	OPEN MOTORS			
MOTOR HORSEPOWER	Number of Poles	2	4	6
	Synchronous Speed (RPM)	3600	1800	1200
0.25		65.6	69.5	67.5
0.33		69.5	73.4	71.4
0.50		73.4	78.2	75.3
0.75		76.8	81.1	81.7
1		77.0	83.5	82.5
1.5		84.0	86.5	83.8
2		85.5	86.5	N/A
3		85.5	86.9	N/A

TABLE C405.8(3) MINIMUM AVERAGE FULL LOAD EFICIENCY POLYPHASE SMALL ELECTRIC MOTORS<sup>®</sup>

a. Average full load efficiencies shall be established in accordance with 10 CFR 431.

TABLE C405.8(4) MINIMUM AVERAGE FULL LOAD EFFICIENCY FOR CAPACITOR-START CAPACITOR-RUN AND CAPACITOR-START INDUCTION-RUN SMALL ELECTRIC MOTORS®

	OPEN MOTORS			
MOTOR	Number of Poles	2	4	6
HORSEPOWER	Synchronous Speed (RPM)	3600	1800	1200
0.25		66.6	68.5	62.2
0.33		70.5	72.4	66.6
0.50		72.4	76.2	76.2
0.75		76.2	81.8	80.2
1		80.4	82.6	81.1
1.5		81.5	83.8	N/A
2		82.9	84.5	N/A
3		84.1	N/A	N/A

a. Average full load efficiencies shall be established in accordance with 10 CFR 431.

# SECTION C406 ADDITIONAL EFFICIENCY PACKAGE OPTIONS

**C406.1 Requirements.** Buildings shall comply with at least one of the following:

- 1. More efficient HVAC performance in accordance with Section C406.2.
- 2. Reduced lighting power density system in accordance with Section C406.3.
- 3. Enhanced lighting controls in accordance with Section C406.4.
- 4. On-site supply of renewable energy in accordance with Section C406.5.
- 5. Provision of a dedicated outdoor air system for certain HVAC equipment in accordance with Section C406.6.
- 6. High-efficiency service water heating in accordance with Section C406.7.

C406.1.1 Tenant spaces. Tenant spaces shall comply with Section C406.2, C406.3, C406.4, C406.6 or C406.7. Alternatively, tenant spaces shall comply with Section C406.5 where the entire building is in compliance.

**C406.2 More efficient HVAC equipment performance.** Equipment shall exceed the minimum efficiency requirements listed in Tables C403.2.3(1) through C403.2.3(7) by 10 percent, in addition to the requirements of Section C403. Where multiple performance requirements are provided, the equipment shall exceed all requirements by 10 percent. *Variable refrigerant flow systems* shall exceed the energy efficiency provisions of ANSI/ASHRAE/IES 90.1 by 10 percent. Equipment not listed in Tables C403.2.3(1) through C403.2.3(7) shall be limited to 10 percent of the total building system capacity.

**C406.3 Reduced lighting power density.** The total interior lighting power (watts) of the building shall be determined by using 90 percent of the lighting power values specified in Table C405.4.2(1) times the floor area for the building types, or by using 90 percent of the interior lighting power allowance calculated by the Space-by-Space Method in Section C405.4.2.

**C406.4 Enhanced digital lighting controls.** Interior lighting in the building shall have the following enhanced lighting controls that shall be located, scheduled and operated in accordance with Section C405.2.2.

- 1. Luminaires shall be capable of continuous dimming.
- 2. Luminaires shall be capable of being addressed individually. Where individual addressability is not available for the luminaire class type, a controlled group of not more than four luminaries shall be allowed.
- 3. Not more than eight luminaires shall be controlled together in a *daylight zone*.
- 4. Fixtures shall be controlled through a digital control system that includes the following function:
  - 4.1. Control reconfiguration based on digital addressability.
  - 4.2. Load shedding.
  - 4.3. Individual user control of overhead general illumination in open offices.
  - 4.4. Occupancy sensors shall be capable of being reconfigured through the digital control system.
- 5. Construction documents shall include submittal of a Sequence of Operations, including a specification outlining each of the functions in Item 4 of this section.
- 6. Functional testing of lighting controls shall comply with Section C408.

C406.5 On-site renewable energy. Total minimum ratings of on-site renewable energy systems shall comply with one of the following:

- 1. Provide not less than 0.50 watts per square foot (5.4 W/ m<sup>2</sup>) of conditioned floor area.
- 2. Provide not less than 3 percent of the energy used within the building for building mechanical and service water heating equipment and lighting regulated in Chapter 4.

**C406.6 Dedicated outdoor air system.** Buildings covered by Section C403.4 shall be equipped with an independent ventilation system designed to provide not less than the minimum 100-percent outdoor air to each individual occupied space, as specified by the *International Mechanical Code*. The ventilation system shall be capable of total energy recovery. The HVAC system shall include supply-air temperature controls that automatically reset the supply-air temperature in response to representative building loads, or to outdoor air temperatures. The controls shall reset the supply-air temperature at least 25 percent of the difference between the design supply-air temperature.

C406.7 Reduced energy use in service water heating. Buildings shall be of the following types to use this compliance method:

1. Group R-1: Boarding houses, hotels or motels.

- 2. Group I-2: Hospitals, psychiatric hospitals and nursing homes.
- 3. Group A-2: Restaurants and banquet halls or buildings containing food preparation areas.
- 4. Group F: Laundries.
- 5. Group R-2: Buildings with residential occupancies.
- 6. Group A-3: Health clubs and spas.
- 7. Buildings showing a service hot water load of 10 percent or more of total building energy loads, as shown with an energy analysis as described in Section C407.

**C406.7.1 Load fraction.** The building service water-heating system shall have one or more of the following that are sized to provide not less than 60 percent of hot water requirements, or sized to provide 100 percent of hot water requirements if the building shall otherwise comply with Section C403.4.7:

- 1. Waste heat recovery from service hot water, heatrecovery chillers, building equipment, process equipment, or a combined heat and power system.
- 2. Solar water-heating systems.

## SECTION C407 TOTAL BUILDING PERFORMANCE

**C407.1 Scope.** This section establishes criteria for compliance using total building performance. The following systems and loads shall be included in determining the total building performance: heating systems, cooling systems, service water heating, fan systems, lighting power, receptacle loads and process loads.

**C407.2 Mandatory requirements.** Compliance with this section requires that the criteria of Sections C402.5, C403.2, C404 and C405 be met.

**C407.3 Performance-based compliance.** Compliance based on total building performance requires that a proposed building (*proposed design*) be shown to have an annual energy cost that is less than or equal to the annual energy cost of the *standard reference design*. Energy prices shall be taken from a source *approved* by the *code official*, such as the Department of Energy, Energy Information Administration's *State Energy Price and Expenditure Report. Code officials* shall be permitted to require time-of-use pricing in energy cost calculations. Nondepletable energy collected off site shall be treated and priced the same as purchased energy. Energy from nondepletable energy cost of the *proposed design*.

**Exception:** Jurisdictions that require site energy (1 kWh = 3413 Btu) rather than energy cost as the metric of comparison.

**C407.4 Documentation.** Documentation verifying that the methods and accuracy of compliance software tools conform to the provisions of this section shall be provided to the *code official*.

**C407.4.1 Compliance report.** Permit submittals shall include a report documenting that the proposed design has annual energy costs less than or equal to the annual energy costs of the *standard reference design*. The compliance documentation shall include the following information:

- 1. Address of the building.
- 2. An inspection checklist documenting the building component characteristics of the *proposed design* as specified in Table C407.5.1(1). The inspection checklist shall show the estimated annual energy cost for both the *standard reference design* and the *proposed design*.
- 3. Name of individual completing the compliance report.
- 4. Name and version of the compliance software tool.

**C407.4.2** Additional documentation. The *code official* shall be permitted to require the following documents:

- 1. Documentation of the building component characteristics of the *standard reference design*.
- 2. Thermal zoning diagrams consisting of floor plans showing the thermal zoning scheme for *standard reference design* and *proposed design*.
- 3. Input and output reports from the energy analysis simulation program containing the complete input and output files, as applicable. The output file shall include energy use totals and energy use by energy source and end-use served, total hours that space conditioning loads are not met and any errors or warning messages generated by the simulation tool as applicable.
- 4. An explanation of any error or warning messages appearing in the simulation tool output.
- 5. A certification signed by the builder providing the building component characteristics of the *proposed design* as given in Table C407.5.1(1).

**C407.5 Calculation procedure.** Except as specified by this section, the *standard reference design* and *proposed design* shall be configured and analyzed using identical methods and techniques.

**C407.5.1 Building specifications.** The *standard reference design* and *proposed design* shall be configured and analyzed as specified by Table C407.5.1(1). Table C407.5.1(1) shall include by reference all notes contained in Table C402.1.4.

**C407.5.2 Thermal blocks.** The *standard reference design* and *proposed design* shall be analyzed using identical thermal blocks as specified in Section C407.5.2.1, C407.5.2.2 or C407.5.2.3.

**C407.5.2.1 HVAC zones designed.** Where HVAC *zones* are defined on HVAC design drawings, each HVAC *zone* shall be modeled as a separate thermal block.

**Exception:** Different HVAC *zones* shall be allowed to be combined to create a single thermal block or identical thermal blocks to which multipliers are applied provided:

- 1. The space use classification is the same throughout the thermal block.
- 2. All HVAC *zones* in the thermal block that are adjacent to glazed exterior walls face the same orientation or their orientations are within 45 degrees (0.79 rad) of each other.
- 3. All of the *zones* are served by the same HVAC system or by the same kind of HVAC system.

**C407.5.2.2 HVAC zones not designed.** Where HVAC *zones* have not yet been designed, thermal blocks shall be defined based on similar internal load densities, occupancy, lighting, thermal and temperature schedules, and in combination with the following guidelines:

- 1. Separate thermal blocks shall be assumed for interior and perimeter spaces. Interior spaces shall be those located more than 15 feet (4572 mm) from an exterior wall. Perimeter spaces shall be those located closer than 15 feet (4572 mm) from an *exterior wall*.
- 2. Separate thermal blocks shall be assumed for spaces adjacent to glazed exterior walls: a separate *zone* shall be provided for each orientation, except orientations that differ by not more than 45 degrees (0.79 rad) shall be permitted to be considered to be the same orientation. Each *zone* shall include floor area that is 15 feet (4572 mm) or less from a glazed perimeter wall, except that floor area within 15 feet (4572 mm) of glazed perimeter walls having more than one orientation shall be divided proportion-ately between *zones*.
- 3. Separate thermal blocks shall be assumed for spaces having floors that are in contact with the ground or exposed to ambient conditions from *zones* that do not share these features.
- 4. Separate thermal blocks shall be assumed for spaces having exterior ceiling or roof assemblies from *zones* that do not share these features.

**C407.5.2.3 Multifamily residential buildings.** Residential spaces shall be modeled using one thermal block per space except that those facing the same orientations are permitted to be combined into one thermal block. Corner units and units with roof or floor loads shall only be combined with units sharing these features.

	BUILDING COMPONENT CHARACTERISTICS	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
	Space use classification	Same as proposed	The space use classification shall be chosen in accordance with Table C405.5.2 for all areas of the building covered by this permit. Where the space use classification for a building is not known, the building shall be categorized as an office building.
		Type: Insulation entirely above deck	As proposed
		Gross area: same as proposed	As proposed
	Roofs	U-factor: as specified in Table C402.1.4	As proposed
		Solar absorptance: 0.75	As proposed
		Emittance: 0.90	As proposed
		Type: Mass wall where proposed wall is mass; otherwise steel-framed wall	As proposed
	Walls shows and	Gross area: same as proposed	As proposed
	wans, above-grade	U-factor: as specified in Table C402.1.4	As proposed
		Solar absorptance: 0.75	As proposed
		Emittance: 0.90	As proposed
		Type: Mass wall	As proposed
	Walls, below-grade	Gross area: same as proposed	As proposed
		<i>U</i> -Factor: as specified in Table C402.1.4 with insulation layer on interior side of walls	As proposed
		Type: joist/framed floor	As proposed
	Floors, above-grade	Gross area: same as proposed	As proposed
		U-factor: as specified in Table C402.1.4	As proposed
	Floors slab-on-grade	Type: Unheated	As proposed
	Tioons, shub on grude	F-factor: as specified in Table C402.1.4	As proposed
		Type: Swinging	As proposed
	Opaque doors	Area: Same as proposed	As proposed
		U-factor: as specified in Table C402.1.4	As proposed
	Vertical fenestration other than	<ol> <li>Area</li> <li>The proposed glazing area; where the proposed glazing area is less than 40 percent of above-grade wall area.</li> <li>40 percent of above-grade wall area; where the proposed glazing area is 40 percent or more of the above-grade wall area.</li> </ol>	As proposed
	opaque doors	U-factor: as specified in Table C402.4	As proposed
		SHGC: as specified in Table C402.4 except that for climates with no requirement (NR) SHGC = $0.40$ shall be used	As proposed
		External shading and PF: None	As proposed
	Skylights	<ol> <li>Area</li> <li>The proposed skylight area; where the proposed skylight area is less than 3 percent of gross area of roof assembly.</li> <li>3 percent of gross area of roof assembly; where the proposed skylight area is 3 percent or more of gross area of roof assembly</li> </ol>	As proposed
		U-factor: as specified in Table C402.4	As proposed
		SHGC: as specified in Table C402.4 except that for climates with no requirement (NR) SHGC = 0.40 shall be used.	As proposed
	Lighting, interior	The interior lighting power shall be determined in accordance with Section C405.4.2. Where the occupancy of the building is not known, the lighting power density shall be 1.0 Watt per square foot $(10.7 \text{ W/m}^2)$ based on the categorization of buildings with unknown space classification as offices.	As proposed
	Lighting, exterior	The lighting power shall be determined in accordance with Table C405.5.2(2). Areas and dimensions of tradable and nontradable surfaces shall be the same as proposed.	As proposed

TABLE C407.5.1(1) SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

(continued)

TABLE C407.5.1(1)—continued
SPECIFICATIONS FOR THE STANDARD REFERENCE AND PROPOSED DESIGNS

BUILDING COMPONENT CHARACTERISTICS	STANDARD REFERENCE DESIGN	PROPOSED DESIGN	
Internal gains	Same as proposed	Receptacle, motor and process loads shall be modeled and estimated based on the space use classification. All end-use load components within and associated with the building shall be modeled to include, but not be limited to, the following: exhaust fans, parking garage ventilation fans, exterior building lighting, swimming pool heaters and pumps, elevators, escalators, refrigeration equipment and cooking equipment.	
Schedules Same as proposed r		Operating schedules shall include hourly profiles for daily operation and shall account for variations between weekdays, weekends, holidays and any seasonal operation. Schedules shall model the time- dependent variations in occupancy, illumination, receptacle loads, thermostat settings, mechanical ventilation, HVAC equipment availability, service hot water usage and any process loads. The schedules shall be typical of the proposed building type as determined by the designer and approved by the jurisdiction.	
Mechanical ventilation	Same as proposed	As proposed, in accordance with Section C403.2.6.	
	Fuel type: same as proposed design	As proposed	
	Equipment type <sup>a</sup> : as specified in Tables C407.5.1(2) and C407.5.1(3)	As proposed	
Heating systems	Efficiency: as specified in Tables C403.2.3(4) and C403.2.3(5)	As proposed	
ricaning systems	Capacity <sup>b</sup> : sized proportionally to the capacities in the proposed design based on sizing runs, and shall be established such that no smaller number of unmet heating load hours and no larger heating capacity safety factors are provided than in the proposed design.	As proposed	
	Fuel type: same as proposed design	As proposed	
	Equipment type <sup>c</sup> : as specified in Tables C407.5.1(2) and C407.5.1(3)	As proposed	
	Efficiency: as specified in Tables C403.2.3(1), C403.2.3(2) and C403.2.3(3)	As proposed	
Cooling systems	Capacity <sup>b</sup> : sized proportionally to the capacities in the proposed design based on sizing runs, and shall be established such that no smaller number of unmet cooling load hours and no larger cooling capacity safety factors are provided than in the proposed design.	As proposed	
	Economizer <sup>d</sup> : same as proposed, in accordance with Section C403.3.	As proposed	
	Fuel type: same as proposed	As proposed	
		For Group R, as proposed multiplied by SWHF.	
Service water heating <sup>e</sup>	Efficiency: as specified in Table C404.2	For other than Group R, as proposed multiplied by efficiency as provided by the manufacturer of the DWHR unit.	
	Capacity: same as proposed		
	Where no service water hot water system exists or is specified in the proposed design, no service hot water heating shall be modeled.	As proposed	

SWHF = Service water heat recovery factor, DWHR = Drain water heat recovery.

a. Where no heating system exists or has been specified, the heating system shall be modeled as fossil fuel. The system characteristics shall be identical in both the standard reference design and proposed design.

b. The ratio between the capacities used in the annual simulations and the capacities determined by sizing runs shall be the same for both the standard reference design and proposed design.

c. Where no cooling system exists or no cooling system has been specified, the cooling system shall be modeled as an air-cooled single-zone system, one unit per thermal zone. The system characteristics shall be identical in both the standard reference design and proposed design.

d. If an economizer is required in accordance with Table C403.3 and where no economizer exists or is specified in the proposed design, then a supply-air economizer shall be provided in the standard reference design in accordance with Section C403.3.

e. The SWHF shall be applied as follows:

1. Where potable water from the DWHR unit supplies not less than one shower and not greater than two showers, of which the drain water from the same showers flows through the DWHR unit then SWHF =  $[1 - (DWHR unit efficiency \cdot 0.36)]$ .

2. Where potable water from the DWHR unit supplies not less than three showers and not greater than four showers, of which the drain water from the same showers flows through the DWHR unit then SWHF =  $[1 - (DWHR unit efficiency \cdot 0.33)]$ .

3. Where potable water from the DWHR unit supplies not less than five showers and not greater than six showers, of which the drain water from the same showers flows through the DWHR unit, then SWHF =  $[1 - (DWHR unit efficiency \cdot 0.26)]$ .

4. Where Items 1 through 3 are not met, SWHF = 1.0.

CONDENSER COOLING SOURCE <sup>®</sup>		STANDARD REFERENCE DESIGN HVC SYSTEM TYPE°			
	CLASSIFICATION	Single-zone Residential System	Single-zone Nonresidential System	All Other	
	Electric resistance	System 5	System 5	System 1	
Water/ground	Heat pump	System 6	System 6	System 6	
	Fossil fuel	System 7	System 7	System 2	
	Electric resistance	System 8	System 9	System 3	
Air/none	Heat pump	System 8	System 9	System 3	
	Fossil fuel	System 10	System 11	System 4	

### TABLE C407.5.1(2) HVAC SYSTEMS MAP

a. Select "water/ground" where the proposed design system condenser is water or evaporatively cooled; select "air/none" where the condenser is air cooled. Closed-circuit dry coolers shall be considered air cooled. Systems utilizing district cooling shall be treated as if the condenser water type were "water." Where no mechanical cooling is specified or the mechanical cooling system in the proposed design does not require heat rejection, the system shall be treated as if the condenser water type were "Air." For proposed designs with ground-source or groundwater-source heat pumps, the standard reference design HVAC system shall be water-source heat pump (System 6).

b. Select the path that corresponds to the proposed design heat source: electric resistance, heat pump (including air source and water source), or fuel fired. Systems utilizing district heating (steam or hot water) and systems with no heating capability shall be treated as if the heating system type were "fossil fuel." For systems with mixed fuel heating sources, the system or systems that use the secondary heating source type (the one with the smallest total installed output capacity for the spaces served by the system) shall be modeled identically in the standard reference design and the primary heating source type shall be used to determine *standard* reference design HVAC system type.

c. Select the standard reference design HVAC system category: The system under "single-zone residential system" shall be selected where the HVAC system in the proposed design is a single-zone system and serves a residential space. The system under "single-zone nonresidential system" shall be selected where the HVAC system in the proposed design is a single-zone system and serves other than residential spaces. The system under "all other" shall be selected for all other cases.

SYSTEM NO.	SYSTEM TYPE	FAN CONTROL	COOLING TYPE	HEATING TYPE
1	Variable air volume with parallel fan-powered boxes <sup>a</sup>	$VAV^d$	Chilled water <sup>e</sup>	Electric resistance
2	Variable air volume with reheat <sup>b</sup>	$VAV^d$	Chilled water <sup>e</sup>	Hot water fossil fuel boiler <sup>f</sup>
3	Packaged variable air volume with parallel fan- powered boxes <sup>a</sup>	$VAV^d$	Direct expansion <sup>e</sup>	Electric resistance
4	Packaged variable air volume with reheat <sup>b</sup>	$VAV^d$	Direct expansion <sup>c</sup>	Hot water fossil fuel boiler <sup>f</sup>
5	Two-pipe fan coil	Constant volume <sup>i</sup>	Chilled water <sup>e</sup>	Electric resistance
6	Water-source heat pump	Constant volume <sup>i</sup>	Direct expansion <sup>c</sup>	Electric heat pump and boiler <sup>g</sup>
7	Four-pipe fan coil	Constant volume <sup>i</sup>	Chilled water <sup>e</sup>	Hot water fossil fuel boiler <sup>f</sup>
8	Packaged terminal heat pump	Constant volume <sup>i</sup>	Direct expansion <sup>c</sup>	Electric heat pump <sup>h</sup>
9	Packaged rooftop heat pump	Constant volume <sup>i</sup>	Direct expansion <sup>c</sup>	Electric heat pump <sup>h</sup>
10	Packaged terminal air conditioner	Constant volume <sup>i</sup>	Direct expansion	Hot water fossil fuel boiler <sup>f</sup>
11	Packaged rooftop air conditioner	Constant volume <sup>i</sup>	Direct expansion	Fossil fuel furnace

 TABLE C407.5.1(3)

 SPECIFICATIONS FOR THE STANDARD REFERENCE DESIGN HVAC SYSTEM DESCRIPTIONS

For SI: 1 foot = 304.8 mm, 1 cfm/ft<sup>2</sup> = 0.4719 L/s, 1 Btu/h = 0.293/W,  $^{\circ}$ C = [( $^{\circ}$ F) -32/1.8].

a. VAV with parallel boxes: Fans in parallel VAV fan-powered boxes shall be sized for 50 percent of the peak design flow rate and shall be modeled with 0.35 W/cfm fan power. Minimum volume setpoints for fan-powered boxes shall be equal to the minimum rate for the space required for ventilation consistent with Section C403.4.4, Exception 4. Supply air temperature setpoint shall be constant at the design condition.

b. VAV with reheat: Minimum volume setpoints for VAV reheat boxes shall be 0.4 cfm/ft<sup>2</sup> of floor area. Supply air temperature shall be reset based on zone demand from the design temperature difference to a 10°F temperature difference under minimum load conditions. Design airflow rates shall be sized for the reset supply air temperature, i.e., a 10°F temperature difference.

c. Direct expansion: The fuel type for the cooling system shall match that of the cooling system in the proposed design.

d. VAV: Where the proposed design system has a supply, return or relief fan motor 25 hp or larger, the corresponding fan in the VAV system of the standard reference design shall be modeled assuming a variable-speed drive. For smaller fans, a forward-curved centrifugal fan with inlet vanes shall be modeled. Where the proposed design's system has a direct digital control system at the zone level, static pressure setpoint reset based on zone requirements in accordance with Section C403.4.1 shall be modeled.

- e. Chilled water: For systems using purchased chilled water, the chillers are not explicitly modeled and chilled water costs shall be based as determined in Sections C407.3 and C407.5.2. Otherwise, the standard reference design's chiller plant shall be modeled with chillers having the number as indicated in Table C407.5.1(4) as a function of standard reference building chiller plant load and type as indicated in Table C407.5.1(5) as a function of individual chiller load. Where chiller fuel source is mixed, the system in the standard reference design shall have chillers with the same fuel types and with capacities having the same proportional capacity as the proposed design's chillers for each fuel type. Chilled water supply temperature shall be modeled at 44°F design supply temperature and 56°F return temperature. Piping losses shall not be modeled in either building model. Chilled water supply water temperature shall be reset in accordance with Section C403.4.3.3. Pump system power for each pumping system shall be the same as the proposed design; where the proposed design has no chilled water pumps, the standard reference design pump power shall be 22 W/gpm (equal to a pump operating against a 75-foot head, 65-percent combined impeller and motor efficiency). The chilled water system shall be modeled as primary-only variable flow with flow maintained at the design rate through each chiller using a bypass. Chilled water pumps shall be modeled as riding the pump curve or with variable-speed drives when required in Section C403.4.3.3. The heat rejection device shall be an axial fan cooling tower with two-speed fans where required in Section C403.4.3. Condenser water design supply temperature shall be 85°F or 10°F approach to design wet-bulb temperature, whichever is lower, with a design temperature rise of 10°F. The tower shall be controlled to maintain a 70°F leaving water temperature where weather permits, floating up to leaving water temperature at design conditions. Pump system power for each pumping system shall be the same as the proposed design; where the proposed design has no condenser water pumps, the standard reference design pump power shall be 19 W/gpm (equal to a pump operating against a 60-foot head, 60-percent combined impeller and motor efficiency). Each chiller shall be modeled with separate condenser water and chilled water pumps interlocked to operate with the associated chiller.
- f. Fossil fuel boiler: For systems using purchased hot water or steam, the boilers are not explicitly modeled and hot water or steam costs shall be based on actual utility rates. Otherwise, the boiler plant shall use the same fuel as the proposed design and shall be natural draft. The standard reference design boiler plant shall be modeled with a single boiler where the standard reference design plant load is 600,000 Btu/h and less and with two equally sized boilers for plant capacities exceeding 600,000 Btu/h. Boilers shall be staged as required by the load. Hot water supply temperature shall be modeled at 180°F design supply temperature and 130°F return temperature. Piping losses shall not be modeled in either building model. Hot water supply water temperature shall be reset in accordance with Section C403.4.3.3. Pump system power for each pumping system shall be the same as the proposed design; where the proposed design has no hot water pumps, the standard reference design pump power shall be 19 W/gpm (equal to a pump operating against a 60-foot head, 60-percent combined impeller and motor efficiency). The hot water system shall be modeled as primary only with continuous variable flow. Hot water pumps shall be modeled as riding the pump curve or with variable speed drives when required by Section C403.4.3.3.
- g. Electric heat pump and boiler: Water-source heat pumps shall be connected to a common heat pump water loop controlled to maintain temperatures between 60°F and 90°F. Heat rejection from the loop shall be provided by an axial fan closed-circuit evaporative fluid cooler with two-speed fans where required in Section C403.4.1. Heat addition to the loop shall be provided by a boiler that uses the same fuel as the proposed design and shall be natural draft. Where no boilers exist in the proposed design, the standard reference building boilers shall be fossil fuel. The standard reference design boiler plant shall be modeled with a single boiler where the standard reference design plant load is 600,000 Btu/h or less and with two equally sized boilers for plant capacities exceeding 600,000 Btu/h. Boilers shall be staged as required by the load. Piping losses shall not be modeled in either building model. Pump system power shall be the same as the proposed design; where the proposed design has no pumps, the standard reference design plant load is 600,000 Btu/h or less and with two equally sized boiler. Pump system power shall be the same as the proposed design; where the proposed design has no pumps, the standard reference design plant be variable with flow shutoff at each heat pump operating against a 75-foot head, with a 65-percent combined impeller and motor efficiency. Loop flow shall be variable with flow shutoff at each heat pump when its compressor cycles off as required by Section C403.4.3.3. Loop pumps shall be modeled as riding the pump curve or with variable speed drives when required by Section C403.4.3.3.
- h. Electric heat pump: Electric air-source heat pumps shall be modeled with electric auxiliary heat. The system shall be controlled with a multistage space thermostat and an outdoor air thermostat wired to energize auxiliary heat only on the last thermostat stage and when outdoor air temperature is less than 40°F.
- i. **Constant volume:** Fans shall be controlled in the same manner as in the proposed design; i.e., fan operation whenever the space is occupied or fan operation cycled on calls for heating and cooling. Where the fan is modeled as cycling and the fan energy is included in the energy efficiency rating of the equipment, fan energy shall not be modeled explicitly.

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TABLE C407.5.1(4) NUMBER OF CHILLERS

TOTAL CHILLER PLANT CAPACITY	NUMBER OF CHILLERS
$\leq$ 300 tons	1
> 300 tons, < 600 tons	2, sized equally
≥ 600 tons	2 minimum, with chillers added so that no chiller is larger than 800 tons, all sized equally

For SI: 1 ton = 3517 W.

#### TABLE C407.5.1(5) WATER CHILLER TYPES

INDIVIDUAL CHILLER PLANT CAPACITY	ELECTRIC CHILLER TYPE	FOSSIL FUEL CHILLER TYPE	
$\leq 100$ tons	Reciprocating	Single-effect absorption, direct fired	
> 100 tons, < 300 tons	Screw	Double-effect absorption, direct fired	
$\geq$ 300 tons	Centrifugal	Double-effect absorption, direct fired	

For SI: 1 ton = 3517 W.

**C407.6 Calculation software tools.** Calculation procedures used to comply with this section shall be software tools capable of calculating the annual energy consumption of all building elements that differ between the *standard reference design* and the *proposed design* and shall include the following capabilities.

- 1. Building operation for a full calendar year (8,760 hours).
- 2. Climate data for a full calendar year (8,760 hours) and shall reflect *approved* coincident hourly data for temperature, solar radiation, humidity and wind speed for the building location.
- 3. Ten or more thermal zones.
- 4. Thermal mass effects.
- 5. Hourly variations in occupancy, illumination, receptacle loads, thermostat settings, mechanical ventilation, HVAC equipment availability, service hot water usage and any process loads.
- 6. Part-load performance curves for mechanical equipment.
- 7. Capacity and efficiency correction curves for mechanical heating and cooling equipment.
- 8. Printed *code official* inspection checklist listing each of the *proposed design* component characteristics from Table C407.5.1(1) determined by the analysis to provide compliance, along with their respective performance ratings including, but not limited to, *R*-value, *U*factor, SHGC, HSPF, AFUE, SEER, EF.

**C407.6.1 Specific approval.** Performance analysis tools complying with the applicable subsections of Section C407 and tested according to ASHRAE Standard 140 shall be permitted to be *approved*. Tools are permitted to be *approved* based on meeting a specified threshold for a jurisdiction. The *code official* shall be permitted to approve tools for a specified application or limited scope.

**C407.6.2 Input values.** Where calculations require input values not specified by Sections C402, C403, C404 and C405, those input values shall be taken from an *approved* source.

**C407.6.3 Exceptional calculation methods.** Where the simulation program does not model a design, material or device of the *proposed design*, an exceptional calculation method shall be used where approved by the *code official*. Where there are multiple designs, materials or devices that the simulation program does not model, each shall be calculated separately and exceptional savings determined for each. The total exceptional savings shall not constitute more than half of the difference between the baseline building performance and the proposed building performance. Applications for approval of an exceptional method shall include all of the following:

- 1. Step-by-step documentation of the exceptional calculation method performed, detailed enough to reproduce the results.
- 2. Copies of all spreadsheets used to perform the calculations.
- 3. A sensitivity analysis of energy consumption where each of the input parameters is varied from half to double the value assumed.
- 4. The calculations shall be performed on a time step basis consistent with the simulation program used.
- 5. The performance rating calculated with and without the exceptional calculation method.

# SECTION C408 SYSTEM COMMISSIONING

**C408.1 General.** This section covers the commissioning of the building mechanical systems in Section C403 and electrical power and lighting systems in Section C405.

**C408.2** Mechanical systems and service water-heating systems commissioning and completion requirements. Prior to the final mechanical and plumbing inspections, the *registered design professional* or *approved agency* shall provide evidence of mechanical systems *commissioning* and completion in accordance with the provisions of this section.

*Construction document* notes shall clearly indicate provisions for *commissioning* and completion requirements in accordance with this section and are permitted to refer to specifications for further requirements. Copies of all documentation shall be given to the owner or owner's authorized agent and made available to the *code official* upon request in accordance with Sections C408.2.4 and C408.2.5.

**Exceptions:** The following systems are exempt:

- 1. Mechanical systems and service water heater systems in buildings where the total mechanical equipment capacity is less than 480,000 Btu/h (140.7 kW) cooling capacity and 600,000 Btu/h (175.8 kW) combined service water-heating and space-heating capacity.
- 2. Systems included in Section C403.3 that serve individual *dwelling units* and *sleeping units*.

**C408.2.1 Commissioning plan.** A *commissioning plan* shall be developed by a *registered design professional* or *approved agency* and shall include the following items:

- 1. A narrative description of the activities that will be accomplished during each phase of *commissioning*, including the personnel intended to accomplish each of the activities.
- 2. A listing of the specific equipment, appliances or systems to be tested and a description of the tests to be performed.
- 3. Functions to be tested including, but not limited to, calibrations and economizer controls.
- 4. Conditions under which the test will be performed. Testing shall affirm winter and summer design conditions and full outside air conditions.
- 5. Measurable criteria for performance.

**C408.2.2 Systems adjusting and balancing.** HVAC systems shall be balanced in accordance with generally accepted engineering standards. Air and water flow rates shall be measured and adjusted to deliver final flow rates within the tolerances provided in the product specifications. Test and balance activities shall include air system and hydronic system balancing.

**C408.2.2.1** Air systems balancing. Each supply air outlet and *zone* terminal device shall be equipped with means for air balancing in accordance with the requirements of Chapter 6 of the *International Mechanical Code*. Discharge dampers used for air-system balancing are prohibited on constant-volume fans and variable-volume fans with motors 10 hp (18.6 kW) and larger. Air systems shall be balanced in a manner to first minimize throttling losses then, for fans with system power

of greater than 1 hp (0.746 kW), fan speed shall be adjusted to meet design flow conditions.

**Exception:** Fans with fan motors of 1 hp (0.74 kW) or less are not required to be provided with a means for air balancing.

**C408.2.2.2 Hydronic systems balancing.** Individual hydronic heating and cooling coils shall be equipped with means for balancing and measuring flow. Hydronic systems shall be proportionately balanced in a manner to first minimize throttling losses, then the pump impeller shall be trimmed or pump speed shall be adjusted to meet design flow conditions. Each hydronic system shall have either the capability to measure pressure across the pump, or test ports at each side of each pump.

**Exceptions:** The following equipment is not required to be equipped with a means for balancing or measuring flow:

- 1. Pumps with pump motors of 5 hp (3.7 kW) or less.
- 2. Where throttling results in no greater than 5 percent of the nameplate horsepower draw above that required if the impeller were trimmed.

**C408.2.3 Functional performance testing.** Functional performance testing specified in Sections C408.2.3.1 through C408.2.3.3 shall be conducted.

**C408.2.3.1 Equipment.** Equipment functional performance testing shall demonstrate the installation and operation of components, systems, and system-to-system interfacing relationships in accordance with approved plans and specifications such that operation, function, and maintenance serviceability for each of the commissioned systems is confirmed. Testing shall include all modes and *sequence of operation*, including under full-load, part-load and the following emergency conditions:

- 1. All modes as described in the *sequence* of *operation*.
- 2. Redundant or *automatic* back-up mode.
- 3. Performance of alarms.
- 4. Mode of operation upon a loss of power and restoration of power.

**Exception:** Unitary or packaged HVAC equipment listed in Tables C403.2.3(1) through C403.2.3(3) that do not require supply air economizers.

**C408.2.3.2 Controls.** HVAC and service water-heating control systems shall be tested to document that control devices, components, equipment and systems are calibrated and adjusted and operate in accordance with approved plans and specifications. Sequences of operation shall be functionally tested to document they operate in accordance with *approved* plans and specifications.

**C408.2.3.3 Economizers.** Air economizers shall undergo a functional test to determine that they operate in accordance with manufacturer's specifications.

**C408.2.4 Preliminary commissioning report.** A preliminary report of *commissioning* test procedures and results shall be completed and certified by the *registered design professional* or *approved agency* and provided to the building owner or owner's authorized agent. The report shall be organized with mechanical and service hot water findings in separate sections to allow independent review. The report shall be identified as "Preliminary Commissioning Report" and shall identify:

- 1. Itemization of deficiencies found during testing required by this section that have not been corrected at the time of report preparation.
- 2. Deferred tests that cannot be performed at the time of report preparation because of climatic conditions.
- 3. Climatic conditions required for performance of the deferred tests.

**C408.2.4.1 Acceptance of report.** Buildings, or portions thereof, shall not be considered acceptable for a final inspection pursuant to Section C104.3 until the *code official* has received a letter of transmittal from the building owner acknowledging that the building owner or owner's authorized agent has received the Preliminary Commissioning Report.

**C408.2.4.2 Copy of report.** The *code official* shall be permitted to require that a copy of the Preliminary Commissioning Report be made available for review by the *code official*.

**C408.2.5 Documentation requirements.** The *construction documents* shall specify that the documents described in this section be provided to the building owner or owner's authorized agent within 90 days of the date of receipt of the *certificate of occupancy*.

**C408.2.5.1 Drawings.** *Construction documents* shall include the location and performance data on each piece of equipment.

**C408.2.5.2 Manuals.** An operating and maintenance manual shall be provided and include all of the following:

- 1. Submittal data stating equipment size and selected options for each piece of equipment requiring maintenance.
- 2. Manufacturer's operation manuals and maintenance manuals for each piece of equipment requiring maintenance, except equipment not furnished as part of the project. Required routine maintenance actions shall be clearly identified.
- 3. Name and address of at least one service agency.
- 4. HVAC and service hot water controls system maintenance and calibration information, including wiring diagrams, schematics and control sequence descriptions. Desired or field-determined set points shall be permanently recorded on control drawings at control devices or, for dig-

ital control systems, in system programming instructions.

- 5. Submittal data indicating all selected options for each piece of lighting equipment and lighting controls.
- 6. Operation and maintenance manuals for each piece of lighting equipment. Required routine maintenance actions, cleaning and recommended relamping shall be clearly identified.
- 7. A schedule for inspecting and recalibrating all lighting controls.
- 8. A narrative of how each system is intended to operate, including recommended set points.

**C408.2.5.3 System balancing report.** A written report describing the activities and measurements completed in accordance with Section C408.2.2.

**C408.2.5.4 Final commissioning report.** A report of test procedures and results identified as "Final Commissioning Report" shall be delivered to the building owner or owner's authorized agent. The report shall be organized with mechanical system and service hot water system findings in separate sections to allow independent review. The report shall include the following:

- 1. Results of functional performance tests.
- 2. Disposition of deficiencies found during testing, including details of corrective measures used or proposed.
- 3. Functional performance test procedures used during the commissioning process including measurable criteria for test acceptance, provided herein for repeatability.

**Exception:** Deferred tests that cannot be performed at the time of report preparation due to climatic conditions.

**C408.3 Lighting system functional testing.** Controls for automatic lighting systems shall comply with this section.

**C408.3.1 Functional testing.** Prior to passing final inspection, the *registered design professional* shall provide evidence that the lighting control systems have been tested to ensure that control hardware and software are calibrated, adjusted, programmed and in proper working condition in accordance with the *construction documents* and manufacturer's instructions. Functional testing shall be in accordance with Sections C408.3.1.1 and C408.3.1.2 for the applicable control type.

**C408.3.1.1 Occupant sensor controls.** Where *occupant sensor controls* are provided, the following procedures shall be performed:

- 1. Certify that the *occupant sensor* has been located and aimed in accordance with manufacturer recommendations.
- 2. For projects with seven or fewer *occupant sensors*, each sensor shall be tested.

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3. For projects with more than seven *occupant sensors*, testing shall be done for each unique combination of sensor type and space geometry. Where multiples of each unique combination of sensor type and space geometry are provided, not less than 10 percent, but in no case less than one, of each combination shall be tested unless the *code official* or design professional requires a higher percentage to be tested. Where 30 percent or more of the tested controls fail, all remaining identical combinations shall be tested.

For *occupant sensor controls* to be tested, verify the following:

- 3.1. Where *occupant sensor controls* include status indicators, verify correct operation.
- 3.2. The controlled lights turn off or down to the permitted level within the required time.
- 3.3. For auto-on *occupant sensor controls*, the lights turn on to the permitted level when an occupant enters the space.
- 3.4. For manual-on *occupant sensor controls*, the lights turn on only when manually activated.
- 3.5. The lights are not incorrectly turned on by movement in adjacent areas or by HVAC operation.

**C408.3.1.2 Time-switch controls.** Where t*ime-switch controls* are provided, the following procedures shall be performed:

- 1. Confirm that the *time-switch control* is programmed with accurate weekday, weekend and holiday schedules.
- 2. Provide documentation to the owner of *time-switch controls* programming including weekday, weekend, holiday schedules, and set-up and preference program settings.
- 3. Verify the correct time and date in the time switch.
- 4. Verify that any battery back-up is installed and energized.
- 5. Verify that the override time limit is set to not more than 2 hours.
- 6. Simulate occupied condition. Verify and document the following:
  - 6.1. All lights can be turned on and off by their respective area control switch.
  - 6.2. The switch only operates lighting in the enclosed space in which the switch is located.
- 7. Simulate unoccupied condition. Verify and document the following:
  - 7.1. Nonexempt lighting turns off.

- 7.2. Manual override switch allows only the lights in the enclosed space where the override switch is located to turn on or remain on until the next scheduled shutoff occurs.
- 8. Additional testing as specified by the *registered design professional*.

**C408.3.1.3 Daylight responsive controls.** Where *daylight responsive controls* are provided, the following shall be verified:

- 1. Control devices have been properly located, field calibrated and set for accurate setpoints and threshold light levels.
- 2. Daylight controlled lighting loads adjust to light level set points in response to available daylight.
- 3. The locations of calibration adjustment equipment are readily accessible only to authorized personnel.

**C408.3.2 Documentation requirements.** The *construction documents* shall specify that documents certifying that the installed lighting controls meet documented performance criteria of Section C405 are to be provided to the building owner within 90 days from the date of receipt of the *certificate of occupancy*.