower) would be subject to the prescriptive requirements. Another example is when an existing VAV system is expanded to serve additional zones, the new VAV boxes are subject to zone controls of HVAC System Control Requirements. Details on prescriptive requirements may be found in other sections of this chapter.

Replacements of electric resistance space heaters for high-rise residential apartments are also not subject to the prescriptive requirements. Replacements of electric heat or electric resistance space heaters are allowed where natural gas is not available.

Alterations to service water heating in nonresidential and hotel/motel buildings must meet all applicable requirements of Section 140.5(a)&(b) with the exception of the solar water heating requirements in Section 170.2(d)3.

For alterations there are special rules for:

- New or Replacement Space Conditioning Systems or Components in Section 141.0(b)2C.
- Altered Duct Systems in Section 141.0(b)2D.
- Altered Space – Conditioning Systems in Section 141.0(b)2E.

Prescriptive Requirements – Air Distribution Duts

Reference: Section 141.0(b)2D

When new or replacement space-conditioning ducts are installed to serve an existing building, the new ducts shall meet the requirements of Pipe and Duct Distribution Systems (e.g., insulation levels, sealing materials and methods, and duct leakage testing).

If the ducts are added to a pre-existing duct system that serves less than 5,000 sq ft and more than 25 percent of the ductwork is outdoors or in unconditioned area, the system must be tested to leak no more than 15 percent. The description of the test method can be found in Section 2.1.4.2 of Reference Nonresidential Appendix NA2. The air distribution acceptance test associated with this can be found in Reference Nonresidential Appendix NA7. This and all acceptance tests are described in Chapter 13 of this manual. If the new ducts are added to a duct system that serves more than 5,000 sq ft or less than 25 percent of the ductwork is outdoors or in unconditioned space, then the new ductwork must meet the duct leakage testing requirements of CMC Section 603.10.1.

If it is not possible to meet the duct sealing requirements of Section 141.0(b)2Dii, all accessible leaks shall be sealed and verified through a visual inspection and smoke test performed by a certified ECC rater utilizing the methods specified in Reference Nonresidential Appendix NA2.1.4.2.2.

Exception: Existing duct systems that are extended, constructed, insulated, or sealed with asbestos.

Once the ducts have been sealed and tested to leak less than the above amounts, an ECC-Rater will be contacted by the contractor to validate the accuracy of the duct sealing measurement on a sample of the systems repaired as described in Reference Nonresidential Appendix NA1. Certified Acceptance Test Technicians (ATT may perform these field verifications only if the Acceptance Test Technician Certification Provider (ATTCP) has been approved to provide this service.

Prescriptive Requirements – Space-Conditioning Systems Alterations

Reference: Section 141.0(b)2C, Section 141.0(b)2D, Section 141.0(b)2E

Similar requirements apply to ducts upon replacement of small (serving less than 5,000 sq ft) constant volume HVAC units or their components (including replacement of the air handler, outdoor condensing unit of a split system air conditioner or heat pump, or cooling or heating coil). The duct sealing requirements are for those systems where over 25 percent of the duct area is outdoors or in unconditioned areas including attic spaces and above insulated ceilings.

One can avoid sealing the ducts by insulating the roof and sealing the attic vents as part of a larger remodel, thereby creating a conditioned space within which the ducts are located, which no longer meets the criteria of Section 140.4(l).

When a space conditioning system is altered by the installation or replacement of space conditioning equipment (including replacement of the air handler, outdoor condensing unit of a split system air conditioner or heat pump, or cooling or heating coil), the duct system that is connected to the new or replaced space conditioning equipment, shall be sealed, as confirmed through field verification and diagnostic testing in accordance with procedures for duct sealing of existing duct systems as specified in the Reference Nonresidential Appendix NA1, to one of the requirements of Section 141.0(b)2D. In addition, the system shall include a setback thermostat that meets requirements of Section 110.12(a).

There are three exceptions to this requirement:

- Buildings altered so that the duct system no longer meets the criteria of Section 140.4(l)1, 2, and 3. Ducts would no longer have to be sealed if the roof deck was insulated and attic ventilation openings sealed.
- Duct systems that are documented to have been previously sealed as confirmed through field verification and diagnostic testing in accordance with procedures in Reference Nonresidential Appendix NA2.
- Existing duct systems constructed, insulated, or sealed with asbestos.

For all altered unitary single zone, air conditioners, heat pumps, and furnaces where the existing thermostat does not comply with Section 110.12(a), the existing thermostat must be replaced with one that does comply. All newly installed space-conditioning systems requiring a thermostat shall be equipped with a thermostat that complies with Section 110.12(a). A thermostat compliant with Section 110.12(a) is also known as an occupant controlled smart thermostat, which is capable of responding to demand response signals in the event of grid congestion and shortages during high electrical demand periods.

New or replacement single zone rooftop air conditioner that cools less than 65,000 Btu/hr must follow the rules in Table 141.0-E-1 or meet the performance standards in Section 141.0(b)3.

Performance Approach

Please refer to Chapter 4.10.4.4 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Acceptance Tests

Please refer to Chapter 4.10.4.5 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Glossary/Reference

Please refer to Chapter 4.11 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Definitions of Efficiency

Please refer to Chapter 4.11.1 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Definitions of Spaces and Systems

Please refer to Chapter 4.11.2 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Types of Air

Please refer to Chapter 4.11.3 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Air-Delivery Systems

Please refer to Chapter 4.11.4 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Return Plenums

Please refer to Chapter 4.11.5 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Zone Reheat, Recool, and Air Mixing

Please refer to Chapter 4.11.6 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Economizers

Air Economizers

Please refer to Chapter 4.11.7.1 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Water Economizers

Please refer to Chapter 4.11.7.1.1.1 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Unusual Sources of Contaminants

Please refer to Chapter 4.11.8 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Demand Controlled Ventilation (DCV)

Please refer to Chapter 4.11.9 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Intermittently Occupied Spaces

Please refer to Chapter 4.11.10 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Mechanical Plan Check and Inspection Documents

Please refer to Chapter 4.12 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Mechanical Inspection

Please refer to Chapter 4.12.1 of the *2022 Nonresidential and Multifamily Compliance Manual*.

Acceptance Requirements

Acceptance requirements can effectively improve code compliance and help determine whether mechanical equipment meets operational goals and whether it should be adjusted to increase efficiency and effectiveness.

For more detailed information on acceptance tests, see Chapter 14.

Acceptance Process

Please refer to Chapter 4.12.2.1 the *2022 Nonresidential and Multifamily Compliance Manual*.

Administration

Please refer to Chapter 4.12.2.2 the *2022 Nonresidential and Multifamily Compliance Manual*.

Plan Review

Please refer to Chapter 4.12.2.3 the *2022 Nonresidential and Multifamily Compliance Manual*.

Testing

The construction inspection is the first step in performing the acceptance tests. In general, this inspection should identify that:

- Mechanical equipment and devices are properly located, identified, and calibrated.
- Setpoints and schedules are established.
- Documentation is available to identify settings and programs for each device.

- Select tests to verify acceptable leakage rates for air distribution systems while equipment access is available. Testing is to be performed on the following devices:
    - VAV systems
    - Constant volume systems
    - Package systems
    - Air distribution systems
    - Economizers
    - Demand control ventilation systems
    - Variable frequency drive fan systems
    - Hydronic control systems
    - Hydronic pump isolation controls and devices
    - Supply water reset controls
    - Water loop heat pump control
    - Variable frequency drive pump systems
    - System programming
    - Time clocks

Chapter 14 contains information on how to complete the acceptance documents. Example test procedures are also available in Chapter 14.

Roles and Responsibilities

Please refer to Chapter 4.12.2.5 the *2022 Nonresidential and Multifamily Compliance Manual*.

Contact Changes

Please refer to Chapter 4.12.2.6 the *2022 Nonresidential and Multifamily Compliance Manual*.