

## CHAPTER 4 [CE]

# COMMERCIAL ENERGY EFFICIENCY

### SECTION C401 GENERAL

**C401.1 Scope.** The requirements contained in this chapter are applicable to commercial buildings, or portions of commercial buildings.

**C401.2 Application.** Commercial buildings shall comply with one of the following:

1. The requirements of ANSI/ASHRAE/IESNA 90.1.
2. The requirements of Sections C402, C403, C404 and C405. In addition, commercial buildings shall comply with either Section C406.2, C406.3 or C406.4.
3. The requirements of Section C407, C402.4, C403.2, C404, C405.2, C405.3, C405.4, C405.6 and C405.7. The building energy cost shall be equal to or less than 85 percent of the standard reference design building.

**C401.2.1 Application to existing buildings.** Additions, alterations and repairs to existing buildings shall comply with one of the following:

1. Sections C402, C403, C404 and C405; or
2. ANSI/ASHRAE/IESNA 90.1.

### SECTION C402 BUILDING ENVELOPE REQUIREMENTS

**C402.1 General (Prescriptive).** The building thermal envelope shall comply with Section C402.1.1. Section C402.1.2 shall be permitted as an alternative to the *R*-values specified in Section C402.1.1.

**C402.1.1 Insulation and fenestration criteria.** The *building thermal envelope* shall meet the requirements of Tables C402.2 and C402.3 based on the climate zone specified in Chapter 3. Commercial buildings or portions of commercial buildings enclosing Group R occupancies shall use the *R*-values from the “Group R” column of Table C402.2. Commercial buildings or portions of commercial buildings enclosing occupancies other than Group R shall use the *R*-values from the “All other” column of Table C402.2. Buildings with a vertical fenestration area or skylight area that exceeds that allowed in Table C402.3 shall comply with the building envelope provisions of ANSI/ASHRAE/IESNA 90.1.

**C402.1.2 *U*-factor alternative.** An assembly with a *U*-factor, *C*-factor, or *F*-factor equal or less than that specified in Table C402.1.2 shall be permitted as an alternative to the *R*-value in Table C402.2. Commercial buildings or portions of commercial buildings enclosing Group R occupancies shall use the *U*-factor, *C*-factor, or *F*-factor from the “Group R” column of Table C402.1.2. Commercial buildings or portions of commercial buildings enclosing occupancies other than Group R shall use the *U*-factor, *C*-factor or *F*-factor from the “All other” column of Table C402.1.2.

**C402.2 Specific insulation requirements (Prescriptive).** Opaque assemblies shall comply with Table C402.2. Where two or more layers of continuous insulation board are used in a construction assembly, the continuous insulation boards shall be installed in accordance with Section C303.2. If the continuous insulation board manufacturer’s installation instructions do not address installation of two or more layers, the edge joints between each layer of continuous insulation boards shall be staggered.

**C402.2.1 Roof assembly.** The minimum thermal resistance (*R*-value) of the insulating material installed either between the roof framing or continuously on the roof assembly shall be as specified in Table C402.2, based on construction materials used in the roof assembly. Skylight curbs shall be insulated to the level of roofs with insulation entirely above deck or R-5, whichever is less.

#### Exceptions:

1. Continuously insulated roof assemblies where the thickness of insulation varies 1 inch (25 mm) or less and where the area-weighted *U*-factor is equivalent to the same assembly with the *R*-value specified in Table C402.2.
2. Unit skylight curbs included as a component of an NFRC 100 rated assembly shall not be required to be insulated.

Insulation installed on a suspended ceiling with removable ceiling tiles shall not be considered part of the minimum thermal resistance of the roof insulation.

**C402.2.1.1 Roof solar reflectance and thermal emittance.** Low-sloped roofs, with a slope less than 2 units vertical in 12 horizontal, directly above cooled *conditioned spaces* in Climate Zones 1, 2, and 3 shall comply with one or more of the options in Table C402.2.1.1.

**Exceptions:** The following roofs and portions of roofs are exempt from the requirements in Table C402.2.1.1:

1. Portions of roofs that include or are covered by:
  - 1.1. Photovoltaic systems or components.
  - 1.2. Solar air or water heating systems or components.
  - 1.3. Roof gardens or landscaped roofs.
  - 1.4. Above-roof decks or walkways.
  - 1.5. Skylights.
  - 1.6. HVAC systems, components, and other opaque objects mounted above the roof.

2. Portions of roofs shaded during the peak sun angle on the summer solstice by permanent features of the building, or by permanent features of adjacent buildings.
3. Portions of roofs that are ballasted with a minimum stone ballast of 17 pounds per square foot (psf) (74 kg/m<sup>2</sup>) or 23 psf (117 kg/m<sup>2</sup>) pavers.
4. Roofs where a minimum of 75 percent of the roof area meets a minimum of one of the exceptions above.

**TABLE C402.2.1.1  
MINIMUM ROOF REFLECTANCE AND EMITTANCE OPTIONS<sup>a</sup>**

Three-year aged solar reflectance <sup>b</sup> of 0.55 and three-year aged thermal emittance <sup>c</sup> of 0.75
Initial solar reflectance <sup>b</sup> of 0.70 and initial thermal emittance <sup>c</sup> of 0.75
Three-year-aged solar reflectance index <sup>d</sup> of 64
Initial solar reflectance index <sup>d</sup> of 82

- a. The use of area-weighted averages to meet these requirements shall be permitted. Materials lacking initial tested values for either solar reflectance or thermal emittance, shall be assigned both an initial solar reflectance of 0.10 and an initial thermal emittance of 0.90. Materials lacking three-year aged tested values for either solar reflectance or thermal emittance shall be assigned both a three-year aged solar reflectance of 0.10 and a three-year aged thermal emittance of 0.90.
- b. Solar reflectance tested in accordance with ASTM C 1549, ASTM E 903 or ASTM E 1918.
- c. Thermal emittance tested in accordance with ASTM C 1371 or ASTM E 408.
- d. Solar reflectance index (SRI) shall be determined in accordance with ASTM E 1980 using a convection coefficient of 2.1 Btu/h × ft<sup>2</sup> × °F (12W/m<sup>2</sup> × K). Calculation of aged SRI shall be based on aged tested values of solar reflectance and thermal emittance. Calculation of initial SRI shall be based on initial tested values of solar reflectance and thermal emittance.

**C402.2.2 Classification of walls.** Walls associated with the building envelope shall be classified in accordance with Section C402.2.2.1 or C402.2.2.2.

**C402.2.2.1 Above-grade walls.** Above-grade walls are those walls covered by Section C402.2.3 on the exterior of the building and completely above grade or walls that are more than 15 percent above grade.

**C402.2.2.2 Below-grade walls.** Below-grade walls covered by Section C402.2.4 are basement or first-story walls associated with the exterior of the building that are at least 85 percent below grade.

**C402.2.3 Thermal resistance of above-grade walls.** The minimum thermal resistance (*R*-value) of the insulating materials installed in the wall cavity between the framing members and continuously on the walls shall be as specified in Table C402.2, based on framing type and construction materials used in the wall assembly. The *R*-value of integral insulation installed in concrete masonry units (CMU) shall not be used in determining compliance with Table C402.2.

“Mass walls” shall include walls weighing not less than:

1. 35 psf (170 kg/m<sup>2</sup>) of wall surface area; or

2. 25 psf (120 kg/m<sup>2</sup>) of wall surface area if the material weight is not more than 120 pounds per cubic foot (pcf) (1900 kg/m<sup>3</sup>).

**C402.2.4 Thermal resistance of below-grade walls.** The minimum thermal resistance (*R*-value) of the insulating material installed in, or continuously on, the below-grade walls shall be as specified in Table C402.2, and shall extend to a depth of 10 feet (3048 mm) below the outside finished ground level, or to the level of the floor, whichever is less.

**C402.2.5 Floors over outdoor air or unconditioned space.** The minimum thermal resistance (*R*-value) of the insulating material installed either between the floor framing or continuously on the floor assembly shall be as specified in Table C402.2, based on construction materials used in the floor assembly.

“Mass floors” shall include floors weighing not less than:

1. 35 psf (170 kg/m<sup>2</sup>) of floor surface area; or
2. 25 psf (120 kg/m<sup>2</sup>) of floor surface area if the material weight is not more than 120 pcf (1,900 kg/m<sup>3</sup>).

**C402.2.6 Slabs on grade.** Where the slab on grade is in contact with the ground, the minimum thermal resistance (*R*-value) of the insulation around the perimeter of unheated or heated slab-on-grade floors shall be as specified in Table C402.2. The insulation shall be placed on the outside of the foundation or on the inside of the foundation wall. The insulation shall extend downward from the top of the slab for a minimum distance as shown in the table or to the top of the footing, whichever is less, or downward to at least the bottom of the slab and then horizontally to the interior or exterior for the total distance shown in the table. Insulation extending away from the building shall be protected by pavement or by a minimum of 10 inches (254 mm) of soil.

**Exception:** Where the slab-on-grade floor is greater than 24 inches (61 mm) below the finished exterior grade, perimeter insulation is not required.

**C402.2.7 Opaque doors.** Opaque doors (doors having less than 50 percent glass area) shall meet the applicable requirements for doors as specified in Table C402.2 and be considered as part of the gross area of above-grade walls that are part of the building envelope.

**C402.2.8 Insulation of radiant heating systems.** Radiant panels, and associated U-bends and headers, designed for sensible heating of an indoor space through heat transfer from the thermally effective panel surfaces to the occupants or indoor space by thermal radiation and natural convection and the bottom surfaces of floor structures incorporating radiant heating shall be insulated with a minimum of R-3.5 (0.62 m<sup>2</sup>/K × W).

TABLE C402.1.2  
OPAQUE THERMAL ENVELOPE ASSEMBLY REQUIREMENTS<sup>a</sup>

CLIMATE ZONE	1		2		3		4 EXCEPT MARINE		5 AND MARINE 4		6		7		8	
	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R	All other	Group R
<b>Roofs</b>																
Insulation entirely above deck	U-0.048	U-0.048	U-0.048	U-0.048	U-0.048	U-0.048	U-0.039	U-0.039	U-0.039	U-0.039	U-0.032	U-0.032	U-0.028	U-0.028	U-0.028	U-0.028
Metal buildings	U-0.044	U-0.035	U-0.035	U-0.035	U-0.035	U-0.035	U-0.035	U-0.035	U-0.035	U-0.031	U-0.031	U-0.029	U-0.029	U-0.029	U-0.029	U-0.029
Attic and other	U-0.027	U-0.027	U-0.027	U-0.027	U-0.027	U-0.027	U-0.027	U-0.027	U-0.027	U-0.021	U-0.021	U-0.021	U-0.021	U-0.021	U-0.021	U-0.021
<b>Walls, Above Grade</b>																
Mass	U-0.142	U-0.142	U-0.123	U-0.142	U-0.110	U-0.104	U-0.090	U-0.078	U-0.078	U-0.078	U-0.071	U-0.061	U-0.061	U-0.061	U-0.061	U-0.061
Metal building	U-0.079	U-0.079	U-0.079	U-0.079	U-0.079	U-0.052	U-0.052	U-0.052	U-0.052	U-0.052	U-0.052	U-0.039	U-0.039	U-0.039	U-0.039	U-0.039
Metal framed	U-0.077	U-0.077	U-0.064	U-0.077	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.057	U-0.064	U-0.052	U-0.052	U-0.045	U-0.045
Wood framed and other	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.064	U-0.051	U-0.051	U-0.051	U-0.051	U-0.051	U-0.036	U-0.036
<b>Walls, Below Grade</b>																
Below-grade wall <sup>b</sup>	C-1.140	C-1.140	C-1.140	C-1.140	C-1.140	C-1.140	C-0.119	C-0.119	C-0.119	C-0.119	C-0.119	C-0.092	C-0.092	C-0.092	C-0.092	C-0.092
<b>Floors</b>																
Mass	U-0.322	U-0.107	U-0.087	U-0.107	U-0.076	U-0.076	U-0.074	U-0.074	U-0.074	U-0.064	U-0.057	U-0.055	U-0.051	U-0.051	U-0.055	U-0.051
Joist/framing	U-0.066	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033	U-0.033
<b>Slab-on-Grade Floors</b>																
Unheated slabs	F-0.73	F-0.73	F-0.73	F-0.73	F-0.73	F-0.73	F-0.54	F-0.54	F-0.54	F-0.54	F-0.52	F-0.40	F-0.40	F-0.40	F-0.40	F-0.40
Heated slabs	F-0.70	F-0.70	F-0.70	F-0.70	F-0.70	F-0.70	F-0.65	F-0.65	F-0.58	F-0.58	F-0.58	F-0.55	F-0.55	F-0.55	F-0.55	F-0.55

a. Use of opaque assembly *U*-factors, *C*-factors, and *F*-factors from ANSI/ASHRAE/IESNA 90.1 Appendix A shall be permitted, provided the construction complies with the applicable construction details from ANSI/ASHRAE/IESNA 90.1 Appendix A.

b. Where heated slabs are below grade, below-grade walls shall comply with the *F*-factor requirements for heated slabs.

TABLE C402.2  
OPAQUE THERMAL ENVELOPE REQUIREMENTS<sup>a</sup>

CLIMATE ZONE	1		2		3		4 EXCEPT MARINE		5 AND MARINE 4		6		7		8	
	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R	All Other	Group R
<b>Roofs</b>																
Insulation entirely above deck	R-20ci	R-20ci	R-20ci	R-20ci	R-20ci	R-20ci	R-25ci	R-25ci	R-25ci	R-30ci	R-35ci	R-35ci	R-35ci	R-35ci	R-35ci	R-35ci
Metal buildings (with R-5 thermal blocks) <sup>a,b</sup>	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-19 + R-11 LS	R-25 + R-11 LS	R-30 + R-11 LS	R-30 + R-11 LS	R-30 + R-11 LS	R-30 + R-11 LS	R-30 + R-11 LS	R-30 + R-11 LS
Attic and other	R-38	R-38	R-38	R-38	R-38	R-38	R-38	R-38	R-38	R-49	R-49	R-49	R-49	R-49	R-49	R-49
<b>Walls, Above Grade</b>																
Mass <sup>c</sup>	R-5.7ci <sup>e</sup>	R-5.7ci <sup>e</sup>	R-7.6ci	R-7.6ci	R-9.5ci	R-11.4ci	R-13.3ci	R-13.3ci	R-13.3ci	R-13.3ci	R-13.3ci	R-13.3ci	R-13.3ci	R-13.3ci	R-13.3ci	R-13.3ci
Metal building	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-6.5ci	R-13 + R-6.5ci
Metal framed	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci	R-13 + R-5ci
Wood framed and other	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20	R-13 + R-3.8ci or R-20
Below-grade wall <sup>d</sup>	NR	NR	NR	NR	NR	NR	R-7.5ci	R-7.5ci	R-7.5ci	R-7.5ci	R-7.5ci	R-7.5ci	R-7.5ci	R-7.5ci	R-7.5ci	R-7.5ci
<b>Floors</b>																
Mass	NR	NR	R-8.3ci	R-10ci	R-10ci	R-10.4ci	R-10ci	R-10ci	R-10ci	R-12.5ci	R-15ci	R-15ci	R-15ci	R-15ci	R-15ci	R-15ci
Joist/framing	NR	NR	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30
<b>Slab-on-Grade Floors</b>																
Unheated slabs	NR	NR	NR	NR	NR	NR	R-10 for 24" below	R-10 for 24" below	R-10 for 24" below	R-10 for 24" below	R-10 for 24" below	R-10 for 24" below	R-10 for 24" below	R-10 for 24" below	R-10 for 24" below	R-10 for 24" below
Heated slabs <sup>d</sup>	R-7.5 for 12" below	R-7.5 for 12" below	R-7.5 for 12" below	R-7.5 for 12" below	R-10 for 24" below	R-15 for 24" below	R-15 for 24" below	R-15 for 24" below	R-15 for 24" below	R-15 for 36" below	R-15 for 36" below	R-15 for 36" below	R-15 for 36" below	R-15 for 36" below	R-15 for 36" below	R-15 for 36" below
Swinging	U-0.61	U-0.61	U-0.61	U-0.61	U-0.61	U-0.61	U-0.61	U-0.61	U-0.61	U-0.37	U-0.37	U-0.37	U-0.37	U-0.37	U-0.37	U-0.37
Roll-up or sliding	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75	R-4.75

For SI: 1 inch = 25.4 mm. ci = Continuous insulation. NR = No requirement.

- a. LS = Liner System—A continuous membrane installed below the purlins and uninterrupted by framing members. Uncompressed, unfaced insulation rests on top of the membrane between the purlins. Assembly descriptions can be found in ANSI/ASHRAE/IESNA Appendix A.
- b. Where using R-value compliance method, a thermal spacer block shall be provided, otherwise use the U-factor compliance method in Table C402.1.2.
- c. R-5.7ci is allowed to be substituted with concrete block walls complying with ASTM C 90, ungrouted or partially grouted at 32 inches or less on center vertically and 48 inches or less on center horizontally, with ungrouted cores filled with materials having a maximum thermal conductivity of 0.44 Btu-in/h·ft<sup>2</sup>·°F.
- d. Where heated slabs are below grade, below-grade walls shall comply with the exterior insulation requirements for heated slabs.
- e. Steel floor joist systems shall be insulated to R-38.

**C402.3 Fenestration (Prescriptive).** Fenestration shall comply with Table C402.3. Automatic daylighting controls specified by this section shall comply with Section C405.2.2.3.2.

**C402.3.1 Maximum area.** The vertical fenestration area (not including opaque doors and opaque spandrel panels) shall not exceed 30 percent of the gross above-grade wall area. The skylight area shall not exceed 3 percent of the gross roof area.

**C402.3.1.1 Increased vertical fenestration area with daylighting controls.** In Climate Zones 1 through 6, a maximum of 40 percent of the gross above-grade wall area shall be permitted to be vertical fenestration, provided:

1. No less than 50 percent of the conditioned floor area is within a daylight zone;
2. Automatic daylighting controls are installed in daylight zones; and
3. Visible transmittance (VT) of vertical fenestration is greater than or equal to 1.1 times solar heat gain coefficient (SHGC).

**Exception:** Fenestration that is outside the scope of NFRC 200 is not required to comply with Item 3.

**C402.3.1.2 Increased skylight area with daylighting controls.** The skylight area shall be permitted to be a maximum of 5 percent of the roof area provided automatic daylighting controls are installed in daylight zones under skylights.

**C402.3.2 Minimum skylight fenestration area.** In an enclosed space greater than 10,000 square feet (929 m<sup>2</sup>), directly under a roof with ceiling heights greater than 15 feet (4572 mm), and used as an office, lobby, atrium, concourse, corridor, storage, gymnasium/exercise center, convention center, automotive service, manufacturing, non-refrigerated warehouse, retail store, distribution/sorting area, transportation, or workshop, the total daylight zone under skylights shall be not less than half the floor area

and shall provide a minimum skylight area to daylight zone under skylights of either:

1. Not less than 3 percent with a skylight VT of at least 0.40; or
2. Provide a minimum skylight effective aperture of at least 1 percent determined in accordance with Equation C4-1.

$$\text{Skylight Effective Aperture} = \frac{0.85 \times \text{Skylight Area} \times \text{Skylight VT} \times \text{WF}}{\text{Daylight zone under skylight}}$$

(Equation C4-1)

where:

- Skylight area = Total fenestration area of skylights.
- Skylight VT = Area weighted average visible transmittance of skylights.
- WF = Area weighted average well factor, where well factor is 0.9 if light well depth is less than 2 feet (610 mm), or 0.7 if light well depth is 2 feet (610 mm) or greater.

Light well depth = Measure vertically from the underside of the lowest point of the skylight glazing to the ceiling plane under the skylight.

**Exception:** Skylights above daylight zones of enclosed spaces are not required in:

1. Buildings in climate zones 6 through 8.
2. Spaces where the designed *general lighting* power densities are less than 0.5 W/ft<sup>2</sup> (5.4 W/m<sup>2</sup>).
3. Areas where it is documented that existing structures or natural objects block direct beam sunlight on at least half of the roof over the enclosed

**TABLE C402.3  
BUILDING ENVELOPE REQUIREMENTS: FENESTRATION**

CLIMATE ZONE	1	2	3	4 EXCEPT MARINE	5 AND MARINE 4	6	7	8
<b>Vertical fenestration</b>								
<b>U-factor</b>								
Fixed fenestration	0.50	0.50	0.46	0.38	0.38	0.36	0.29	0.29
Operable fenestration	0.65	0.65	0.60	0.45	0.45	0.43	0.37	0.37
Entrance doors	1.10	0.83	0.77	0.77	0.77	0.77	0.77	0.77
<b>SHGC</b>								
SHGC	0.25	0.25	0.25	0.40	0.40	0.40	0.45	0.45
<b>Skylights</b>								
<b>U-factor</b>	0.75	0.65	0.55	0.50	0.50	0.50	0.50	0.50
<b>SHGC</b>	0.35	0.35	0.35	0.40	0.40	0.40	NR	NR

NR = No requirement.

area for more than 1,500 daytime hours per year between 8 am and 4 pm.

4. Spaces where the daylight zone under rooftop monitors is greater than 50 percent of the enclosed space floor area.

**C402.3.2.1 Lighting controls in daylight zones under skylights.** All lighting in the daylight zone shall be controlled by multilevel lighting controls that comply with Section C405.2.2.3.3.

**Exception:** Skylights above daylight zones of enclosed spaces are not required in:

1. Buildings in Climate Zones 6 through 8.
2. Spaces where the designed *general lighting* power densities are less than 0.5 W/ft<sup>2</sup> (5.4 W/m<sup>2</sup>).
3. Areas where it is documented that existing structures or natural objects block direct beam sunlight on at least half of the roof over the enclosed area for more than 1,500 daytime hours per year between 8 am and 4 pm.
4. Spaces where the daylight zone under rooftop monitors is greater than 50 percent of the enclosed space floor area.

**C402.3.2.2 Haze factor.** Skylights in office, storage, automotive service, manufacturing, nonrefrigerated warehouse, retail store, and distribution/sorting area spaces shall have a glazing material or diffuser with a measured haze factor greater than 90 percent when tested in accordance with ASTM D 1003.

**Exception:** Skylights designed to exclude direct sunlight entering the occupied space by the use of fixed or automated baffles, or the geometry of skylight and light well need not comply with Section C402.3.2.2.

**C402.3.3 Maximum U-factor and SHGC.** For vertical fenestration, the maximum U-factor and solar heat gain coefficient (SHGC) shall be as specified in Table C402.3, based on the window projection factor. For skylights, the maximum U-factor and solar heat gain coefficient (SHGC) shall be as specified in Table C402.3.

The window projection factor shall be determined in accordance with Equation C4-2.

$$PF = A/B \quad \text{(Equation C4-2)}$$

where:

PF = Projection factor (decimal).

A = Distance measured horizontally from the furthest continuous extremity of any overhang, eave, or permanently attached shading device to the vertical surface of the glazing.

B = Distance measured vertically from the bottom of the glazing to the underside of the overhang, eave, or permanently attached shading device.

Where different windows or glass doors have different PF values, they shall each be evaluated separately.

**C402.3.3.1 SHGC adjustment.** Where the fenestration projection factor for a specific vertical fenestration product is greater than or equal to 0.2, the required maximum SHGC from Table C402.3 shall be adjusted by multiplying the required maximum SHGC by the multiplier specified in Table C402.3.3.1 corresponding with the orientation of the fenestration product and the projection factor.

**TABLE C402.3.3.1  
SHGC ADJUSTMENT MULTIPLIERS**

PROJECTION FACTOR	ORIENTED WITHIN 45 DEGREES OF TRUE NORTH	ALL OTHER ORIENTATION
0.2 ≤ PF < 0.5	1.1	1.2
PF ≥ 0.5	1.2	1.6

**C402.3.3.2 Increased vertical fenestration SHGC.** In Climate Zones 1, 2 and 3, vertical fenestration entirely located not less than 6 feet (1729 mm) above the finished floor shall be permitted a maximum SHGC of 0.40.

**C402.3.3.3 Increased skylight SHGC.** In Climate Zones 1 through 6, skylights shall be permitted a maximum SHGC of 0.60 where located above daylight zones provided with automated daylighting controls.

**C402.3.3.4 Increased skylight U-factor.** Where skylights are installed above daylight zones provided with automatic daylighting controls, a maximum U-factor of 0.9 shall be permitted in Climate Zones 1 through 3; and a maximum U-factor of 0.75 shall be permitted in Climate Zones 4 through 8.

**C402.3.3.5 Dynamic glazing.** For compliance with Section C402.3.3, the SHGC for dynamic glazing shall be determined using the manufacturer's lowest-rated SHGC, and the VT/SHGC ratio shall be determined using the maximum VT and maximum SHGC. Dynamic glazing shall be considered separately from other fenestration, and area-weighted averaging with other fenestration that is not dynamic glazing shall not be permitted.

**C402.3.4 Area-weighted U-factor.** An area-weighted average shall be permitted to satisfy the U-factor requirements for each fenestration product category listed in Table C402.3. Individual fenestration products from different fenestration product categories listed in Table C402.3 shall not be combined in calculating area-weighted average U-factor.

**C402.4 Air leakage (Mandatory).** The thermal envelope of buildings shall comply with Sections C402.4.1 through C402.4.8.

**C402.4.1 Air barriers.** A continuous air barrier shall be provided throughout the building thermal envelope. The air barriers shall be permitted to be located on the inside or outside of the building envelope, located within the assemblies composing the envelope, or any combination thereof. The air barrier shall comply with Sections C402.4.1.1 and C402.4.1.2.

**Exception:** Air barriers are not required in buildings located in Climate Zones 1, 2 and 3.

\*

**C402.4.1.1 Air barrier construction.** The *continuous air barrier* shall be constructed to comply with the following:

1. The air barrier shall be continuous for all assemblies that are the thermal envelope of the building and across the joints and assemblies.
2. Air barrier joints and seams shall be sealed, including sealing transitions in places and changes in materials. Air barrier penetrations shall be sealed in accordance with Section C402.4.2. The joints and seals shall be securely installed in or on the joint for its entire length so as not to dislodge, loosen or otherwise impair its ability to resist positive and negative pressure from wind, stack effect and mechanical ventilation.
3. Recessed lighting fixtures shall comply with Section C402.4.8. Where similar objects are installed which penetrate the air barrier, provisions shall be made to maintain the integrity of the air barrier.

**Exception:** Buildings that comply with Section C402.4.1.2.3 are not required to comply with Items 1 and 3.

**C402.4.1.2 Air barrier compliance options.** A continuous air barrier for the opaque building envelope shall comply with Section C402.4.1.2.1, C402.4.1.2.2, or C402.4.1.2.3.

**C402.4.1.2.1 Materials.** Materials with an air permeability no greater than 0.004 cfm/ft<sup>2</sup> (0.02 L/s · m<sup>2</sup>) under a pressure differential of 0.3 inches water gauge (w.g.) (75 Pa) when tested in accordance with ASTM E 2178 shall comply with this section. Materials in Items 1 through 15 shall be deemed to comply with this section provided joints are sealed and materials are installed as air barriers in accordance with the manufacturer's instructions.

1. Plywood with a thickness of not less than <sup>3</sup>/<sub>8</sub> inch (10 mm).
2. Oriented strand board having a thickness of not less than <sup>3</sup>/<sub>8</sub> inch (10 mm).
3. Extruded polystyrene insulation board having a thickness of not less than <sup>1</sup>/<sub>2</sub> inch (12 mm).
4. Foil-back polyisocyanurate insulation board having a thickness of not less than <sup>1</sup>/<sub>2</sub> inch (12 mm).
5. Closed cell spray foam a minimum density of 1.5 pcf (2.4 kg/m<sup>3</sup>) having a thickness of not less than 1<sup>1</sup>/<sub>2</sub> inches (36 mm).
6. Open cell spray foam with a density between 0.4 and 1.5 pcf (0.6 and 2.4 kg/m<sup>3</sup>) and having a thickness of not less than 4.5 inches (113 mm).
7. Exterior or interior gypsum board having a thickness of not less than <sup>1</sup>/<sub>2</sub> inch (12 mm).

8. Cement board having a thickness of not less than <sup>1</sup>/<sub>2</sub> inch (12 mm).
9. Built up roofing membrane.
10. Modified bituminous roof membrane.
11. Fully adhered single-ply roof membrane.
12. A Portland cement/sand parge, or gypsum plaster having a thickness of not less than <sup>5</sup>/<sub>8</sub> inch (16 mm).
13. Cast-in-place and precast concrete.
14. Fully grouted concrete block masonry.
15. Sheet steel or aluminum.

**C402.4.1.2.2 Assemblies.** Assemblies of materials and components with an average air leakage not to exceed 0.04 cfm/ft<sup>2</sup> (0.2 L/s · m<sup>2</sup>) under a pressure differential of 0.3 inches of water gauge (w.g.) (75 Pa) when tested in accordance with ASTM E 2357, ASTM E 1677 or ASTM E 283 shall comply with this section. Assemblies listed in Items 1 and 2 shall be deemed to comply provided joints are sealed and requirements of Section C402.4.1.1 are met.

1. Concrete masonry walls coated with one application either of block filler and two applications of a paint or sealer coating;
2. A Portland cement/sand parge, stucco or plaster minimum <sup>1</sup>/<sub>2</sub> inch (12 mm) in thickness.

**C402.4.1.2.3 Building test.** The completed building shall be tested and the air leakage rate of the *building envelope* shall not exceed 0.40 cfm/ft<sup>2</sup> at a pressure differential of 0.3 inches water gauge (2.0 L/s · m<sup>2</sup> at 75 Pa) in accordance with ASTM E 779 or an equivalent method approved by the code official.

**C402.4.2 Air barrier penetrations.** Penetrations of the air barrier and paths of air leakage shall be caulked, gasketed or otherwise sealed in a manner compatible with the construction materials and location. Joints and seals shall be sealed in the same manner or taped or covered with a moisture vapor-permeable wrapping material. Sealing materials shall be appropriate to the construction materials being sealed. The joints and seals shall be securely installed in or on the joint for its entire length so as not to dislodge, loosen or otherwise impair its ability to resist positive and negative pressure from wind, stack effect and mechanical ventilation.

**C402.4.3 Air leakage of fenestration.** The air leakage of fenestration assemblies shall meet the provisions of Table C402.4.3. Testing shall be in accordance with the applicable reference test standard in Table C402.4.3 by an accredited, independent testing laboratory and *labeled* by the manufacturer.

**Exceptions:**

1. Field-fabricated fenestration assemblies that are sealed in accordance with Section C402.4.1.
2. Fenestration in buildings that comply with Section C402.4.1.2.3 are not required to meet the air leakage requirements in Table C402.4.3.

**TABLE C402.4.3  
MAXIMUM AIR INFILTRATION RATE  
FOR FENESTRATION ASSEMBLIES**

FENESTRATION ASSEMBLY	MAXIMUM RATE (CFM/FT <sup>2</sup> )	TEST PROCEDURE
Windows	0.20 <sup>a</sup>	AAMA/WDMA/ CSA101/I.S.2/A440 or NFRC 400
Sliding doors	0.20 <sup>a</sup>	
Swinging doors	0.20 <sup>a</sup>	
Skylights – with condensation weepage openings	0.30	
Skylights – all other	0.20 <sup>a</sup>	
Curtain walls	0.06	NFRC 400 or ASTM E 283 at 1.57 psf (75 Pa)
Storefront glazing	0.06	
Commercial glazed swinging entrance doors	1.00	
Revolving doors	1.00	ANSI/DASMA 105, NFRC 400, or ASTM E 283 at 1.57 psf (75 Pa)
Garage doors	0.40	
Rolling doors	1.00	

For SI: 1 cubic foot per minute = 0.47L/s, 1 square foot = 0.093 m<sup>2</sup>.

a. The maximum rate for windows, sliding and swinging doors, and skylights is permitted to be 0.3 cfm per square foot of fenestration or door area when tested in accordance with AAMA/WDMA/CSA101/I.S.2/A440 at 6.24 psf (300 Pa).

**C402.4.4 Doors and access openings to shafts, chutes, stairways, and elevator lobbies.** Doors and access openings from conditioned space to shafts, chutes stairways and elevator lobbies shall either meet the requirements of Section C402.4.3 or shall be gasketed, weatherstripped or sealed.

**Exception:** Door openings required to comply with Section 716 or 716.4 of the *International Building Code*; or doors and door openings required by the *International Building Code* to comply with UL 1784 shall not be required to comply with Section C402.4.4.

**C402.4.5 Air intakes, exhaust openings, stairways and shafts.** Stairway enclosures and elevator shaft vents and other outdoor air intakes and exhaust openings integral to the building envelope shall be provided with dampers in accordance with Sections C402.4.5.1 and C402.4.5.2.

**C402.4.5.1 Stairway and shaft vents.** Stairway and shaft vents shall be provided with Class I motorized dampers with a maximum leakage rate of 4 cfm/ft<sup>2</sup> (20.3 L/s · m<sup>2</sup>) at 1.0 inch water gauge (w.g.) (249 Pa) when tested in accordance with AMCA 500D.

Stairway and shaft vent dampers shall be installed with controls so that they are capable of automatically opening upon:

1. The activation of any fire alarm initiating device of the building's fire alarm system; or
2. The interruption of power to the damper.

**C402.4.5.2 Outdoor air intakes and exhausts.** *Outdoor air* supply and exhaust openings shall be provided with Class IA motorized dampers with a maximum

leakage rate of 4 cfm/ft<sup>2</sup> (20.3 L/s · m<sup>2</sup>) at 1.0 inch water gauge (w.g.) (249 Pa) when tested in accordance with AMCA 500D.

**Exceptions:**

1. Gravity (nonmotorized) dampers having a maximum leakage rate of 20 cfm/ft<sup>2</sup> (101.6 L/s · m<sup>2</sup>) at 1.0 inch water gauge (w.g.) (249 Pa) when tested in accordance with AMCA 500D are permitted to be used as follows:
  - 1.1. In buildings for exhaust and relief dampers.
  - 1.2. In buildings less than three stories in height above grade.
  - 1.3. For ventilation air intakes and exhaust and relief dampers in buildings of any height located in Climate Zones 1, 2 and 3.
  - 1.4. Where the design *outdoor air* intake or exhaust capacity does not exceed 300 cfm (141 L/s).

Gravity (nonmotorized) dampers for ventilation air intakes shall be protected from direct exposure to wind.

2. Dampers smaller than 24 inches (610 mm) in either dimension shall be permitted to have a leakage of 40 cfm/ft<sup>2</sup> (203.2 L/s · m<sup>2</sup>) at 1.0 inch water gauge (w.g.) (249 Pa) when tested in accordance with AMCA 500D.

**C402.4.6 Loading dock weatherseals.** Cargo doors and loading dock doors shall be equipped with weatherseals to restrict infiltration when vehicles are parked in the doorway.

**C402.4.7 Vestibules.** All building entrances shall be protected with an enclosed vestibule, with all doors opening into and out of the vestibule equipped with self-closing devices. Vestibules shall be designed so that in passing through the vestibule it is not necessary for the interior and exterior doors to open at the same time. The installation of one or more revolving doors in the building entrance shall not eliminate the requirement that a vestibule be provided on any doors adjacent to revolving doors.

**Exceptions:**

1. Buildings in Climate Zones 1 and 2.
2. Doors not intended to be used by the public, such as doors to mechanical or electrical equipment rooms, or intended solely for employee use.
3. Doors opening directly from a *sleeping unit* or dwelling unit.
4. Doors that open directly from a space less than 3,000 square feet (298 m<sup>2</sup>) in area.
5. Revolving doors.



- Doors used primarily to facilitate vehicular movement or material handling and adjacent personnel doors.

**C402.4.8 Recessed lighting.** Recessed luminaires installed in the *building thermal envelope* shall be sealed to limit air leakage between conditioned and unconditioned spaces. All recessed luminaires shall be IC-rated and *labeled* as having an air leakage rate of not more than 2.0 cfm (0.944 L/s) when tested in accordance with ASTM E 283 at a 1.57 psf (75 Pa) pressure differential. All recessed luminaires shall be sealed with a gasket or caulk between the housing and interior wall or ceiling covering.

### SECTION C403 BUILDING MECHANICAL SYSTEMS

**C403.1 General.** Mechanical systems and equipment serving the building heating, cooling or ventilating needs shall comply with Section C403.2 (referred to as the mandatory provisions) and either:

- Section C403.3 (Simple systems); or
- Section C403.4 (Complex systems).

**C403.2 Provisions applicable to all mechanical systems (Mandatory).** Mechanical systems and equipment serving the building heating, cooling or ventilating needs shall comply with Sections C403.2.1 through C403.2.11.

**C403.2.1 Calculation of heating and cooling loads.** Design loads shall be determined in accordance with the procedures described in ANSI/ASHRAE/ACCA Standard 183. The design loads shall account for the building envelope, lighting, ventilation and occupancy loads based on the project design. Heating and cooling loads shall be adjusted to account for load reductions that are achieved where energy recovery systems are utilized in the HVAC system in accordance with the ASHRAE *HVAC Systems and Equipment Handbook*. Alternatively, design loads shall be determined by an *approved* equivalent computation procedure, using the design parameters specified in Chapter 3.

**C403.2.2 Equipment and system sizing.** The output capacity of heating and cooling equipment and systems shall not exceed the loads calculated in accordance with Section C403.2.1. A single piece of equipment providing both heating and cooling shall satisfy this provision for one function with the capacity for the other function as small as possible, within available equipment options.

**Exceptions:**

- Required standby equipment and systems provided with controls and devices that allow such systems or equipment to operate automatically only when the primary equipment is not operating.
- Multiple units of the same equipment type with combined capacities exceeding the design load and provided with controls that have the capability to sequence the operation of each unit based on load.

**C403.2.3 HVAC equipment performance requirements.** Equipment shall meet the minimum efficiency requirements

of Tables C403.2.3(1), C403.2.3(2), C403.2.3(3), C403.2.3(4), C403.2.3(5), C403.2.3(6), C403.2.3(7) and C403.2.3(8) when tested and rated in accordance with the applicable test procedure. Plate-type liquid-to-liquid heat exchangers shall meet the minimum requirements of Table C403.2.3(9). The efficiency shall be verified through certification under an *approved* certification program or, if no certification program exists, the equipment efficiency ratings shall be supported by data furnished by the manufacturer. Where multiple rating conditions or performance requirements are provided, the equipment shall satisfy all stated requirements. Where components, such as indoor or outdoor coils, from different manufacturers are used, calculations and supporting data shall be furnished by the designer that demonstrates that the combined efficiency of the specified components meets the requirements herein.

**C403.2.3.1 Water-cooled centrifugal chilling packages.** Equipment not designed for operation at AHRI Standard 550/590 test conditions of 44°F (7°C) leaving chilled-water temperature and 85°F (29°C) entering condenser water temperature with 3 gpm/ton (0.054 l/s · kW) condenser water flow shall have maximum full-load kW/ton and *NPLV* ratings adjusted using Equations C4-3 and C4-4.

$$\text{Adjusted minimum full-load COP ratings} = (\text{Full-load COP from Table 6.8.1C of AHRI Standard 550/590}) \times K_{adj} \quad \text{(Equation C4-3)}$$

$$\text{Adjusted minimum NPLV rating} = (\text{IPLV from Table 6.8.1C of AHRI Standard 550/590}) \times K_{adj} \quad \text{(Equation C4-4)}$$

where:

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

$$A = 0.0000015318 \times (\text{LIFT})^4 - 0.000202076 \times (\text{LIFT})^3 + 0.0101800 \times (\text{LIFT})^2 - 0.264958 \times \text{LIFT} + 3.930196$$

$$B = 0.0027 \times L_{vg}^{\text{Evap}} (\text{°C}) + 0.982$$

$$\text{LIFT} = L_{vg}^{\text{Cond}} - L_{vg}^{\text{Evap}}$$

$$L_{vg}^{\text{Cond}} = \text{Full-load condenser leaving water temperature (°C)}$$

$$L_{vg}^{\text{Evap}} = \text{Full-load leaving evaporator temperature (°C)}$$

SI units shall be used in the  $K_{adj}$  equation.

The adjusted full-load and *NPLV* values shall only be applicable for centrifugal chillers meeting all of the following full-load design ranges:

- The leaving evaporator fluid temperature is not less than 36°F (2.2°C).
- The leaving condenser fluid temperature is not greater than 115°F (46.1°C).
- LIFT is not less than 20°F (11.1 °C) and not greater than 80°F (44.4°C).

**Exception:** Centrifugal chillers designed to operate outside of these ranges need not comply with this code.

**TABLE C403.2.3(1)**  
**MINIMUM EFFICIENCY REQUIREMENTS:**  
**ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS**

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE <sup>a</sup>		
				Before 6/1/2011	As of 6/1/2011			
Air conditioners, air cooled	< 65,000 Btu/h <sup>b</sup>	All	Split System	13.0 SEER	13.0 SEER	AHRI 210/240		
			Single Package	13.0 SEER	13.0 SEER			
Through-the-wall (air cooled)	≤ 30,000 Btu/h <sup>b</sup>	All	Split system	12.0 SEER	12.0 SEER			
			Single Package	12.0 SEER	12.0 SEER			
Small-duct high-velocity (air cooled)	< 65,000 Btu/h <sup>b</sup>	All	Split System	10.0 SEER	10.0 SEER			
Air conditioners, air cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.2 EER 11.4 IEER	11.2 EER 11.4 IEER		AHRI 340/360	
			All other	Split System and Single Package	11.0 EER 11.2 IEER	11.0 EER 11.2 IEER		
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)		Split System and Single Package	11.0 EER 11.2 IEER	11.0 EER 11.2 IEER		
			All other	Split System and Single Package	10.8 EER 11.0 IEER	10.8 EER 11.0 IEER		
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)		Split System and Single Package	10.0 EER 10.1 IEER	10.0 EER 10.1 IEER		
			All other	Split System and Single Package	9.8 EER 9.9 IEER	9.8 EER 9.9 IEER		
	≥ 760,000 Btu/h	Electric Resistance (or None)		Split System and Single Package	9.7 EER 9.8 IEER	9.7 EER 9.8 IEER		
			All other	Split System and Single Package	9.5 EER 9.6 IEER	9.5 EER 9.6 IEER		
	Air conditioners, water cooled	< 65,000 Btu/h <sup>b</sup>		All	Split System and Single Package	12.1 EER 12.3 IEER		12.1 EER 12.3 IEER
			≥ 65,000 Btu/h and < 135,000 Btu/h		Electric Resistance (or None)	Split System and Single Package		11.5 EER 11.7 IEER
All other		Split System and Single Package		11.3 EER 11.5 IEER		11.9 EER 12.1 IEER		
		≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	12.5 EER 12.7 IEER		
All other				Split System and Single Package	10.8 EER 11.0 IEER	12.3 EER 12.5 IEER		
		≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.1 IEER	12.4 EER 12.6 EER		
All other				Split System and Single Package	10.8 EER 10.9 IEER	12.2 EER 12.4 EER		
		≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.1 IEER	12.0 EER 12.4 EER		
All other				Split System and Single Package	10.8 EER 10.9 IEER	12.0 EER 12.2 EER		

*(continued)*

**TABLE C403.2.3(1)—continued  
MINIMUM EFFICIENCY REQUIREMENTS:  
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS**

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUB-CATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE <sup>a</sup>	
				Before 6/1/2011	As of 6/1/2011		
Air conditioners, evaporatively cooled	< 65,000 Btu/h <sup>b</sup>	All	Split System and Single Package	12.1 EER 12.3 IEER	12.1 EER 12.3 IEER	AHRI 210/240	
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.5 EER 11.7 IEER	12.1 EER 12.3 IEER	AHRI 340/360	
		All other	Split System and Single Package	11.3 EER 11.5 IEER	11.9 EER 12.1 IEER		
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	12.0 EER 12.2 IEER		
		All other	Split System and Single Package	10.8 EER 11.0 IEER	11.8 EER 12.0 IEER		
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.1 IEER	11.9 EER 12.1 IEER		
		All other	Split System and Single Package	10.8 EER 10.9 IEER	12.2 EER 11.9 IEER		
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.1 IEER	11.7 EER 11.9 IEER		
		All other	Split System and Single Package	10.8 EER 10.9 IEER	11.5 EER 11.7 IEER		
	Condensing units, air cooled	≥ 135,000 Btu/h			10.1 EER 11.4 IEER		10.5 EER 14.0 IEER
Condensing units, water cooled	≥ 135,000 Btu/h			13.1 EER 13.6 IEER	13.5 EER 14.0 IEER		
Condensing units, evaporatively cooled	≥ 135,000 Btu/h			13.1 EER 13.6 IEER	13.5 EER 14.0 IEER		

For SI: 1 British thermal unit per hour = 0.2931 W.

- a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.
- b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

**TABLE C403.2.3(2)**  
**MINIMUM EFFICIENCY REQUIREMENTS:**  
**ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS**

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE <sup>a</sup>
Air cooled (cooling mode)	< 65,000 Btu/h <sup>b</sup>	All	Split System	13.0 SEER	AHRI 210/240
			Single Packaged	13.0 SEER	
Through-the-wall, air cooled	≤ 30,000 Btu/h <sup>b</sup>	All	Split System	13.0 SEER	
			Single Packaged	13.0 SEER	
Single-duct high-velocity air cooled	< 65,000 Btu/h <sup>b</sup>	All	Split System	10.0 SEER	
Air cooled (cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	
		All other	Split System and Single Package	10.8 EER 11.0 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.6 EER 10.7 IEER	
		All other	Split System and Single Package	10.4 EER 10.5 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 9.6 IEER	
		All other	Split System and Single Package	9.3 EER 9.4 IEER	
Water source (cooling mode)	< 17,000 Btu/h	All	86°F entering water	11.2 EER	ISO 13256-1
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	12.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	12.0 EER	
Ground water source (cooling mode)	< 135,000 Btu/h	All	59°F entering water	16.2 EER	
		All	77°F entering water	13.4 EER	
Water-source water to water (cooling mode)	< 135,000 Btu/h	All	86°F entering water	10.6 EER	
			59°F entering water	16.3 EER	
Ground water source Brine to water (cooling mode)	< 135,000 Btu/h	All	77°F entering fluid	12.1 EER	
Air cooled (heating mode)	< 65,000 Btu/h <sup>b</sup>	—	Split System	7.7 HSPF	AHRI 210/240
		—	Single Package	7.7 HSPF	
Through-the-wall, (air cooled, heating mode)	≤ 30,000 Btu/h <sup>b</sup> (cooling capacity)	—	Split System	7.4 HSPF	
		—	Single Package	7.4 HSPF	
Small-duct high velocity (air cooled, heating mode)	< 65,000 Btu/h <sup>b</sup>	—	Split System	6.8 HSPF	

(continued)

**TABLE C403.2.3(2)—continued  
MINIMUM EFFICIENCY REQUIREMENTS:  
ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS**

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUB-CATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE <sup>a</sup>
Air cooled (heating mode)	≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb Outdoor Air	3.3 COP	AHRI 340/360
			17°F db/15°F wb Outdoor Air	2.25 COP	
	≥ 135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb Outdoor Air	3.2 COP	
			17°F db/15°F wb Outdoor Air	2.05 COP	
Water source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	4.2 COP	ISO 13256-1
Ground water source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering water	3.6 COP	
Ground source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	3.1 COP	
Water-source water to water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	3.7 COP	ISO 13256-2
		—	50°F entering water	3.1 COP	
Ground source brine to water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	2.5 COP	

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.

- a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.
- b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

**TABLE C403.2.3(3)**  
**MINIMUM EFFICIENCY REQUIREMENTS:**  
**ELECTRICALLY OPERATED PACKAGED TERMINAL AIR CONDITIONERS,**  
**PACKAGED TERMINAL HEAT PUMPS, SINGLE-PACKAGE VERTICAL AIR CONDITIONERS,**  
**SINGLE VERTICAL HEAT PUMPS, ROOM AIR CONDITIONERS AND ROOM AIR-CONDITIONER HEAT PUMPS**

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE <sup>a</sup>
			Before 10/08/2012	As of 10/08/2012	
PTAC (cooling mode) new construction	All Capacities	95°F db outdoor air	12.5 - (0.213 × Cap/1000) EER	13.8 - (0.300 × Cap/1000) EER	AHRI 310/380
PTAC (cooling mode) replacements <sup>b</sup>	All Capacities	95°F db outdoor air	10.9 - (0.213 × Cap/1000) EER	10.9 - (0.213 × Cap/1000) EER	
PTHP (cooling mode) new construction	All Capacities	95°F db outdoor air	12.3 - (0.213 × Cap/1000) EER	14.0 - (0.300 × Cap/1000) EER	
PTHP (cooling mode) replacements <sup>b</sup>	All Capacities	95°F db outdoor air	10.8 - (0.213 × Cap/1000) EER	10.8 - (0.213 × Cap/1000) EER	
PTHP (heating mode) new construction	All Capacities	—	3.2 - (0.026 × Cap/1000) COP	3.2 - (0.026 × Cap/1000) COP	
PTHP (heating mode) replacements <sup>b</sup>	All Capacities	—	2.9 - (0.026 × Cap/1000) COP	2.9 - (0.026 × Cap/1000) COP	
SPVAC (cooling mode)	< 65,000 Btu/h	95°F db/ 75°F wb outdoor air	9.0 EER	9.0 EER	AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h	95°F db/ 75°F wb outdoor air	8.9 EER	8.9 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95°F db/ 75°F wb outdoor air	8.6 EER	8.6 EER	
SPVHP (cooling mode)	< 65,000 Btu/h	95°F db/ 75°F wb outdoor air	9.0 EER	9.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	95°F db/ 75°F wb outdoor air	8.9 EER	8.9 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95°F db/ 75°F wb outdoor air	8.6 EER	8.6 EER	
SPVHP (heating mode)	<65,000 Btu/h	47°F db/ 43°F wb outdoor air	3.0 COP	3.0 COP	AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h	47°F db/ 43°F wb outdoor air	3.0 COP	3.0 COP	
	≥ 135,000 Btu/h and < 240,000 Btu/h	47°F db/ 75°F wb outdoor air	2.9 COP	2.9 COP	

*(continued)*

**TABLE C403.2.3(3)—continued  
MINIMUM EFFICIENCY REQUIREMENTS:  
ELECTRICALLY OPERATED PACKAGED TERMINAL AIR CONDITIONERS,  
PACKAGED TERMINAL HEAT PUMPS, SINGLE-PACKAGE VERTICAL AIR CONDITIONERS,  
SINGLE VERTICAL HEAT PUMPS, ROOM AIR CONDITIONERS AND ROOM AIR-CONDITIONER HEAT PUMPS**

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE <sup>a</sup>
			Before 10/08/2012	As of 10/08/2012	
Room air conditioners, with louvered slides	< 6,000 Btu/h	—	9.7 SEER	9.7 SEER	ANSI/AHA-MRAC-1
	≥ 6,000 Btu/h and < 8,000 Btu/h	—	9.7 EER	9.7 EER	
	≥ 8,000 Btu/h and < 14,000 Btu/h	—	9.8 EER	9.8 EER	
	≥ 14,000 Btu/h and < 20,000 Btu/h	—	9.7 SEER	9.7 SEER	
	≥ 20,000 Btu/h	—	8.5 EER	8.5 EER	
Room air conditioners, without louvered slides	< 8,000 Btu/h	—	9.0 EER	9.0 EER	
	≥ 8,000 Btu/h and < 20,000 Btu/h	—	8.5 EER	8.5 EER	
	≥ 20,000 Btu/h	—	8.5 EER	8.5 EER	
Room air-conditioner heat pumps with louvered sides	< 20,000 Btu/h	—	9.0 EER	9.0 EER	
	≥ 20,000 Btu/h	—	8.5 EER	8.5 EER	
Room air-conditioner heat pumps without louvered sides	< 14,000 Btu/h	—	8.5 EER	8.5 EER	
	≥ 14,000 Btu/h	—	8.0 EER	8.0 EER	
Room air conditioner casement only	All capacities	—	8.7 EER	8.7 EER	
Room air conditioner casement-slider	All capacities	—	9.5 EER	9.5 EER	

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.

“Cap” = The rated cooling capacity of the project in Btu/h. If the unit’s capacity is less than 7000 Btu/h, use 7000 Btu/h in the calculation. If the unit’s capacity is greater than 15,000 Btu/h, use 15,000 Btu/h in the calculations.

- a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
- b. Replacement unit shall be factory labeled as follows: “MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS.” Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406 mm) in height and less than 42 inches (1067 mm) in width.

**TABLE 403.2.3(4)**  
**WARM AIR FURNACES AND COMBINATION WARM AIR FURNACES/AIR-CONDITIONING UNITS,**  
**WARM AIR DUCT FURNACES AND UNIT HEATERS, MINIMUM EFFICIENCY REQUIREMENTS**

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY <sup>d,e</sup>	TEST PROCEDURE <sup>a</sup>
Warm air furnaces, gas fired	< 225,000 Btu/h	—	78% AFUE or 80% $E_t^c$	DOE 10 CFR Part 430 or ANSI Z21.47
	≥ 225,000 Btu/h	Maximum capacity <sup>c</sup>	80% $E_t^f$	ANSI Z21.47
Warm air furnaces, oil fired	< 225,000 Btu/h	—	78% AFUE or 80% $E_t^c$	DOE 10 CFR Part 430 or UL 727
	≥ 225,000 Btu/h	Maximum capacity <sup>b</sup>	81% $E_t^g$	UL 727
Warm air duct furnaces, gas fired	All capacities	Maximum capacity <sup>b</sup>	80% $E_c$	ANSI Z83.8
Warm air unit heaters, gas fired	All capacities	Maximum capacity <sup>b</sup>	80% $E_c$	ANSI Z83.8
Warm air unit heaters, oil fired	All capacities	Maximum capacity <sup>b</sup>	80% $E_c$	UL 731

- For SI: 1 British thermal unit per hour = 0.2931 W.
- a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
- b. Minimum and maximum ratings as provided for and allowed by the unit's controls.
- c. Combination units not covered by the National Appliance Energy Conservation Act of 1987 (NAECA) (3-phase power or cooling capacity greater than or equal to 65,000 Btu/h [19 kW]) shall comply with either rating.
- d.  $E_t$  = Thermal efficiency. See test procedure for detailed discussion.
- e.  $E_c$  = Combustion efficiency (100% less flue losses). See test procedure for detailed discussion.
- f.  $E_t$  = Combustion efficiency. Units must also include an IID, have jackets not exceeding 0.75 percent of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.
- g.  $E_t$  = Thermal efficiency. Units must also include an IID, have jacket losses not exceeding 0.75 percent of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.



**TABLE C403.2.3(5)**  
**MINIMUM EFFICIENCY REQUIREMENTS: GAS- AND OIL-FIRED BOILERS**

EQUIPMENT TYPE <sup>a</sup>	SUBCATEGORY OR RATING CONDITION	SIZE CATEGORY (INPUT)	MINIMUM EFFICIENCY	TEST PROCEDURE
Boilers, hot water	Gas-fired	< 300,000 Btu/h	80% AFUE	10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h <sup>b</sup>	80% $E_t$	10CFR Part 431
		> 2,500,00 Btu/h <sup>a</sup>	82% $E_c$	
	Oil-fired <sup>c</sup>	< 300,000 Btu/h	80% AFUE	10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h <sup>b</sup>	82% $E_t$	10 CFR Part 431
		> 2,500,000 Btu/h <sup>a</sup>	84% $E_c$	
Boilers, steam	Gas-fired	< 300,000 Btu/h	75% AFUE	10 CFR Part 430
	Gas-fired- all, except natural draft	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h <sup>b</sup>	79% $E_t$	10CFR Part 431
		> 2,500,000 Btu/h <sup>a</sup>	79% $E_t$	
	Gas-fired-natural draft	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h <sup>b</sup>	77% $E_t$	
		> 2,500,000 Btu/h <sup>a</sup>	77% $E_t$	
	Oil-fired <sup>c</sup>	< 300,000 Btu/h	80% AFUE	10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h <sup>b</sup>	81% $E_t$	10CFR Part 431
		> 2,500,000 Btu/h <sup>a</sup>	81% $E_t$	

For SI: 1 British thermal unit per hour = 0.2931 W.

$E_c$  = Combustion efficiency (100 percent less flue losses).  $E_t$  = Thermal efficiency. See referenced standard document for detailed information.

- a. These requirements apply to boilers with rated input of 8,000,000 Btu/h or less that are not packaged boilers and to all packaged boilers. Minimum efficiency requirements for boilers cover all capacities of packaged boilers.
- b. Maximum capacity – minimum and maximum ratings as provided for and allowed by the unit’s controls.
- c. Includes oil-fired (residual).

**TABLE C403.2.3(6)**  
**MINIMUM EFFICIENCY REQUIREMENTS:**  
**CONDENSING UNITS, ELECTRICALLY OPERATED**

EQUIPMENT TYPE	SIZE CATEGORY	MINIMUM EFFICIENCY <sup>b</sup>	TEST PROCEDURE <sup>a</sup>
Condensing units, air cooled	≥ 135,000 Btu/h	10.1 EER 11.2 IPLV	AHRI 365
Condensing units, water or evaporatively cooled	≥ 135,000 Btu/h	13.1 EER 13.1 IPLV	

For SI: 1 British thermal unit per hour = 0.2931 W.

- a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
- b. IPLVs are only applicable to equipment with capacity modulation.

**TABLE C403.2.3(7)**  
**MINIMUM EFFICIENCY REQUIREMENTS:**  
**WATER CHILLING PACKAGES<sup>a</sup>**

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2010		AS OF 1/1/2010 <sup>b</sup>				TEST PROCEDURE <sup>c</sup>
			FULL LOAD	IPLV	PATH A		PATH B		
					FULL LOAD	IPLV	FULL LOAD	IPLV	
Air-cooled chillers	< 150 tons	EER	≥ 9.562	≥ 10.4 16	≥ 9.562	≥ 12.500	NA	NA	AHRI 550/590
	≥ 150 tons	EER			≥ 9.562	≥ 12.750	NA	NA	
Air cooled without condenser, electrical operated	All capacities	EER	≥ 10.586	≥ 11.782	Air-cooled chillers without condensers shall be rated with matching condensers and comply with the air-cooled chiller efficiency requirements				
Water cooled, electrically operated, reciprocating	All capacities	kW/ton	≤ 0.837	≤ 0.696	Reciprocating units shall comply with water cooled positive displacement efficiency requirements				
Water cooled, electrically operated, positive displacement	< 75 tons	kW/ton	≤ 0.790	≤ 0.676	≤ 0.780	≤ 0.630	≤ 0.800	≤ 0.600	
	≥ 75 tons and < 150 tons	kW/ton			≤ 0.775	≤ 0.615	≤ 0.790	≤ 0.586	
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.717	≤ 0.627	≤ 0.680	≤ 0.580	≤ 0.718	≤ 0.540	
	≥ 300 tons	kW/ton	≤ 0.639	≤ 0.571	≤ 0.620	≤ 0.540	≤ 0.639	≤ 0.490	
Water cooled, electrically operated, centrifugal	< 150 tons	kW/ton	≤ 0.703	≤ 0.669	≤ 0.634	≤ 0.596	≤ 0.639	≤ 0.450	
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.634	≤ 0.596					
	≥ 300 tons and < 600 tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.576	≤ 0.549	≤ 0.600	≤ 0.400	
	≥ 600 tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.570	≤ 0.539	≤ 0.590	≤ 0.400	
Air cooled, absorption single effect	All capacities	COP	≥ 0.600	NR	≥ 0.600	NR	NA	NA	AHRI 560
Water cooled, absorption single effect	All capacities	COP	≥ 0.700	NR	≥ 0.700	NR	NA	NA	
Absorption double effect, indirect fired	All capacities	COP	≥ 1.000	≥ 1.050	≥ 1.000	≥ 1.050	NA	NA	
Absorption double effect, direct fired	All capacities	COP	≥ 1.000	≥ 1.000	≥ 1.000	≥ 1.000	NA	NA	

For SI: 1 ton = 3517 W, 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.

NA = Not applicable, not to be used for compliance; NR = No requirement.

- a. The centrifugal chiller equipment requirements, after adjustment in accordance with Section C403.2.3.1 or Section C403.2.3.2, do not apply to chillers used in low-temperature applications where the design leaving fluid temperature is less than 36°F. The requirements do not apply to positive displacement chillers with leaving fluid temperatures less than or equal to 32°F. The requirements do not apply to absorption chillers with design leaving fluid temperatures less than 40°F.
- b. Compliance with this standard can be obtained by meeting the minimum requirements of Path A or B. However, both the full load and IPLV shall be met to fulfill the requirements of Path A or B.
- c. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

**TABLE C403.2.3(8)  
MINIMUM EFFICIENCY REQUIREMENTS:  
HEAT REJECTION EQUIPMENT**

EQUIPMENT TYPE <sup>a</sup>	TOTAL SYSTEM HEAT REJECTION CAPACITY AT RATED CONDITIONS	SUBCATEGORY OR RATING CONDITION	PERFORMANCE REQUIRED <sup>b, c, d</sup>	TEST PROCEDURE <sup>e, f</sup>
Propeller or axial fan open circuit cooling towers	All	95°F Entering Water 85°F Leaving Water 75°F Entering wb	≥ 38.2 gpm/hp	CTI ATC-105 and CTI STD-201
Centrifugal fan open circuit cooling towers	All	95°F Entering Water 85°F Leaving Water 75°F Entering wb	≥ 20.0 gpm/hp	CTI ATC-105 and CTI STD-201
Propeller or axial fan closed circuit cooling towers	All	102°F Entering Water 90°F Leaving Water 75°F Entering wb	≥ 14.0 gpm/hp	CTI ATC-105S and CTI STD-201
Centrifugal closed circuit cooling towers	All	102°F Entering Water 90°F Leaving Water 75°F Entering wb	≥ 7.0 gpm/hp	CTI ATC-105S and CTI STD-201
Air-cooled condensers	All	125°F Condensing Temperature R-22 Test Fluid 190°F Entering Gas Temperature 15°F Subcooling 95°F Entering db	≥ 176,000 Btu/h-hp	ARI 460

For SI: °C = [(°F)-32]/1.8, L/s · kW = (gpm/hp)/(11.83), COP = (Btu/h · hp)/(2550.7).

db = dry bulb temperature, °F, wb = wet bulb temperature, °F.

- The efficiencies and test procedures for both open and closed circuit cooling towers are not applicable to hybrid cooling towers that contain a combination of wet and dry heat exchange sections.
- For purposes of this table, open circuit cooling tower performance is defined as the water flow rating of the tower at the thermal rating condition listed in Table 403.2.3(8) divided by the fan nameplate rated motor power.
- For purposes of this table, closed circuit cooling tower performance is defined as the water flow rating of the tower at the thermal rating condition listed in Table 403.2.3(8) divided by the sum of the fan nameplate rated motor power and the spray pump nameplate rated motor power.
- For purposes of this table, air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the fan nameplate rated motor power.
- Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
- If a certification program exists for a covered product, and it includes provisions for verification and challenge of equipment efficiency ratings, then the product shall be listed in the certification program, or, if a certification program exists for a covered product, and it includes provisions for verification and challenge of equipment efficiency ratings, but the product is not listed in the existing certification program, the ratings shall be verified by an independent laboratory test report.

**TABLE C403.2.3(9)  
HEAT TRANSFER EQUIPMENT**

EQUIPMENT TYPE	SUBCATEGORY	MINIMUM EFFICIENCY	TEST PROCEDURE <sup>a</sup>
Liquid-to-liquid heat exchangers	Plate type	NR	AHRI 400

NR = No Requirement

- Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

**C403.2.3.2 Positive displacement (air- and water-cooled) chilling packages.** Equipment with a leaving fluid temperature higher than 32°F (0°C), shall meet the requirements of Table C403.2.3(7) when tested or certified with water at standard rating conditions, in accordance with the referenced test procedure.

**C403.2.4 HVAC system controls.** Each heating and cooling system shall be provided with thermostatic controls as specified in Section C403.2.4.1, C403.2.4.2, C403.2.4.3, C403.2.4.4, C403.4.1, C403.4.2, C403.4.3 or C403.4.4.

**C403.2.4.1 Thermostatic controls.** The supply of heating and cooling energy to each *zone* shall be controlled by individual thermostatic controls capable of responding to temperature within the *zone*. Where humidification or dehumidification or both is provided, at least one humidity control device shall be provided for each humidity control system.

**Exception:** Independent perimeter systems that are designed to offset only building envelope heat losses

or gains or both serving one or more perimeter *zones* also served by an interior system provided:

1. The perimeter system includes at least one thermostatic control *zone* for each building exposure having exterior walls facing only one orientation (within +/-45 degrees) (0.8 rad) for more than 50 contiguous feet (15 240 mm); and
2. The perimeter system heating and cooling supply is controlled by a thermostats located within the *zones* served by the system.

**C403.2.4.1.1 Heat pump supplementary heat.** Heat pumps having supplementary electric resistance heat shall have controls that, except during defrost, prevent supplementary heat operation where the heat pump can meet the heating load.

**C403.2.4.2 Set point overlap restriction.** Where used to control both heating and cooling, *zone* thermostatic controls shall provide a temperature range or deadband of at least 5°F (2.8°C) within which the supply of heating and cooling energy to the *zone* is capable of being shut off or reduced to a minimum.

**Exception:** Thermostats requiring manual change-over between heating and cooling modes.

**C403.2.4.3 Off-hour controls.** Each *zone* shall be provided with thermostatic setback controls that are controlled by either an automatic time clock or programmable control system.

**Exceptions:**

1. *Zones* that will be operated continuously.
2. *Zones* with a full HVAC load demand not exceeding 6,800 Btu/h (2 kW) and having a readily accessible manual shutoff switch.

**C403.2.4.3.1 Thermostatic setback capabilities.** Thermostatic setback controls shall have the capability to set back or temporarily operate the system to maintain *zone* temperatures down to 55°F (13°C) or up to 85°F (29°C).

**C403.2.4.3.2 Automatic setback and shutdown capabilities.** Automatic time clock or programmable controls shall be capable of starting and stopping the system for seven different daily schedules per week and retaining their programming and time setting during a loss of power for at least 10 hours. Additionally, the controls shall have a manual override that allows temporary operation of the system for up to 2 hours; a manually operated timer capable of being adjusted to operate the system for up to 2 hours; or an occupancy sensor.

**C403.2.4.3.3 Automatic start capabilities.** Automatic start controls shall be provided for each HVAC system. The controls shall be capable of automatically adjusting the daily start time of the HVAC system in order to bring each space to the desired occupied temperature immediately prior to scheduled occupancy.

**C403.2.4.4 Shutoff damper controls.** Both outdoor air supply and exhaust ducts shall be equipped with motorized dampers that will automatically shut when the systems or spaces served are not in use.

**Exceptions:**

1. Gravity dampers shall be permitted in buildings less than three stories in height.
2. Gravity dampers shall be permitted for buildings of any height located in Climate Zones 1, 2 and 3.
3. Gravity dampers shall be permitted for outside air intake or exhaust airflows of 300 cfm (0.14 m<sup>3</sup>/s) or less.

**C403.2.4.5 Snow melt system controls.** Snow- and ice-melting systems, supplied through energy service to the building, shall include automatic controls capable of shutting off the system when the pavement temperature is above 50°F (10°C) and no precipitation is falling and an automatic or manual control that will allow shutoff when the outdoor temperature is above 40°F (4°C) so that the potential for snow or ice accumulation is negligible.

**C403.2.5 Ventilation.** Ventilation, either natural or mechanical, shall be provided in accordance with Chapter 4 of the *International Mechanical Code*. Where mechanical ventilation is provided, the system shall provide the capability to reduce the outdoor air supply to the minimum required by Chapter 4 of the *International Mechanical Code*.

**C403.2.5.1 Demand controlled ventilation.** Demand control ventilation (DCV) shall be provided for spaces larger than 500 square feet (50 m<sup>2</sup>) and with an average occupant load of 25 people per 1000 square feet (93 m<sup>2</sup>) of floor area (as established in Table 403.3 of the *International Mechanical Code*) and served by systems with one or more of the following:

1. An air-side economizer;
2. Automatic modulating control of the outdoor air damper; or
3. A design outdoor airflow greater than 3,000 cfm (1400 L/s).

**Exception:** Demand control ventilation is not required for systems and spaces as follows:

1. Systems with energy recovery complying with Section C403.2.6.
2. Multiple-*zone* systems without direct digital control of individual *zones* communicating with a central control panel.
3. System with a design outdoor airflow less than 1,200 cfm (600 L/s).
4. Spaces where the supply airflow rate minus any makeup or outgoing transfer air requirement is less than 1,200 cfm (600 L/s).
5. Ventilation provided for process loads only.

**C403.2.6 Energy recovery ventilation systems.** Where the supply airflow rate of a fan system exceeds the values specified in Table C403.2.6, the system shall include an energy recovery system. The energy recovery system shall have the capability to provide a change in the enthalpy of the outdoor air supply of not less than 50 percent of the difference between the outdoor air and return air enthalpies, at design conditions. Where an air economizer is required, the energy recovery system shall include a bypass or controls which permit operation of the economizer as required by Section C403.4

**Exception:** An energy recovery ventilation system shall not be required in any of the following conditions:

1. Where energy recovery systems are prohibited by the *International Mechanical Code*.
2. Laboratory fume hood systems that include at least one of the following features:
  - 2.1. Variable-air-volume hood exhaust and room supply systems capable of reducing exhaust and makeup air volume to 50 percent or less of design values.
  - 2.2. Direct makeup (auxiliary) air supply equal to at least 75 percent of the exhaust rate, heated no warmer than 2°F (1.1°C) above room setpoint, cooled to no cooler than 3°F (1.7°C) below room setpoint, no humidification added, and no simultaneous heating and cooling used for dehumidification control.
3. Systems serving spaces that are heated to less than 60°F (15.5°C) and are not cooled.
4. Where more than 60 percent of the outdoor heating energy is provided from site-recovered or site solar energy.
5. Heating energy recovery in Climate Zones 1 and 2.
6. Cooling energy recovery in Climate Zones 3C, 4C, 5B, 5C, 6B, 7 and 8.
7. Systems requiring dehumidification that employ energy recovery in series with the cooling coil.
8. Where the largest source of air exhausted at a single location at the building exterior is less than 75 percent of the design *outdoor air* flow rate.

9. Systems expected to operate less than 20 hours per week at the *outdoor air* percentage covered by Table C403.2.6

**C403.2.7 Duct and plenum insulation and sealing.** All supply and return air ducts and plenums shall be insulated with a minimum of R-6 insulation where located in unconditioned spaces and a minimum of R-8 insulation where located outside the building. Where located within a building envelope assembly, the duct or plenum shall be separated from the building exterior or unconditioned or exempt spaces by a minimum of R-8 insulation.

**Exceptions:**

1. Where located within equipment.
2. Where the design temperature difference between the interior and exterior of the duct or plenum does not exceed 15°F (8°C).

All ducts, air handlers and filter boxes shall be sealed. Joints and seams shall comply with Section 603.9 of the *International Mechanical Code*.

**C403.2.7.1 Duct construction.** Ductwork shall be constructed and erected in accordance with the *International Mechanical Code*.

**C403.2.7.1.1 Low-pressure duct systems.** All longitudinal and transverse joints, seams and connections of supply and return ducts operating at a static pressure less than or equal to 2 inches water gauge (w.g.) (500 Pa) shall be securely fastened and sealed with welds, gaskets, mastics (adhesives), mastic-plus-embedded-fabric systems or tapes installed in accordance with the manufacturer’s installation instructions. Pressure classifications specific to the duct system shall be clearly indicated on the construction documents in accordance with the *International Mechanical Code*.

**Exception:** Continuously welded and locking-type longitudinal joints and seams on ducts operating at static pressures less than 2 inches water gauge (w.g.) (500 Pa) pressure classification.

**C403.2.7.1.2 Medium-pressure duct systems.** All ducts and plenums designed to operate at a static pressure greater than 2 inches water gauge (w.g.) (500 Pa) but less than 3 inches w.g. (750 Pa) shall be insulated and sealed in accordance with Section C403.2.7. Pressure classifications specific to the duct system shall be

**TABLE C403.2.6  
ENERGY RECOVERY REQUIREMENT**

CLIMATE ZONE	PERCENT (%) OUTDOOR AIR AT FULL DESIGN AIRFLOW RATE					
	≥ 30% and < 40%	≥ 40% and < 50%	≥ 50% and < 60%	≥ 60% and < 70%	≥ 70% and < 80%	≥ 80%
	DESIGN SUPPLY FAN AIRFLOW RATE (cfm)					
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	≥ 5000	≥ 5000
1B, 2B, 5C	NR	NR	≥ 26000	≥ 12000	≥ 5000	≥ 4000
6B	≥ 11000	≥ 5500	≥ 4500	≥ 3500	≥ 2500	≥ 1500
1A, 2A, 3A, 4A, 5A, 6A	≥ 5500	≥ 4500	≥ 3500	≥ 2000	≥ 1000	> 0
7, 8	≥ 2500	≥ 1000	> 0	> 0	> 0	> 0

NR = not required

clearly indicated on the construction documents in accordance with the *International Mechanical Code*.

**C403.2.7.1.3 High-pressure duct systems.** Ducts designed to operate at static pressures in excess of 3 inches water gauge (w.g.) (750 Pa) shall be insulated and sealed in accordance with Section C403.2.7. In addition, ducts and plenums shall be leak-tested in accordance with the *SMACNA HVAC Air Duct Leakage Test Manual* with the rate of air leakage (*CL*) less than or equal to 6.0 as determined in accordance with Equation C4-5.

$$CL = F/P^{0.65} \quad \text{(Equation C4-5)}$$

where:

*F* = The measured leakage rate in cfm per 100 square feet of duct surface.

*P* = The static pressure of the test.

Documentation shall be furnished by the designer demonstrating that representative sections totaling at least 25 percent of the duct area have been tested and that all tested sections meet the requirements of this section.

**C403.2.8 Piping insulation.** All piping serving as part of a heating or cooling system shall be thermally insulated in accordance with Table C403.2.8.

**Exceptions:**

1. Factory-installed piping within HVAC equipment tested and rated in accordance with a test procedure referenced by this code.
2. Factory-installed piping within room fan-coils and unit ventilators tested and rated according to

AHRI 440 (except that the sampling and variation provisions of Section 6.5 shall not apply) and 840, respectively.

3. Piping that conveys fluids that have a design operating temperature range between 60°F (15°C) and 105°F (41°C).
4. Piping that conveys fluids that have not been heated or cooled through the use of fossil fuels or electric power.
5. Strainers, control valves, and balancing valves associated with piping 1 inch (25 mm) or less in diameter.
6. Direct buried piping that conveys fluids at or below 60°F (15°C)

**C403.2.8.1 Protection of piping insulation.** Piping insulation exposed to weather shall be protected from damage, including that due to sunlight, moisture, equipment maintenance and wind, and shall provide shielding from solar radiation that can cause degradation of the material. Adhesives tape shall not be permitted.

**C403.2.9 Mechanical systems commissioning and completion requirements.** Mechanical systems shall be commissioned and completed in accordance with Section C408.2.

**C403.2.10 Air system design and control.** Each HVAC system having a total fan system motor nameplate horsepower (hp) exceeding 5 horsepower (hp) (3.7 kW) shall meet the provisions of Sections C403.2.10.1 through C403.2.10.2.

**C403.2.10.1 Allowable fan motor horsepower.** Each HVAC system at fan system design conditions shall not exceed the allowable *fan system motor nameplate hp*

**TABLE C403.2.8**  
**MINIMUM PIPE INSULATION THICKNESS (thickness in inches)<sup>a</sup>**

FLUID OPERATING TEMPERATURE RANGE AND USAGE (°F)	INSULATION CONDUCTIVITY		NOMINAL PIPE OR TUBE SIZE (inches)				
	Conductivity Btu · in./(h · ft <sup>2</sup> · °F) <sup>b</sup>	Mean Rating Temperature, °F	< 1	1 to < 1½	1½ to < 4	4 to < 8	≥ 8
> 350	0.32 – 0.34	250	4.5	5.0	5.0	5.0	5.0
251 – 350	0.29 – 0.32	200	3.0	4.0	4.5	4.5	4.5
201 – 250	0.27 – 0.30	150	2.5	2.5	2.5	3.0	3.0
141 – 200	0.25 – 0.29	125	1.5	1.5	2.0	2.0	2.0
105 – 140	0.21 – 0.28	100	1.0	1.0	1.5	1.5	1.5
40 – 60	0.21 – 0.27	75	0.5	0.5	1.0	1.0	1.0
< 40	0.20 – 0.26	75	0.5	1.0	1.0	1.0	1.5

a. For piping smaller than 1½ inch (38 mm) and located in partitions within *conditioned spaces*, reduction of these thicknesses by 1 inch (25 mm) shall be permitted (before thickness adjustment required in footnote b) but not to a thickness less than 1 inch (25 mm).

b. For insulation outside the stated conductivity range, the minimum thickness (*T*) shall be determined as follows:

$$T = r\{(1 + t/r)^{K/k} - 1\}$$

where:

*T* = minimum insulation thickness,

*r* = actual outside radius of pipe,

*t* = insulation thickness listed in the table for applicable fluid temperature and pipe size,

*K* = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (Btu × in/h × ft<sup>2</sup> × °F) and

*k* = the upper value of the conductivity range listed in the table for the applicable fluid temperature.

c. For direct-buried heating and hot water system piping, reduction of these thicknesses by 1½ inches (38 mm) shall be permitted (before thickness adjustment required in footnote b) but not to thicknesses less than 1 inch (25 mm).

(Option 1) or *fan system bhp* (Option 2) as shown in Table C403.2.10.1(1). This includes supply fans, return/relief fans, and fan-powered terminal units associated with systems providing heating or cooling capability. Single *zone* variable-air-volume systems shall comply with the constant volume fan power limitation.

**Exception:** The following fan systems are exempt from allowable fan floor horsepower requirement.

1. Hospital, vivarium and laboratory systems that utilize flow control devices on exhaust and/or return to maintain space pressure relationships necessary for occupant health and safety or environmental control shall be permitted to use variable volume fan power limitation.
2. Individual exhaust fans with motor nameplate horsepower of 1 hp or less.

**C403.2.10.2 Motor nameplate horsepower.** For each fan, the selected fan motor shall be no larger than the first available motor size greater than the brake horsepower

(bhp). The fan brake horsepower (bhp) shall be indicated on the design documents to allow for compliance verification by the *code official*.

**Exceptions:**

1. For fans less than 6 bhp (4413 W), where the first available motor larger than the brake horsepower has a nameplate rating within 50 percent of the bhp, selection of the next larger nameplate motor size is allowed.
2. For fans 6 bhp (4413 W) and larger, where the first available motor larger than the bhp has a nameplate rating within 30 percent of the bhp, selection of the next larger nameplate motor size is allowed.

**C403.2.11 Heating outside a building.** Systems installed to provide heat outside a building shall be radiant systems.

Such heating systems shall be controlled by an occupancy sensing device or a timer switch, so that the system is automatically deenergized when no occupants are present.

**TABLE C403.2.10.1(1)  
FAN POWER LIMITATION**

	LIMIT	CONSTANT VOLUME	VARIABLE VOLUME
Option 1: Fan system motor nameplate hp	Allowable nameplate motor hp	$hp \leq CFM_s \times 0.0011$	$hp \leq CFM_s \times 0.0015$
Option 2: Fan system bhp	Allowable fan system bhp	$bhp \leq CFM_s \times 0.00094 + A$	$bhp \leq CFM_s \times 0.0013 + A$

where:

- CFM<sub>s</sub> = The maximum design supply airflow rate to conditioned spaces served by the system in cubic feet per minute.
- hp = The maximum combined motor nameplate horsepower.
- Bhp = The maximum combined fan brake horsepower.
- A = Sum of  $[PD \times CFM_p / 4131]$

For SI: 1 cfm = 0.471 L/s.

where:

- PD = Each applicable pressure drop adjustment from Table C403.2.10.1(2) in. w.c.
- CFM<sub>p</sub> = The design airflow through each applicable device from Table C403.2.10.1(2) in cubic feet per minute.

For SI: 1 bhp = 735.5 W, 1 hp = 745.5 W.

**TABLE C403.2.10.1(2)  
FAN POWER LIMITATION PRESSURE DROP ADJUSTMENT**

DEVICE	ADJUSTMENT
<b>Credits</b>	
Fully ducted return and/or exhaust air systems	0.5 inch w.c. (2.15 in w.c. for laboratory and vivarium systems)
Return and/or exhaust air flow control devices	0.5 inch w.c.
Exhaust filters, scrubbers, or other exhaust treatment.	The pressure drop of device calculated at fan system design condition
Particulate filtration credit: MERV 9 thru 12	0.5 inch w.c.
Particulate filtration credit: MERV 13 thru 15	0.9 inch. w.c.
Particulate filtration credit: MERV 16 and greater and electronically enhanced filters	Pressure drop calculated at 2x clean filter pressure drop at fan system design condition.
Carbon and other gas-phase air cleaners	Clean filter pressure drop at fan system design condition.
Biosafety cabinet	Pressure drop of device at fan system design condition.
Energy recovery device, other than coil runaround loop	$(2.2 \times \text{energy recovery effectiveness}) - 0.5$ inch w.c. for each airstream
Coil runaround loop	0.6 inch w.c. for each airstream
Evaporative humidifier/cooler in series with another cooling coil	Pressure drop of device at fan system design conditions
Sound attenuation section	0.15 inch w.c.
Exhaust system serving fume hoods	0.35 inch w.c.
Laboratory and vivarium exhaust systems in high-rise buildings	0.25 inch w.c./100 feet of vertical duct exceeding 75 feet

w.c. = water column

For SI: 1 inch w.c. = 249 Pa, 1 inch = 25.4 mm.

**C403.3 Simple HVAC systems and equipment (Prescriptive).** This section applies to buildings served by unitary or packaged HVAC equipment listed in Tables C403.2.3(1) through C403.2.3(8), each serving one *zone* and controlled by a single thermostat in the *zone* served. It also applies to two-pipe heating systems serving one or more *zones*, where no cooling system is installed.

**C403.3.1 Economizers.** Each cooling system that has a fan shall include either an air or water economizer meeting the requirements of Sections C403.3.1.1 through C403.3.1.1.4.

**Exception:** Economizers are not required for the systems listed below.

1. Individual fan-cooling units with a supply capacity less than the minimum listed in Table C403.3.1(1).
2. Where more than 25 percent of the air designed to be supplied by the system is to spaces that are designed to be humidified above 35°F (1.7 °C) dew-point temperature to satisfy process needs.
3. Systems that serve *residential* spaces where the system capacity is less than five times the requirement listed in Table C403.3.1(1).
4. Systems expected to operate less than 20 hours per week.
5. Where the use of *outdoor air* for cooling will affect supermarket open refrigerated casework systems.
6. Where the cooling *efficiency* meets or exceeds the *efficiency* requirements in Table C403.3.1(2).

**TABLE C403.3.1(1)  
ECONOMIZER REQUIREMENTS**

CLIMATE ZONES	ECONOMIZER REQUIREMENT
1A, 1B	No requirement
2A, 2B, 3A, 3B, 3C, 4A, 4B, 4C, 5A, 5B, 5C, 6A, 6B, 7, 8	Economizers on all cooling systems ≥ 33,000 Btu/h <sup>a</sup>

For SI: 1 British thermal unit per hour = 0.2931 W.

a. The total capacity of all systems without economizers shall not exceed 300,000 Btu/h per *building*, or 20 percent of its air economizer capacity, whichever is greater.

**TABLE C403.3.1(2)  
EQUIPMENT EFFICIENCY PERFORMANCE  
EXCEPTION FOR ECONOMIZERS**

CLIMATE ZONES	COOLING EQUIPMENT PERFORMANCE IMPROVEMENT (EER OR IPLV)
2B	10% Efficiency Improvement
3B	15% Efficiency Improvement
4B	20% Efficiency Improvement

**C403.3.1.1 Air economizers.** Air economizers shall comply with Sections C403.3.1.1.1 through C403.3.1.1.4.

**C403.3.1.1.1 Design capacity.** Air economizer systems shall be capable of modulating *outdoor air* and

return air dampers to provide up to 100 percent of the design supply air quantity as *outdoor air* for cooling.

**C403.3.1.1.2 Control signal.** Economizer dampers shall be capable of being sequenced with the mechanical cooling equipment and shall not be controlled by only mixed air temperature.

**Exception:** The use of mixed air temperature limit control shall be permitted for systems controlled from space temperature (such as single-*zone* systems).

**C403.3.1.1.3 High-limit shutoff.** Air economizers shall be capable of automatically reducing *outdoor air* intake to the design minimum *outdoor air* quantity when *outdoor air* intake will no longer reduce cooling energy usage. High-limit shutoff control types for specific climates shall be chosen from Table C403.3.1.1.3(1). High-limit shutoff control settings for these control types shall be those specified in Table C403.3.1.1.3(2).

**C403.3.1.1.4 Relief of excess outdoor air.** Systems shall be capable of relieving excess *outdoor air* during air economizer operation to prevent over-pressurizing the building. The relief air outlet shall be located to avoid recirculation into the building.

**C403.3.2 Hydronic system controls.** Hydronic systems of at least 300,000 Btu/h (87 930 W) design output capacity supplying heated and chilled water to comfort conditioning systems shall include controls that meet the requirements of Section C403.4.3.

**C403.4 Complex HVAC systems and equipment. (Prescriptive).** This section applies to buildings served by HVAC equipment and systems not covered in Section C403.3.

**C403.4.1 Economizers.** Economizers shall comply with Sections C403.4.1.1 through C403.4.1.4.

**C403.4.1.1 Design capacity.** Water economizer systems shall be capable of cooling supply air by indirect evaporation and providing up to 100 percent of the expected system cooling load at *outdoor air* temperatures of 50°F dry bulb (10°C dry bulb)/45°F wet bulb (7.2°C wet bulb) and below.

**Exception:** Systems in which a water economizer is used and where dehumidification requirements cannot be met using outdoor air temperatures of 50°F dry bulb (10°C dry bulb)/45°F wet bulb (7.2°C wet bulb) shall satisfy 100 percent of the expected system cooling load at 45°F dry bulb (7.2°C dry bulb)/40°F wet bulb (4.5°C wet bulb).

**C403.4.1.2 Maximum pressure drop.** Precooling coils and water-to-water heat exchangers used as part of a water economizer system shall either have a water-side pressure drop of less than 15 feet (4572 mm) of water or a secondary loop shall be created so that the coil or heat exchanger pressure drop is not seen by the circulating pumps when the system is in the normal cooling (noneconomizer) mode.



**TABLE C403.3.1.1.3(1)  
HIGH-LIMIT SHUTOFF CONTROL OPTIONS FOR AIR ECONOMIZERS**

CLIMATE ZONES	ALLOWED CONTROL TYPES	PROHIBITED CONTROL TYPES
1B, 2B, 3B, 3C, 4B, 4C, 5B, 5C, 6B, 7, 8	Fixed dry bulb Differential dry bulb Electronic enthalpy <sup>a</sup> Differential enthalpy Dew-point and dry-bulb temperatures	Fixed enthalpy
1A, 2A, 3A, 4A	Fixed dry bulb Fixed enthalpy Electronic enthalpy <sup>a</sup> Differential enthalpy Dew-point and dry-bulb temperatures	Differential dry bulb
All other climates	Fixed dry bulb Differential dry bulb Fixed enthalpy Electronic enthalpy <sup>a</sup> Differential enthalpy Dew-point and dry-bulb temperatures	—

a. Electronic enthalpy controllers are devices that use a combination of humidity and dry-bulb temperature in their switching algorithm.

**TABLE C403.3.1.1.3(2)  
HIGH-LIMIT SHUTOFF CONTROL SETTING FOR AIR ECONOMIZERS**

DEVICE TYPE	CLIMATE ZONE	REQUIRED HIGH LIMIT (ECONOMIZER OFF WHEN):	
		EQUATION	DESCRIPTION
Fixed dry bulb	1B, 2B, 3B, 3C, 4B, 4C, 5B, 5C, 6B, 7, 8	$T_{OA} > 75^{\circ}\text{F}$	Outdoor air temperature exceeds 75°F
	5A, 6A, 7A	$T_{OA} > 70^{\circ}\text{F}$	Outdoor air temperature exceeds 70°F
	All other zones	$T_{OA} > 65^{\circ}\text{F}$	Outdoor air temperature exceeds 65°F
Differential dry bulb	1B, 2B, 3B, 3C, 4B, 4C, 5A, 5B, 5C, 6A, 6B, 7, 8	$T_{OA} > T_{RA}$	Outdoor air temperature exceeds return air temperature
Fixed enthalpy	All	$h_{OA} > 28 \text{ Btu/lb}^a$	Outdoor air enthalpy exceeds 28 Btu/lb of dry air <sup>a</sup>
Electronic Enthalpy	All	$(T_{OA}, RH_{OA}) > A$	Outdoor air temperature/RH exceeds the “A” setpoint curve <sup>b</sup>
Differential enthalpy	All	$h_{OA} > h_{RA}$	Outdoor air enthalpy exceeds return air enthalpy
Dew-point and dry bulb temperatures	All	$DP_{OA} > 55^{\circ}\text{F}$ or $T_{OA} > 75^{\circ}\text{F}$	Outdoor air dry bulb exceeds 75°F or outside dew point exceeds 55°F (65 gr/lb)

For SI: °C = (°F - 32) × 5/9, 1 Btu/lb = 2.33 kJ/kg.

a. At altitudes substantially different than sea level, the Fixed Enthalpy limit shall be set to the enthalpy value at 75°F and 50-percent relative humidity. As an example, at approximately 6,000 feet elevation the fixed enthalpy limit is approximately 30.7 Btu/lb.

b. Setpoint “A” corresponds to a curve on the psychometric chart that goes through a point at approximately 75°F and 40-percent relative humidity and is nearly parallel to dry-bulb lines at low humidity levels and nearly parallel to enthalpy lines at high humidity levels.

**C403.4.1.3 Integrated economizer control.** Economizer systems shall be integrated with the mechanical cooling system and be capable of providing partial cooling even where additional mechanical cooling is required to meet the remainder of the cooling load.

**Exceptions:**

1. Direct expansion systems that include controls that reduce the quantity of *outdoor air* required to prevent coil frosting at the lowest step of compressor unloading, provided this lowest step is no greater than 25 percent of the total system capacity.
2. Individual direct expansion units that have a rated cooling capacity less than 54,000 Btu/h (15 827 W) and use nonintegrated economizer controls that preclude simultaneous operation of the economizer and mechanical cooling.

**C403.4.1.4 Economizer heating system impact.** HVAC system design and economizer controls shall be such that economizer operation does not increase the building heating energy use during normal operation.

**Exception:** Economizers on VAV systems that cause *zone* level heating to increase due to a reduction in supply air temperature.

**C403.4.2 Variable air volume (VAV) fan control.** Individual VAV fans with motors of 7.5 horsepower (5.6 kW) or greater shall be:

1. Driven by a mechanical or electrical variable speed drive;
2. Driven by a vane-axial fan with variable-pitch blades; or
3. The fan shall have controls or devices that will result in fan motor demand of no more than 30 percent of their design wattage at 50 percent of design airflow when static pressure set point equals one-third of the total design static pressure, based on manufacturer's certified fan data.

**C403.4.2.1 Static pressure sensor location.** Static pressure sensors used to control VAV fans shall be placed in a position such that the controller setpoint is no greater than one-third the total design fan static pressure, except for systems with *zone* reset control complying with Section C403.4.2.2. For sensors installed down-stream of major duct splits, at least one sensor shall be located on each major branch to ensure that static pressure can be maintained in each branch.

**C403.4.2.2 Set points for direct digital control.** For systems with direct digital control of individual *zone* boxes reporting to the central control panel, the static pressure set point shall be reset based on the *zone* requiring the most pressure, i.e., the set point is reset lower until one *zone* damper is nearly wide open.

**C403.4.3 Hydronic systems controls.** The heating of fluids that have been previously mechanically cooled and the cooling of fluids that have been previously mechanically heated shall be limited in accordance with Sections

C403.4.3.1 through C403.4.3.3. Hydronic heating systems comprised of multiple-packaged boilers and designed to deliver conditioned water or steam into a common distribution system shall include automatic controls capable of sequencing operation of the boilers. Hydronic heating systems comprised of a single boiler and greater than 500,000 Btu/h (146 550 W) input design capacity shall include either a multistaged or modulating burner.

**C403.4.3.1 Three-pipe system.** Hydronic systems that use a common return system for both hot water and chilled water are prohibited.

**C403.4.3.2 Two-pipe changeover system.** Systems that use a common distribution system to supply both heated and chilled water shall be designed to allow a dead band between changeover from one mode to the other of at least 15°F (8.3°C) outside air temperatures; be designed to and provided with controls that will allow operation in one mode for at least 4 hours before changing over to the other mode; and be provided with controls that allow heating and cooling supply temperatures at the changeover point to be no more than 30°F (16.7°C) apart.

**C403.4.3.3 Hydronic (water loop) heat pump systems.** Hydronic heat pump systems shall comply with Sections C403.4.3.3.1 through C403.4.3.3.3.

**C403.4.3.3.1 Temperature dead band.** Hydronic heat pumps connected to a common heat pump water loop with central devices for heat rejection and heat addition shall have controls that are capable of providing a heat pump water supply temperature dead band of at least 20°F (11.1°C) between initiation of heat rejection and heat addition by the central devices.

**Exception:** Where a system loop temperature optimization controller is installed and can determine the most efficient operating temperature based on realtime conditions of demand and capacity, dead bands of less than 20°F (11°C) shall be permitted.

**C403.4.3.3.2 Heat rejection.** Heat rejection equipment shall comply with Sections C403.4.3.3.2.1 and C403.4.3.3.2.2.

**Exception:** Where it can be demonstrated that a heat pump system will be required to reject heat throughout the year.

**C403.4.3.3.2.1 Climate Zones 3 and 4.** For Climate Zones 3 and 4:

1. If a closed-circuit cooling tower is used directly in the heat pump loop, either an automatic valve shall be installed to bypass all but a minimal flow of water around the tower, or lower leakage positive closure dampers shall be provided.
2. If an open-circuit tower is used directly in the heat pump loop, an automatic valve shall be installed to bypass all heat pump water flow around the tower.

3. If an open- or closed-circuit cooling tower is used in conjunction with a separate heat exchanger to isolate the cooling tower from the heat pump loop, then heat loss shall be controlled by shutting down the circulation pump on the cooling tower loop.

**C403.4.3.3.2 Climate Zones 5 through 8.** For Climate Zones 5 through 8, if an open- or closed-circuit cooling tower is used, then a separate heat exchanger shall be provided to isolate the cooling tower from the heat pump loop, and heat loss shall be controlled by shutting down the circulation pump on the cooling tower loop and providing an automatic valve to stop the flow of fluid.

**C403.4.3.3.3 Two position valve.** Each hydronic heat pump on the hydronic system having a total pump system power exceeding 10 horsepower (hp) (7.5 kW) shall have a two-position valve.

**C403.4.3.4 Part load controls.** Hydronic systems greater than or equal to 300,000 Btu/h (87 930 W) in design output capacity supplying heated or chilled water to comfort conditioning systems shall include controls that have the capability to:

1. Automatically reset the supply-water temperatures using zone-return water temperature, building-return water temperature, or outside air temperature as an indicator of building heating or cooling demand. The temperature shall be capable of being reset by at least 25 percent of the design supply-to-return water temperature difference; or
2. Reduce system pump flow by at least 50 percent of design flow rate utilizing adjustable speed drive(s) on pump(s), or multiple-staged pumps where at least one-half of the total pump horsepower is capable of being automatically turned off or control valves designed to modulate or step down, and close, as a function of load, or other *approved* means.

**C403.4.3.5 Pump isolation.** Chilled water plants including more than one chiller shall have the capability to reduce flow automatically through the chiller plant when a chiller is shut down. Chillers piped in series for the purpose of increased temperature differential shall be considered as one chiller.

Boiler plants including more than one boiler shall have the capability to reduce flow automatically through the boiler plant when a boiler is shut down.

**C403.4.4 Heat rejection equipment fan speed control.** Each fan powered by a motor of 7.5 hp (5.6 kW) or larger shall have the capability to operate that fan at two-thirds of full speed or less, and shall have controls that automatically change the fan speed to control the leaving fluid tem-

perature or condensing temperature/pressure of the heat rejection device.

**Exception:** Factory-installed heat rejection devices within HVAC equipment tested and rated in accordance with Tables C403.2.3(6) and C403.2.3(7).

**C403.4.5 Requirements for complex mechanical systems serving multiple zones.** Sections C403.4.5.1 through C403.4.5.4 shall apply to complex mechanical systems serving multiple zones. Supply air systems serving multiple zones shall be VAV systems which, during periods of occupancy, are designed and capable of being controlled to reduce primary air supply to each *zone* to one of the following before reheating, recooling or mixing takes place:

1. Thirty percent of the maximum supply air to each *zone*.
2. Three hundred cfm (142 L/s) or less where the maximum flow rate is less than 10 percent of the total fan system supply airflow rate.
3. The minimum ventilation requirements of Chapter 4 of the *International Mechanical Code*.

**Exception:** The following define where individual *zones* or where entire air distribution systems are exempted from the requirement for VAV control:

1. *Zones* where special pressurization relationships or cross-contamination requirements are such that VAV systems are impractical.
2. *Zones* or supply air systems where at least 75 percent of the energy for reheating or for providing warm air in mixing systems is provided from a site-recovered or site-solar energy source.
3. *Zones* where special humidity levels are required to satisfy process needs.
4. *Zones* with a peak supply air quantity of 300 cfm (142 L/s) or less and where the flow rate is less than 10 percent of the total fan system supply airflow rate.
5. *Zones* where the volume of air to be reheated, recoolled or mixed is no greater than the volume of outside air required to meet the minimum ventilation requirements of Chapter 4 of the *International Mechanical Code*.
6. *Zones* or supply air systems with thermostatic and humidistatic controls capable of operating in sequence the supply of heating and cooling energy to the *zones* and which are capable of preventing reheating, recooling, mixing or simultaneous supply of air that has been previously cooled, either mechanically or through the use of economizer systems, and air that has been previously mechanically heated.

**C403.4.5.1 Single duct variable air volume (VAV) systems, terminal devices.** Single duct VAV systems shall use terminal devices capable of reducing the supply of primary supply air before reheating or recooling takes place.

**C403.4.5.2 Dual duct and mixing VAV systems, terminal devices.** Systems that have one warm air duct and one cool air duct shall use terminal devices which are capable of reducing the flow from one duct to a minimum before mixing of air from the other duct takes place.

**C403.4.5.3 Single fan dual duct and mixing VAV systems, economizers.** Individual dual duct or mixing heating and cooling systems with a single fan and with total capacities greater than 90,000 Btu/h [(26 375 W) 7.5 tons] shall not be equipped with air economizers.

**C403.4.5.4 Supply-air temperature reset controls.** Multiple *zone* HVAC systems shall include controls that automatically reset the supply-air temperature in response to representative building loads, or to outdoor air temperature. The controls shall be capable of resetting the supply air temperature at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.

**Exceptions:**

1. Systems that prevent reheating, recooling or mixing of heated and cooled supply air.
2. Seventy five percent of the energy for reheating is from site-recovered or site solar energy sources.
3. Zones with peak supply air quantities of 300 cfm (142 L/s) or less.

**C403.4.6 Heat recovery for service water heating.** Condenser heat recovery shall be installed for heating or reheating of service hot water provided the facility operates 24 hours a day, the total installed heat capacity of water-cooled systems exceeds 6,000,000 Btu/hr (1 758 600 W) of heat rejection, and the design service water heating load exceeds 1,000,000 Btu/h (293 100 W).

The required heat recovery system shall have the capacity to provide the smaller of:

1. Sixty percent of the peak heat rejection load at design conditions; or
2. The preheating required to raise the peak service hot water draw to 85°F (29°C).

**Exceptions:**

1. Facilities that employ condenser heat recovery for space heating or reheat purposes with a heat recovery design exceeding 30 percent of the peak water-cooled condenser load at design conditions.
2. Facilities that provide 60 percent of their service water heating from site solar or site recovered energy or from other sources.

**C403.4.7 Hot gas bypass limitation.** Cooling systems shall not use hot gas bypass or other evaporator pressure control systems unless the system is designed with multiple steps of unloading or continuous capacity modulation. The capacity of the hot gas bypass shall be limited as indicated in Table C403.4.7

**Exception:** Unitary packaged systems with cooling capacities not greater than 90,000 Btu/h (26 379 W).

**TABLE C403.4.7  
MAXIMUM HOT GAS BYPASS CAPACITY**

RATED CAPACITY	MAXIMUM HOT GAS BYPASS CAPACITY (% of total capacity)
≤ 240,000 Btu/h	50
> 240,000 Btu/h	25

For SI: 1 British thermal unit per hour = 0.2931 W.

**SECTION C404  
SERVICE WATER HEATING  
(Mandatory)**

**C404.1 General.** This section covers the minimum efficiency of, and controls for, service water-heating equipment and insulation of service hot water piping.

**C404.2 Service water-heating equipment performance efficiency.** Water-heating equipment and hot water storage tanks shall meet the requirements of Table C404.2. The efficiency shall be verified through data furnished by the manufacturer or through certification under an *approved* certification program.

**C404.3 Temperature controls.** Service water-heating equipment shall be provided with controls to allow a setpoint of 110°F (43°C) for equipment serving dwelling units and 90°F (32°C) for equipment serving other occupancies. The outlet temperature of lavatories in public facility rest rooms shall be limited to 110°F (43°C).

**C404.4 Heat traps.** Water-heating equipment not supplied with integral heat traps and serving noncirculating systems shall be provided with heat traps on the supply and discharge piping associated with the equipment.

**C404.5 Pipe insulation.** For automatic-circulating hot water and heat-traced systems, piping shall be insulated with not less than 1 inch (25 mm) of insulation having a conductivity not exceeding 0.27 Btu per inch/h × ft<sup>2</sup> × °F (1.53 W per 25 mm/m<sup>2</sup> × K). The first 8 feet (2438 mm) of piping in non-hot-water-supply temperature maintenance systems served by equipment without integral heat traps shall be insulated with 0.5 inch (12.7 mm) of material having a conductivity not exceeding 0.27 Btu per inch/h × ft<sup>2</sup> × °F (1.53 W per 25 mm/m<sup>2</sup> × K).

**Exception:** Heat-traced piping systems shall meet the insulation thickness requirements per the manufacturer's installation instructions. Untraced piping within a heat traced system shall be insulated with not less than 1 inch (25 mm) of insulation having a conductivity not exceeding 0.27 Btu per inch/h × ft<sup>2</sup> × °F (1.53 W per 25 mm/m<sup>2</sup> × K).

**TABLE C404.2  
MINIMUM PERFORMANCE OF WATER-HEATING EQUIPMENT**

EQUIPMENT TYPE	SIZE CATEGORY (input)	SUBCATEGORY OR RATING CONDITION	PERFORMANCE REQUIRED <sup>a, b</sup>	TEST PROCEDURE
Water heaters, electric	≤ 12 kW	Resistance	0.97 - 0.00 132V, EF	DOE 10 CFR Part 430
	> 12 kW	Resistance	1.73V+ 155 SL, Btu/h	ANSI Z21.10.3
	≤ 24 amps and ≤ 250 volts	Heat pump	0.93 - 0.00 132V, EF	DOE 10 CFR Part 430
Storage water heaters, gas	≤ 75,000 Btu/h	≥ 20 gal	0.67 - 0.0019V, EF	DOE 10 CFR Part 430
	> 75,000 Btu/h and ≤ 155,000 Btu/h	< 4,000 Btu/h/gal	$80\% E_t$ $(Q/800 + 110\sqrt{V})SL$ , Btu/h	ANSI Z21.10.3
	> 155,000 Btu/h	< 4,000 Btu/h/gal	$80\% E_t$ $(Q/800 + 110\sqrt{V})SL$ , Btu/h	
Instantaneous water heaters, gas	> 50,000 Btu/h and < 200,000 Btu/h <sup>c</sup>	≥ 4,000 (Btu/h)/gal and < 2 gal	0.62 - 0.00 19V, EF	DOE 10 CFR Part 430
	≥ 200,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	$80\% E_t$	ANSI Z21.10.3
	≥ 200,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal	$80\% E_t$ $(Q/800 + 110\sqrt{V})SL$ , Btu/h	
Storage water heaters, oil	≤ 105,000 Btu/h	≥ 20 gal	0.59 - 0.0019V, EF	DOE 10 CFR Part 430
	≥ 105,000 Btu/h	< 4,000 Btu/h/gal	$78\% E_t$ $(Q/800 + 110\sqrt{V})SL$ , Btu/h	ANSI Z21.10.3
Instantaneous water heaters, oil	≤ 210,000 Btu/h	≥ 4,000 Btu/h/gal and < 2 gal	0.59 - 0.0019V, EF	DOE 10 CFR Part 430
	> 210,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	$80\% E_t$	ANSI Z21.10.3
	> 210,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal	$78\% E_t$ $(Q/800 + 110\sqrt{V})SL$ , Btu/h	
Hot water supply boilers, gas and oil	≥ 300,000 Btu/h and < 12,500,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	$80\% E_t$	ANSI Z21.10.3
Hot water supply boilers, gas	≥ 300,000 Btu/h and < 12,500,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal	$80\% E_t$ $(Q/800 + 110\sqrt{V})SL$ , Btu/h	
Hot water supply boilers, oil	> 300,000 Btu/h and < 12,500,000 Btu/h	> 4,000 Btu/h/gal and > 10 gal	$78\% E_t$ $(Q/800 + 110\sqrt{V})SL$ , Btu/h	
Pool heaters, gas and oil	All	—	$78\% E_t$	ASHRAE 146
Heat pump pool heaters	All	—	4.0 COP	AHRI 1160
Unfired storage tanks	All	—	Minimum insulation requirement R-12.5 (h · ft <sup>2</sup> · °F)/Btu	(none)

For SI: °C = [(°F) - 32]/1.8, 1 British thermal unit per hour = 0.2931 W, 1 gallon = 3.785 L, 1 British thermal unit per hour per gallon = 0.078 W/L.

a. Energy factor (EF) and thermal efficiency ( $E_t$ ) are minimum requirements. In the EF equation,  $V$  is the rated volume in gallons.

b. Standby loss (SL) is the maximum Btu/h based on a nominal 70°F temperature difference between stored water and ambient requirements. In the SL equation,  $Q$  is the nameplate input rate in Btu/h. In the SL equation for electric water heaters,  $V$  is the rated volume in gallons. In the SL equation for oil and gas water heaters and boilers,  $V$  is the rated volume in gallons.

c. Instantaneous water heaters with input rates below 200,000 Btu/h must comply with these requirements if the water heater is designed to heat water to temperatures 180°F or higher.

**C404.6 Hot water system controls.** Circulating hot water system pumps or heat trace shall be arranged to be turned off either automatically or manually when there is limited hot water demand. Ready access shall be provided to the operating controls.

**C404.7 Pools and inground permanently installed spas (Mandatory).** Pools and inground permanently installed spas shall comply with Sections C404.7.1 through C404.7.3.

**C404.7.1 Heaters.** All heaters shall be equipped with a readily *accessible* on-off switch that is mounted outside of the heater to allow shutting off the heater without adjusting the thermostat setting. Gas-fired heaters shall not be equipped with constant burning pilot lights.

**C404.7.2 Time switches.** Time switches or other control method that can automatically turn off and on heaters and pumps according to a preset schedule shall be installed on all heaters and pumps. Heaters, pumps and motors that have built in timers shall be deemed in compliance with this requirement.

**Exceptions:**

1. Where public health standards require 24-hour pump operation.
2. Where pumps are required to operate solar- and waste-heat-recovery pool heating systems.

**C404.7.3 Covers.** Heated pools and inground permanently installed spas shall be provided with a vapor-retardant cover.

**Exception:** A vapor-retardant cover is not required for pools deriving over 70 percent of the energy for heating from site-recovered energy, such as a heat pump or solar energy source computed over an operating season.

**SECTION C405  
ELECTRICAL POWER AND LIGHTING SYSTEMS  
(MANDATORY)**

**C405.1 General (Mandatory).** This section covers lighting system controls, the connection of ballasts, the maximum lighting power for interior applications, electrical energy consumption, and minimum acceptable lighting equipment for exterior applications.

**Exception:** Dwelling units within commercial buildings shall not be required to comply with Sections C405.2 through C405.5 provided that not less than 75 percent of the permanently installed light fixtures, other than low-voltage lighting, shall be fitted for, and contain only, high efficacy lamps.

**C405.2 Lighting controls (Mandatory).** Lighting systems shall be provided with controls as specified in Sections C405.2.1, C405.2.2, C405.2.3 and C405.2.4.

**C405.2.1 Manual lighting controls.** All buildings shall include manual lighting controls that meet the requirements of Sections C405.2.1.1 and C405.2.1.2.

**C405.2.1.1 Interior lighting controls.** Each area enclosed by walls or floor-to-ceiling partitions shall have at least one manual control for the lighting serving

that area. The required controls shall be located within the area served by the controls or be a remote switch that identifies the lights served and indicates their status.

**Exceptions:**

1. Areas designated as security or emergency areas that need to be continuously lighted.
2. Lighting in stairways or corridors that are elements of the means of egress.

**C405.2.1.2 Light reduction controls.** Each area that is required to have a manual control shall also allow the occupant to reduce the connected lighting load in a reasonably uniform illumination pattern by at least 50 percent. Lighting reduction shall be achieved by one of the following or other *approved* method:

1. Controlling all lamps or luminaires;
2. Dual switching of alternate rows of luminaires, alternate luminaires or alternate lamps;
3. Switching the middle lamp luminaires independently of the outer lamps; or
4. Switching each luminaire or each lamp.

**Exception:** Light reduction controls need not be provided in the following areas and spaces:

1. Areas that have only one luminaire, with rated power less than 100 watts.
2. Areas that are controlled by an occupant-sensing device.
3. Corridors, equipment rooms, storerooms, restrooms, public lobbies, electrical or mechanical rooms.
4. *Sleeping unit* (see Section C405.2.3).
5. Spaces that use less than 0.6 watts per square foot (6.5 W/m<sup>2</sup>).
6. Daylight spaces complying with Section C405.2.2.3.2.

**C405.2.2 Additional lighting controls.** Each area that is required to have a manual control shall also have controls that meet the requirements of Sections C405.2.2.1, C405.2.2.2 and C405.2.2.3.

**Exception:** Additional lighting controls need not be provided in the following spaces:

1. *Sleeping units*.
2. Spaces where patient care is directly provided.
3. Spaces where an automatic shutoff would endanger occupant safety or security.
4. Lighting intended for continuous operation.

**C405.2.2.1 Automatic time switch control devices.** Automatic time switch controls shall be installed to control lighting in all areas of the building.

**Exceptions:**

1. Emergency egress lighting does not need to be controlled by an automatic time switch.

2. Lighting in spaces controlled by occupancy sensors does not need to be controlled by automatic time switch controls.

The automatic time switch control device shall include an override switching device that complies with the following:

1. The override switch shall be in a readily accessible location;
2. The override switch shall be located where the lights controlled by the switch are visible; or the switch shall provide a mechanism which announces the area controlled by the switch;
3. The override switch shall permit manual operation;
4. The override switch, when initiated, shall permit the controlled lighting to remain on for a maximum of 2 hours; and
5. Any individual override switch shall control the lighting for a maximum area of 5,000 square feet (465 m<sup>2</sup>).

**Exception:** Within malls, arcades, auditoriums, single tenant retail spaces, industrial facilities and arenas:

1. The time limit shall be permitted to exceed 2 hours provided the override switch is a captive key device; and
2. The area controlled by the override switch is permitted to exceed 5,000 square feet (465 m<sup>2</sup>), but shall not exceed 20,000 square feet (1860 m<sup>2</sup>).

**C405.2.2.2 Occupancy sensors.** Occupancy sensors shall be installed in all classrooms, conference/meeting rooms, employee lunch and break rooms, private offices, restrooms, storage rooms and janitorial closets, and other spaces 300 square feet (28 m<sup>2</sup>) or less enclosed by floor-to-ceiling height partitions. These automatic control devices shall be installed to automatically turn off lights within 30 minutes of all occupants leaving the space, and shall either be manual on or shall be controlled to automatically turn the lighting on to not more than 50 percent power.

**Exception:** Full automatic-on controls shall be permitted to control lighting in public corridors, stairways, restrooms, primary building entrance areas and lobbies, and areas where manual-on operation would endanger the safety or security of the room or building occupants

**C405.2.2.3 Daylight zone control.** Daylight zones shall be designed such that lights in the daylight zone are controlled independently of general area lighting and are controlled in accordance with either Section C405.2.2.3.1 or Section C405.2.2.3.2. Each daylight control zone shall not exceed 2,500 square feet (232 m<sup>2</sup>). Contiguous daylight zones adjacent to vertical fenestration are allowed to be controlled by a single con-

trolling device provided that they do not include zones facing more than two adjacent cardinal orientations (i.e., north, east, south, west). Daylight zones under skylights more than 15 feet (4572 mm) from the perimeter shall be controlled separately from daylight zones adjacent to vertical fenestration.

**Exception:** Daylight zones enclosed by walls or ceiling height partitions and containing two or fewer light fixtures are not required to have a separate switch for general area lighting.

**C405.2.2.3.1 Manual daylighting controls.** Manual controls shall be installed in daylight zones unless automatic controls are installed in accordance with Section C405.2.2.3.2.

**C405.2.2.3.2 Automatic daylighting controls.** Set-point and other controls for calibrating the lighting control device shall be readily accessible.

Daylighting controls device shall be capable of automatically reducing the lighting power in response to available daylight by either one of the following methods:

1. Continuous dimming using dimming ballasts and daylight-sensing automatic controls that are capable of reducing the power of general lighting in the daylit zone continuously to less than 35 percent of rated power at maximum light output.
2. Stepped dimming using multi-level switching and daylight-sensing controls that are capable of reducing lighting power automatically. The system shall provide a minimum of two control channels per zone and be installed in a manner such that at least one control step is between 50 percent and 70 percent of design lighting power and another control step is no greater than 35 percent of design power.

**C405.2.2.3.3 Multi-level lighting controls.** Where multi-level lighting controls are required by this code, the general lighting in the daylight zone shall be separately controlled by at least one multi-level lighting control that reduces the lighting power in response to daylight available in the space. Where the daylit illuminance in the space is greater than the rated illuminance of the general lighting of daylight zones, the general lighting shall be automatically controlled so that its power draw is no greater than 35 percent of its rated power. The multi-level lighting control shall be located so that calibration and set point adjustment controls are readily accessible and separate from the light sensor.

**C405.2.3 Specific application controls.** Specific application controls shall be provided for the following:

1. Display and accent light shall be controlled by a dedicated control which is independent of the controls for other lighting within the room or space.

2. Lighting in cases used for display case purposes shall be controlled by a dedicated control which is independent of the controls for other lighting within the room or space.
3. Hotel and motel sleeping units and guest suites shall have a master control device at the main room entry that controls all permanently installed luminaires and switched receptacles.
4. Supplemental task lighting, including permanently installed under-shelf or under-cabinet lighting, shall have a control device integral to the luminaires or be controlled by a wall-mounted control device provided the control device is readily accessible.
5. Lighting for nonvisual applications, such as plant growth and food warming, shall be controlled by a dedicated control which is independent of the controls for other lighting within the room or space.
6. Lighting equipment that is for sale or for demonstrations in lighting education shall be controlled by a dedicated control which is independent of the controls for other lighting within the room or space.

**C405.2.4 Exterior lighting controls.** Lighting not designated for dusk-to-dawn operation shall be controlled by either a combination of a photosensor and a time switch, or an astronomical time switch. Lighting designated for dusk-to-dawn operation shall be controlled by an astronomical time switch or photosensor. All time switches shall be capable of retaining programming and the time setting during loss of power for a period of at least 10 hours.

**C405.3 Tandem wiring (Mandatory).** The following luminaires located within the same area shall be tandem wired:

1. Fluorescent luminaires equipped with one, three or odd-numbered lamp configurations, that are recess-mounted within 10 feet (3048 mm) center-to-center of each other.
2. Fluorescent luminaires equipped with one, three or any odd-numbered lamp configuration, that are pendant- or surface-mounted within 1 foot (305 mm) edge-to-edge of each other.

**Exceptions:**

1. Where electronic high-frequency ballasts are used.
2. Luminaires on emergency circuits.
3. Luminaires with no available pair in the same area.

**C405.4 Exit signs (Mandatory).** Internally illuminated exit signs shall not exceed 5 watts per side.

**C405.5 Interior lighting power requirements (Prescriptive).** A building complies with this section if its total connected lighting power calculated under Section C405.5.1 is no greater than the interior lighting power calculated under Section C405.5.2.

**C405.5.1 Total connected interior lighting power.** The total connected interior lighting power (watts) shall be the sum of the watts of all interior lighting equipment as deter-

mined in accordance with Sections C405.5.1.1 through C405.5.1.4.

**Exceptions:**

1. The connected power associated with the following lighting equipment is not included in calculating total connected lighting power.
  - 1.1. Professional sports arena playing field lighting.
  - 1.2. *Sleeping unit* lighting in hotels, motels, boarding houses or similar buildings.
  - 1.3. Emergency lighting automatically off during normal building operation.
  - 1.4. Lighting in spaces specifically designed for use by occupants with special lighting needs including the visually impaired visual impairment and other medical and age-related issues.
  - 1.5. Lighting in interior spaces that have been specifically designated as a registered interior historic landmark.
  - 1.6. Casino gaming areas.
2. Lighting equipment used for the following shall be exempt provided that it is in addition to general lighting and is controlled by an independent control device:
  - 2.1. Task lighting for medical and dental purposes.
  - 2.2. Display lighting for exhibits in galleries, museums and monuments.
3. Lighting for theatrical purposes, including performance, stage, film production and video production.
4. Lighting for photographic processes.
5. Lighting integral to equipment or instrumentation and is installed by the manufacturer.
6. Task lighting for plant growth or maintenance.
7. Advertising signage or directional signage.
8. In restaurant buildings and areas, lighting for food warming or integral to food preparation equipment.
9. Lighting equipment that is for sale.
10. Lighting demonstration equipment in lighting education facilities.
11. Lighting *approved* because of safety or emergency considerations, inclusive of exit lights.
12. Lighting integral to both open and glass-enclosed refrigerator and freezer cases.



- 13. Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions.
- 14. Furniture mounted supplemental task lighting that is controlled by automatic shutoff.

**C405.5.1.1 Screw lamp holders.** The wattage shall be the maximum *labeled* wattage of the luminaire.

**C405.5.1.2 Low-voltage lighting.** The wattage shall be the specified wattage of the transformer supplying the system.

**C405.5.1.3 Other luminaires.** The wattage of all other lighting equipment shall be the wattage of the lighting equipment verified through data furnished by the manufacturer or other *approved* sources.

**C405.5.1.4 Line-voltage lighting track and plug-in busway.** The wattage shall be:

- 1. The specified wattage of the luminaires included in the system with a minimum of 30 W/lin ft. (98 W/lin. m);
- 2. The wattage limit of the system’s circuit breaker; or
- 3. The wattage limit of other permanent current limiting device(s) on the system.

**C405.5.2 Interior lighting power.** The total interior lighting power allowance (watts) is determined according to Table C405.5.2(1) using the Building Area Method, or Table C405.5.2(2) using the Space-by-Space Method, for all areas of the building covered in this permit. For the Building Area Method, the interior lighting power allowance is the floor area for each building area type listed in Table C405.5.2(1) times the value from Table C405.5.2(1) for that area. For the purposes of this method, an “area” shall be defined as all contiguous spaces that accommodate or are associated with a single building area type as listed in Table C405.5.2(1). Where this method is used to calculate the total interior lighting power for an entire building, each building area type shall be treated as a separate area. For the Space-by-Space Method, the interior lighting power allowance is determined by multiplying the floor area of each space times the value for the space type in Table C405.5.2(2) that most closely represents the proposed use of the space, and then summing the lighting power allowances for all spaces. Tradeoffs among spaces are permitted.

**C405.6 Exterior lighting (Mandatory).** Where the power for exterior lighting is supplied through the energy service to the building, all exterior lighting, other than low-voltage landscape lighting, shall comply with Sections C405.6.1 and C405.6.2.

**Exception:** Where *approved* because of historical, safety, signage or emergency considerations.

**C405.6.1 Exterior building grounds lighting.** All exterior building grounds luminaires that operate at greater than 100 watts shall contain lamps having a minimum efficacy of 60 lumens per watt unless the luminaire is controlled by a motion sensor or qualifies for one of the exceptions under Section C405.6.2.

**TABLE C405.5.2(1)  
INTERIOR LIGHTING POWER ALLOWANCES:  
BUILDING AREA METHOD**

BUILDING AREA TYPE	LPD (w/ft²)
Automotive facility	0.9
Convention center	1.2
Courthouse	1.2
Dining: bar lounge/leisure	1.3
Dining: cafeteria/fast food	1.4
Dining: family	1.6
Dormitory	1.0
Exercise center	1.0
Fire station	0.8
Gymnasium	1.1
Health care clinic	1.0
Hospital	1.2
Hotel	1.0
Library	1.3
Manufacturing facility	1.3
Motel	1.0
Motion picture theater	1.2
Multifamily	0.7
Museum	1.1
Office	0.9
Parking garage	0.3
Penitentiary	1.0
Performing arts theater	1.6
Police station	1.0
Post office	1.1
Religious building	1.3
Retail	1.4
School/university	1.2
Sports arena	1.1
Town hall	1.1
Transportation	1.0
Warehouse	0.6
Workshop	1.4

**TABLE C405.5.2(2)  
INTERIOR LIGHTING POWER ALLOWANCES:  
SPACE-BY-SPACE METHOD**

COMMON SPACE-BY-SPACE TYPES	LPD (w/ft <sup>2</sup> )
Atrium – First 40 feet in height	0.03 per ft. ht.
Atrium – Above 40 feet in height	0.02 per ft. ht.
Audience/seating area – permanent	
For auditorium	0.9
For performing arts theater	2.6
For motion picture theater	1.2
Classroom/lecture/training	1.30
Conference/meeting/multipurpose	1.2
Corridor/transition	0.7
Dining area	
Bar/lounge/leisure dining	1.40
Family dining area	1.40
Dressing/fitting room performing arts theater	1.1
Electrical/mechanical	1.10
Food preparation	1.20
Laboratory for classrooms	1.3
Laboratory for medical/industrial/research	1.8
Lobby	1.10
Lobby for performing arts theater	3.3
Lobby for motion picture theater	1.0
Locker room	0.80
Lounge recreation	0.8
Office – enclosed	1.1
Office – open plan	1.0
Restroom	1.0
Sales area	1.6 <sup>a</sup>
Stairway	0.70
Storage	0.8
Workshop	1.60
Courthouse/police station/penetentiary	
Courtroom	1.90
Confinement cells	1.1
Judge chambers	1.30
Penitentiary audience seating	0.5
Penitentiary classroom	1.3
Penitentiary dining	1.1
<b>BUILDING SPECIFIC SPACE-BY-SPACE TYPES</b>	
Automotive – service/repair	0.70
Bank/office – banking activity area	1.5
Dormitory living quarters	1.10
Gymnasium/fitness center	
Fitness area	0.9
Gymnasium audience/seating	0.40
Playing area	1.40

(continued)

**TABLE C405.5.2(2)—continued  
INTERIOR LIGHTING POWER ALLOWANCES:  
SPACE-BY-SPACE METHOD**

COMMON SPACE-BY-SPACE TYPES	LPD (w/ft <sup>2</sup> )
Healthcare clinic/hospital	
Corridors/transition	1.00
Exam/treatment	1.70
Emergency	2.70
Public and staff lounge	0.80
Medical supplies	1.40
Nursery	0.9
Nurse station	1.00
Physical therapy	0.90
Patient room	0.70
Pharmacy	1.20
Radiology/imaging	1.3
Operating room	2.20
Recovery	1.2
Lounge/recreation	0.8
Laundry – washing	0.60
Hotel	
Dining area	1.30
Guest rooms	1.10
Hotel lobby	2.10
Highway lodging dining	1.20
Highway lodging guest rooms	1.10
Library	
Stacks	1.70
Card file and cataloguing	1.10
Reading area	1.20
Manufacturing	
Corridors/transition	0.40
Detailed manufacturing	1.3
Equipment room	1.0
Extra high bay (> 50-foot floor-ceiling height)	1.1
High bay (25- – 50-foot floor-ceiling height)	1.20
Low bay (< 25-foot floor-ceiling height)	1.2
Museum	
General exhibition	1.00
Restoration	1.70
Parking garage – garage areas	0.2
Convention center	
Exhibit space	1.50
Audience/seating area	0.90
Fire stations	
Engine room	0.80
Sleeping quarters	0.30
Post office	
Sorting area	0.9
Religious building	
Fellowship hall	0.60
Audience seating	2.40
Worship pulpit/choir	2.40
Retail	
Dressing/fitting area	0.9
Mall concourse	1.6
Sales area	1.6 <sup>a</sup>

(continued)

**TABLE C405.5.2(2)—continued  
INTERIOR LIGHTING POWER ALLOWANCES:  
SPACE-BY-SPACE METHOD**

BUILDING SPECIFIC SPACE-BY-SPACE TYPES	LPD (w/ft <sup>2</sup> )
Sports arena	
Audience seating	0.4
Court sports area – Class 4	0.7
Court sports area – Class 3	1.2
Court sports area – Class 2	1.9
Court sports area – Class 1	3.0
Ring sports area	2.7
Transportation	
Air/train/bus baggage area	1.00
Airport concourse	0.60
Terminal – ticket counter	1.50
Warehouse	
Fine material storage	1.40
Medium/bulky material	0.60

For SI: 1 foot = 304.8 mm, 1 watt per square foot = 11 W/m<sup>2</sup>.

a. Where lighting equipment is specified to be installed to highlight specific merchandise in addition to lighting equipment specified for general lighting and is switched or dimmed on circuits different from the circuits for general lighting, the smaller of the actual wattage of the lighting equipment installed specifically for merchandise, or additional lighting power as determined below shall be added to the interior lighting power determined in accordance with this line item.

Calculate the additional lighting power as follows:

Additional Interior Lighting Power Allowance = 500 watts + (Retail Area 1 × 0.6 W/ft<sup>2</sup>) + (Retail Area 2 × 0.6 W/ft<sup>2</sup>) + (Retail Area 3 × 1.4 W/ft<sup>2</sup>) + (Retail Area 4 × 2.5 W/ft<sup>2</sup>).

where:

Retail Area 1 = The floor area for all products not listed in Retail Area 2, 3 or 4.

Retail Area 2 = The floor area used for the sale of vehicles, sporting goods and small electronics.

Retail Area 3 = The floor area used for the sale of furniture, clothing, cosmetics and artwork.

Retail Area 4 = The floor area used for the sale of jewelry, crystal and china.

**Exception:** Other merchandise categories are permitted to be included in Retail Areas 2 through 4 above, provided that justification documenting the need for additional lighting power based on visual inspection, contrast, or other critical display is *approved* by the authority having jurisdiction.

**C405.6.2 Exterior building lighting power.** The total exterior lighting power allowance for all exterior building applications is the sum of the base site allowance plus the individual allowances for areas that are to be illuminated and are permitted in Table C405.6.2(2) for the applicable lighting zone. Tradeoffs are allowed only among exterior lighting applications listed in Table C405.6.2(2), Tradable Surfaces section. The lighting zone for the building exterior is determined from Table C405.6.2(1) unless otherwise specified by the local jurisdiction. Exterior lighting for all applications (except those included in the exceptions to Section C405.6.2) shall comply with the requirements of Section C405.6.1.

**Exception:** Lighting used for the following exterior applications is exempt where equipped with a control

device independent of the control of the nonexempt lighting:

1. Specialized signal, directional and marker lighting associated with transportation;
2. Advertising signage or directional signage;
3. Integral to equipment or instrumentation and is installed by its manufacturer;
4. Theatrical purposes, including performance, stage, film production and video production;
5. Athletic playing areas;
6. Temporary lighting;
7. Industrial production, material handling, transportation sites and associated storage areas;
8. Theme elements in theme/amusement parks; and
9. Used to highlight features of public monuments and registered historic landmark structures or buildings.

**TABLE C405.6.2(1)  
EXTERIOR LIGHTING ZONES**

LIGHTING ZONE	DESCRIPTION
1	Developed areas of national parks, state parks, forest land, and rural areas
2	Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed use areas
3	All other areas
4	High-activity commercial districts in major metropolitan areas as designated by the local land use planning authority

**C405.7 Electrical energy consumption (Mandatory).** In buildings having individual dwelling units, provisions shall be made to determine the electrical energy consumed by each tenant by separately metering individual dwelling units.

**SECTION C406  
ADDITIONAL EFFICIENCY PACKAGE OPTIONS**

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

1. Efficient HVAC Performance in accordance with Section C406.2.
2. Efficient Lighting System in accordance with Section C406.3.
3. On-Site Supply of Renewable Energy in accordance with Section C406.4.

Individual tenant spaces shall comply with either Section C406.2 or Section C406.3 unless documentation can be provided that demonstrates compliance with Section C406.4 for the entire building

**TABLE C405.6.2(2)  
INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS**

		LIGHTING ZONES			
		Zone 1	Zone 2	Zone 3	Zone 4
Base Site Allowance (Base allowance is usable in tradable or nontradable surfaces.)		500 W	600 W	750 W	1300 W
Tradable Surfaces (Lighting power densities for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs and outdoor sales areas are tradable.)	<b>Uncovered Parking Areas</b>				
	Parking areas and drives	0.04 W/ft <sup>2</sup>	0.06 W/ft <sup>2</sup>	0.10 W/ft <sup>2</sup>	0.13 W/ft <sup>2</sup>
	<b>Building Grounds</b>				
	Walkways less than 10 feet wide	0.7 W/linear foot	0.7 W/linear foot	0.8 W/linear foot	1.0 W/linear foot
	Walkways 10 feet wide or greater, plaza areas special feature areas	0.14 W/ft <sup>2</sup>	0.14 W/ft <sup>2</sup>	0.16 W/ft <sup>2</sup>	0.2 W/ft <sup>2</sup>
	Stairways	0.75 W/ft <sup>2</sup>	1.0 W/ft <sup>2</sup>	1.0 W/ft <sup>2</sup>	1.0 W/ft <sup>2</sup>
	Pedestrian tunnels	0.15 W/ft <sup>2</sup>	0.15 W/ft <sup>2</sup>	0.2 W/ft <sup>2</sup>	0.3 W/ft <sup>2</sup>
	<b>Building Entrances and Exits</b>				
	Main entries	20 W/linear foot of door width	20 W/linear foot of door width	30 W/linear foot of door width	30 W/linear foot of door width
	Other doors	20 W/linear foot of door width	20 W/linear foot of door width	20 W/linear foot of door width	20 W/linear foot of door width
	Entry canopies	0.25 W/ft <sup>2</sup>	0.25 W/ft <sup>2</sup>	0.4 W/ft <sup>2</sup>	0.4 W/ft <sup>2</sup>
	<b>Sales Canopies</b>				
	Free-standing and attached	0.6 W/ft <sup>2</sup>	0.6 W/ft <sup>2</sup>	0.8 W/ft <sup>2</sup>	1.0 W/ft <sup>2</sup>
	<b>Outdoor Sales</b>				
	Open areas (including vehicle sales lots)	0.25 W/ft <sup>2</sup>	0.25 W/ft <sup>2</sup>	0.5 W/ft <sup>2</sup>	0.7 W/ft <sup>2</sup>
Street frontage for vehicle sales lots in addition to "open area" allowance	No allowance	10 W/linear foot	10 W/linear foot	30 W/linear foot	
Nontradable Surfaces (Lighting power density calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the "Tradable Surfaces" section of this table.)	Building facades	No allowance	0.1 W/ft <sup>2</sup> for each illuminated wall or surface or 2.5 W/linear foot for each illuminated wall or surface length	0.15 W/ft <sup>2</sup> for each illuminated wall or surface or 3.75 W/linear foot for each illuminated wall or surface length	0.2 W/ft <sup>2</sup> for each illuminated wall or surface or 5.0 W/linear foot for each illuminated wall or surface length
	Automated teller machines and night depositories	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location
	Entrances and gatehouse inspection stations at guarded facilities	0.75 W/ft <sup>2</sup> of covered and uncovered area	0.75 W/ft <sup>2</sup> of covered and uncovered area	0.75 W/ft <sup>2</sup> of covered and uncovered area	0.75 W/ft <sup>2</sup> of covered and uncovered area
	Loading areas for law enforcement, fire, ambulance and other emergency service vehicles	0.5 W/ft <sup>2</sup> of covered and uncovered area	0.5 W/ft <sup>2</sup> of covered and uncovered area	0.5 W/ft <sup>2</sup> of covered and uncovered area	0.5 W/ft <sup>2</sup> of covered and uncovered area
	Drive-up windows/doors	400 W per drive-through	400 W per drive-through	400 W per drive-through	400 W per drive-through
	Parking near 24-hour retail entrances	800 W per main entry	800 W per main entry	800 W per main entry	800 W per main entry

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m<sup>2</sup>.

**TABLE C406.2(1)**  
**UNITARY AIR CONDITIONERS AND CONDENSING UNITS, ELECTRICALLY OPERATED, EFFICIENCY REQUIREMENTS**

EQUIPMENT TYPE	SIZE CATEGORY	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY <sup>a</sup>	
			CLIMATE ZONES 1 - 5	CLIMATE ZONES 6 - 8
Air conditioners, air cooled	< 65,000 Btu/h	Split system	15.0 SEER 12.5 EER	14 SEER 12 EER
		Single package	15.0 SEER 12.0 EER	14.0 SEER 11.6 EER
	≥ 65,000 Btu/h and < 240,000 Btu/h	Split system and single package	12.0 EER <sup>b</sup> 12.54 IEER <sup>b</sup>	11.5 EER <sup>b</sup> 12.0 IEER <sup>b</sup>
	≥ 240,000 Btu/h and < 760,000 Btu/h	Split system and single package	10.8 EER <sup>b</sup> 11.3 IEER <sup>b</sup>	10.5 EER <sup>b</sup> 11.0 IEER <sup>b</sup>
	≥ 760,000 Btu/h	—	10.2 EER <sup>b</sup> 10.7 IEER <sup>b</sup>	9.7 EER <sup>b</sup> 10.2 IEER <sup>b</sup>
Air conditioners, water and evaporatively cooled	—	Split system and single package	14.0 EER	14.0 EER

For SI: 1 British thermal unit per hour = 0.2931 W.

a. IEERs are only applicable to equipment with capacity modulation.

b. Deduct 0.2 from the required EERs and IPLVs for units with a heating section other than electric resistance heat.

**TABLE C406.2(2)**  
**UNITARY AND APPLIED HEAT PUMPS, ELECTRICALLY OPERATED, EFFICIENCY REQUIREMENTS**

EQUIPMENT TYPE	SIZE CATEGORY	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY <sup>a</sup>	
			CLIMATE ZONES 1 - 5	CLIMATE ZONES 6 - 8
Air cooled (Cooling mode)	< 65,000 Btu/h	Split system	15.0 SEER, 12.5 EER	14.0 SEER, 12.0 EER
		Single package	15.0 SEER, 12.0 EER	14.0 SEER 11.6 EER
	≥ 65,000 Btu/h and < 240,000 Btu/h	Split system and single package	12.0 SEER, 12.4 EER	11.5 EER <sup>b</sup> , 12.0 IEER <sup>b</sup>
	≥ 240,000 Btu/h	Split system and single package	12.0 SEER, 12.4 EER	10.5 EER <sup>b</sup> , 10.5 IEER <sup>b</sup>
Water sources (Cooling mode)	< 135,000 Btu/h	85°F entering water	14.0 EER	14.0 EER
Air cooled (Heating mode)	< 65,000 Btu/h (Cooling capacity)	Split system	9.0 HSPF	8.5 HSPF
		Single package	8.5 HSPF	8.0 HSPF
	≥ 65,000 Btu/h and < 135,000 Btu/h (Cooling capacity)	47°F db/43°F wb outdoor air	3.4 COP	3.4 COP
		17°F db/15°F wb outdoor air	2.4 COP	2.4 COP
	≥ 135,000 Btu/h (Cooling capacity)	47°F db/43°F wb outdoor air	3.2 COP	3.2 COP
77°F db/15°F wb outdoor air		2.1 COP	2.1 COP	
Water sources (Heating mode)	< 135,000 Btu/h (Cooling capacity)	70°F entering water	4.6 COP	4.6 COP

For SI: °C = [(°F) - 32] / 1.8, 1 British thermal unit per hour = 0.2931 W.

db = dry-bulb temperature, °F; wb = wet-bulb temperature, °F.

a. IEERs and Part load rating conditions are only applicable to equipment with capacity modulation.

b. Deduct 0.2 from the required EERs and IPLVs for units with a heating section other than electric resistance heat.

**TABLE C406.2(3)**  
**PACKAGED TERMINAL AIR CONDITIONERS AND PACKAGED TERMINAL HEAT PUMPS**

EQUIPMENT TYPE	SIZE CATEGORY	MINIMUM EFFICIENCY
Air conditioners and heat pumps (cooling mode)	< 7,000 Btu/h	11.9 EER
	7,000 Btu/h and < 10,000 Btu/h	11.3 EER
	10,000 Btu/h and ≤ 13,000 Btu/h	10.7 EER
	> 13,000 Btu/h	9.5 EER

**TABLE C406.2(4)**  
**WARM AIR FURNACES AND COMBINATION WARM AIR FURNACES/AIR-CONDITIONING UNITS,**  
**WARM AIR DUCT FURNACES AND UNIT HEATERS, EFFICIENCY REQUIREMENTS**

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE
Warm air furnaces, gas fired <sup>a</sup>	< 225,000 Btu/h	—	For Climate Zones 1 and 2 NR	DOE 10 CFR Part 430 or ANSI Z21.47
			For Climate Zones 3 and 4 90 AFUE or 90 $E_t^c$	
			For Climate Zones 4 – 8 92 AFUE or 92 $E_t^c$	
	≥ 225,000 Btu/h	Maximum capacity	90% $E_c^b$	ANSI Z21.47
Warm air furnaces, oil fired <sup>a</sup>	< 225,000 Btu/h	—	For Climate Zones 1 and 2 NR	DOE 10 CFR Part 430 or UL 727
			For Climate Zones 3 – 8 85 AFUE or 85 $E_t^c$	
	≥ 225,000 Btu/h	Maximum capacity	85% $E_t^b$	UL 727
Warm air duct furnaces, gas fired <sup>a</sup>	All capacities	Maximum capacity	90% $E_c$	ANSI Z83.8
Warm air unit heaters, gas fired	All capacities	Maximum capacity	90% $E_c$	ANSI Z83.8
Warm air unit heaters, oil fired	All capacities	Maximum capacity	90% $E_c$	UL 731

For SI: 1 British thermal unit per hour = 0.2931 W.

$E_t$  = Thermal efficiency.  $E_c$  = Combustion efficiency (100 percent less flue losses).

- a. Efficient furnace fan: Fossil fuel furnaces in climate zones 3 to 8 shall have a furnace electricity ratio not greater than 2 percent and shall include a manufacturer's designation of the furnace electricity ratio.
- b. Units shall also include an IID (intermittent ignition device), have jacket losses not exceeding 0.75 percent of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.
- c. Where there are two ratings for units not covered by NAECA (3-phase power or cooling capacity greater than or equal to 65,000 Btu/h [19 kW]), units shall be permitted to comply with either rating.

**TABLE C406.2(5)**  
**BOILER, EFFICIENCY REQUIREMENTS**

EQUIPMENT TYPE	FUEL	SIZE CATEGORY	TEST PROCEEDURE	MINIMUM EFFICIENCY
Steam	Gas	< 300,000 Btu/h	DOE 10 CFR Part 430	83% AFUE
		> 300,000 Btu / h and > 2.5 m Btu/h	DOE 10 CFR Part 431	81% $E_t$
		>2.5 m Btu/h		82% $E_c$
	Oil	< 300,000 Btu/h	DOE 10 CFR Part 430	85% AFUE
		> 300,000 Btu/h and > 2.5 m Btu/h	DOE 10 CFR Part 431	83% $E_t$
		>2.5 m Btu/h		84% $E_c$
Hot water	Gas	< 300,000 Btu/h	DOE 10 CFR Part 430	97% AFUE
		> 300,000 Btu/h and > 2.5 m Btu/h	DOE 10 CFR Part 431	97% $E_t$
		>2.5 m Btu/h		94% $E_c$
	Oil	< 300,000 Btu/h	DOE 10 CFR Part 430	90% AFUE
		> 300,000 Btu/h and > 2.5 m Btu/h	DOE 10 CFR Part 431	88% $E_t$
		>2.5 m Btu/h		87% $E_c$

For SI: 1 British thermal unit per hour = 0.2931 W.

$E_t$  = Thermal efficiency.  $E_c$  = Combustion efficiency (100 percent less flue losses).

**TABLE C406.2(6)  
CHILLERS—EFFICIENCY REQUIREMENTS**

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	MINIMUM EFFICIENCY <sup>c</sup> (I-P)				Test Procedure <sup>b</sup>
			Path A		Path B <sup>c</sup>		
			Full Load	IPLV	Full Load	IPLV	
Air-cooled chillers with condenser, electrically operated	< 150 tons	EER	10.000	12.500	NA	NA	AHRI 550/590 <sup>f</sup>
	≥ 150 tons	EER	10.000	12.750	NA	NA	
Air-cooled without condenser, electrical operated	All capacities	EER	Condenserless units shall be rated with matched condensers				AHRI 550/590 <sup>f</sup>
Water-cooled, electrically operated, positive displacement (reciprocating)	All capacities	kw/ton	Reciprocating units required to comply with water cooled positive displacement requirements				AHRI 550/590 <sup>f</sup>
Water-cooled electrically operated, positive displacement	< 75 tons	kw/ton	0.780	0.630	0.800	0.600	AHRI 550/590 <sup>f</sup>
	≥ 75 tons and < 150 tons	kw/ton	0.775	0.615	0.790	0.586	
	≥ 150 tons and < 300 tons	kw/ton	0.680	0.580	0.718	0.540	
	≥ 300 tons	kw/ton	0.620	0.540	0.639	0.490	
Water-cooled electrically operated, centrifugal <sup>d</sup>	< 150 tons	kw/ton	0.634	0.596	0.639	0.450	AHRI 550/590 <sup>f</sup>
	≥ 150 tons and < 300 tons	kw/ton	0.634	0.596	0.639	0.450	
	≥ 300 tons and < 600 tons	kw/ton	0.576	0.549	0.600	0.400	
	≥ 600 tons	kw/ton	0.570	0.539	0.590	0.400	
Air-cooled absorption single effect <sup>e</sup>	All capacities	COP	0.600	NR	NA	NA	AHRI 560
Water-cooled absorption single effect <sup>e</sup>	All capacities	COP	0.700	NR	NA	NA	
Absorption double effect indirect-fired	All capacities	COP	1.000	1.050	NA	NA	
Absorption double effect direct fired	All capacities	COP	1.000	1.000	NA	NA	

For SI: 1 Ton = 3516 W.

NA = Not applicable and cannot be used for compliance. NR = No minimum requirements.

- a. Compliance with this standard can be obtained by meeting the minimum requirements of Path A or Path B. However both the full load and IPLV shall be met to fulfill the requirements of Path A and Path B.
- b. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
- c. Path B is intended for applications with significant operating time at part load. All Path B machines shall be equipped with demand limiting capable controls.
- d. The chiller equipment requirements do not apply for chillers used in low-temperature applications where the design leaving fluid temperature is greater than 40°F.
- e. Only allowed to be used in heat recovery applications.

f. Packages that are not designed for operation at ARI Standard 550/590 test conditions (and, thus, cannot be tested to meet the requirements of Table C-3) of 44°F leaving chilled-water temperature and 85°F entering condenser-water temperature with 3 gpm/ton condenser-water flow shall have maximum full-load kW/ton and NPLV ratings adjusted using the following equation:

$$\text{Adjusted maximum full load kW/ton rating} = (\text{full load kW/ton from Table C-3})/K_{adj}$$

$$\text{Adjusted maximum NPLV rating} = (\text{IPLV from Table C-3})/K_{adj}$$

where:

$$K_{adj} = 6.174722 - 0.303668(X) + 0.00629466(X)^2 - 0.000045780(X)^3$$

$$X = DT_{std} + \text{LIFT } (^\circ\text{F})$$

$$DT_{std} = [(24 + (\text{full load kW/ton from Table C-3}) \times 6.83)]/\text{flow } (^\circ\text{F})$$

$$\text{Flow} = \text{condenser-water flow (gpm)} / \text{cooling full load capacity (tons)}$$

$$\text{LIFT} = \text{CEWT} - \text{CLWT } (^\circ\text{F})$$

$$\text{CEWT} = \text{full load entering condenser-water temperature } (^\circ\text{F})$$

$$\text{CLWT} = \text{full load leaving chilled-water temperature } (^\circ\text{F})$$

The adjusted full load and NPLV values are only applicable over the following full-load design ranges:

Minimum leaving chilled-water temperature: 38°F

Maximum condenser entering water temperature: 102°F

Condenser-water flow: 1 to 6 gpm/ton

$$X \geq 39^\circ\text{F and } \leq 60^\circ\text{F}$$

**TABLE C406.2(7)  
ABSORPTION CHILLERS—EFFICIENCY REQUIREMENTS**

EQUIPMENT TYPE	MINIMUM EFFICIENCY FULL LOAD COP (IPLV)
Air cooled, single effect	0.60, allowed only in heat recovery applications
Water cooled, single effect	0.70, allowed only in heat recovery applications
Double effect – direct fired	1.0 (1.05 )
Double effect – indirect fired	1.20

**C406.2 Efficient HVAC performance.** Equipment shall meet the minimum efficiency requirements of Tables C406.2.(1) through C406.2(7) in addition to the requirements in Section C403. This section shall only be used where the equipment efficiencies in Tables C406.2(1) through C406.2(7) are greater than the equipment efficiencies listed in Table C403.2.3(1) through 403.2.3(7) for the equipment type.

**C406.3 Efficient lighting system.** Whole building lighting power density (Watts/sf) shall comply with the requirements of Section C406.3.1.

**C406.3.1 Reduced lighting power density.** The total interior lighting power (watts) of the building shall be determined by using the reduced whole building interior lighting power in Table C406.3 times the floor area for the building types.

**C406.4 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 1.75 Btu (1850 W), or 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 this chapter.

**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 C402.4, 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 sources collected on site shall be omitted from the annual 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.

**TABLE C406.3  
REDUCED INTERIOR LIGHTING POWER**

BUILDING AREA TYPE <sup>a</sup>	LPD (w/ft <sup>2</sup> )
Automotive facility	0.82
Convention center	1.08
Courthouse	1.05
Dining: bar lounge/leisure	0.99
Dining: cafeteria/fast food	0.90
Dining: family	0.89
Dormitory	0.61
Exercise center	0.88
Fire station	0.71
Gymnasium	1.0
Health care clinic	0.87
Hospital	1.10
Library	1.18
Manufacturing facility	1.11
Hotel/motel	0.88
Motion picture theater	0.83
Museum	1.06
Multifamily	0.60
Office	0.90/0.85 <sup>b</sup>
Performing arts theater	1.39
Police station	0.96
Post office	0.87
Religious building	1.05
Retail	1.4/1.3 <sup>b</sup>
School/ university	0.99
Sports arena	0.78
Town hall	0.92
Transportation	0.77
Warehouse <sup>c</sup>	0.6
Workshop	1.2

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m<sup>2</sup>.

- a. In cases where both a general building area type and a more specific building area type are listed, the more specific building area type shall apply.
- b. First LPD value applies if no less than 30 percent of conditioned floor area is in daylight zones. Automatic daylighting controls shall be installed in daylight zones and shall meet the requirements of Section C405.2.2.3. In all other cases, second LPD value applies.
- c. No less than 70 percent of the floor area shall be in the daylight zone. Automatic daylighting controls shall be installed in daylight zones and shall meet the requirements of Section C405.2.2.3.



**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.** Compliance software tools shall generate a report that documents 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 listed 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; and
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 report(s) 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; and
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 C402.2.

**C407.5.2 Thermal blocks.** The *standard reference design* and *proposed design* shall be analyzed using identical ther-

mal 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 no 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 proportionately 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.

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

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.
Roofs	Type: Insulation entirely above deck Gross area: same as proposed U-factor: from Table C402.1.2 Solar absorptance: 0.75 Emittance: 0.90	As proposed As proposed As proposed As proposed As proposed
Walls, above-grade	Type: Mass wall if proposed wall is mass; otherwise steel-framed wall Gross area: same as proposed U-factor: from Table C402.1.2 Solar absorptance: 0.75 Emittance: 0.90	As proposed As proposed As proposed As proposed As proposed
Walls, below-grade	Type: Mass wall Gross area: same as proposed U-Factor: from Table C402.1.2 with insulation layer on interior side of walls	As proposed As proposed As proposed
Floors, above-grade	Type: joist/framed floor Gross area: same as proposed U-factor: from Table C402.1.2	As proposed As proposed As proposed
Floors, slab-on-grade	Type: Unheated F-factor: from Table C402.1.2	As proposed As proposed
Doors	Type: Swinging Area: Same as proposed U-factor: from Table C402.2	As proposed As proposed As proposed
Glazing	Area 1. The proposed glazing area; where the proposed glazing area is less than 40 percent of above-grade wall area. 2. 40 percent of above-grade wall area; where the proposed glazing area is 40 percent or more of the above-grade wall area. U-factor: from Table C402.3 SHGC: from Table C402.3 except that for climates with no requirement (NR) SHGC = 0.40 shall be used External shading and PF: None	As proposed  As proposed As proposed As proposed
Skylights	Area 1. The proposed skylight area; where the proposed skylight area is less than 3 percent of gross area of roof assembly. 2. 3 percent of gross area of roof assembly; where the proposed skylight area is 3 percent or more of gross area of roof assembly U-factor: from Table C402.3 SHGC: from Table C402.3 except that for climates with no requirement (NR) SHGC = 0.40 shall be used.	As proposed  As proposed As proposed
Lighting, interior	The interior lighting power shall be determined in accordance with Section C405.5.2. Where the occupancy of the building is not known, the lighting power density shall be 1.0 Watt per square foot (10.73 W/m <sup>2</sup> ) 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 C405.6.2(2). Areas and dimensions of tradable and nontradable surfaces shall be the same as proposed.	As proposed

(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	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 C403.2.5.
Heating systems	Fuel type: same as proposed design Equipment type <sup>a</sup> : from Tables C407.5.1(2) and C407.5.1(3) Efficiency: from Tables C403.2.3(4) and C403.2.3(5) 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 As proposed As proposed As proposed
Cooling systems	Fuel type: same as proposed design Equipment type <sup>c</sup> : from Tables C407.5.1(2) and C407.5.1(3) Efficiency: from Tables C403.2.3(1), C403.2.3(2) and C403.2.3(3) 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. Economizer <sup>d</sup> : same as proposed, in accordance with Section C403.4.1.	As proposed As proposed As proposed As proposed As proposed
Service water heating	Fuel type: same as proposed Efficiency: from Table C404.2 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 As proposed As proposed

- 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 C403.3.1(1), and if no economizer exists or is specified in the proposed design, then a supply air economizer shall be provided in accordance with Section C403.4.1.

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

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

- a. Select “water/ground” if the proposed design system condenser is water or evaporatively cooled; select “air/none” if 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.” If 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 if 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 if 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.

**TABLE C407.5.1(3)**  
**SPECIFICATIONS FOR THE STANDARD REFERENCE DESIGN HVAC SYSTEM DESCRIPTIONS**

SYSTEM NO.	SYSTEM TYPE	FAN CONTROL	COOLING TYPE	HEATING TYPE
1	Variable air volume with parallel fan-powered boxes <sup>a</sup>	VAV <sup>d</sup>	Chilled water <sup>e</sup>	Electric resistance
2	Variable air volume with reheat <sup>b</sup>	VAV <sup>d</sup>	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 <sup>d</sup>	Direct expansion <sup>c</sup>	Electric resistance
4	Packaged variable air volume with reheat <sup>b</sup>	VAV <sup>d</sup>	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

For SI: 1 foot = 304.8 mm, 1 cfm/ft<sup>2</sup> = 0.0004719, 1 Btu/h = 0.293/W, °C = [(°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 C403.4.5, Exception 5. 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:** Constant volume can be modeled if the system qualifies for Exception 1, Section C403.4.5. When the proposed design system has a supply, return or relief fan motor 25 horsepower (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. If 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 C403.4.2 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 C403.4.3.4. Pump system power for each pumping system shall be the same as the proposed design; if 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 C403.4.3.4. The heat rejection device shall be an axial fan cooling tower with two-speed fans if required in Section C403.4.4. 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; if 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 if 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 C403.4.3.4. Pump system power for each pumping system shall be the same as the proposed design; if 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 C403.4.3.4.
- 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 if required in Section C403.4.2. 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. If 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 if 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; if the proposed design has no pumps, the standard reference design pump power shall be 22 W/gpm, which is equal to a 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 C403.4.3.4.
- 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. If 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.

**TABLE C407.5.1(4)  
NUMBER OF CHILLERS**

TOTAL CHILLER PLANT CAPACITY	NUMBER OF CHILLERS
≤ 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
≤ 100 tons	Reciprocating	Single-effect absorption, direct fired
> 100 tons, < 300 tons	Screw	Double-effect absorption, direct fired
≥ 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. Computer generation of the *standard reference design* using only the input for the *proposed design*. The calculation procedure shall not allow the user to directly modify the building component characteristics of the *standard reference design*.
2. Building operation for a full calendar year (8,760 hours).
3. 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.
4. Ten or more thermal zones.
5. Thermal mass effects.
6. Hourly variations in occupancy, illumination, receptacle loads, thermostat settings, mechanical ventilation, HVAC equipment availability, service hot water usage and any process loads.
7. Part-load performance curves for mechanical equipment.
8. Capacity and efficiency correction curves for mechanical heating and cooling equipment.
9. 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 (e.g., *R*-value, *U*-factor, SHGC, HSPF, AFUE, SEER, EF, etc.).

**C407.6.1 Specific approval.** Performance analysis tools meeting the applicable subsections of Section C407 and tested according to ASHRAE Standard 140 shall be per-

mitted 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.

## 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 commissioning and completion requirements.** Prior to passing the final mechanical inspection, the *registered design professional* shall provide evidence of mechanical systems *commissioning* and completion in accordance 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 and made available to the *code official* upon request in accordance with Sections C408.2.4 and C408.2.5.

**Exception:** The following systems are exempt from the commissioning requirements:

1. Mechanical systems in buildings where the total mechanical equipment capacity is less than 480,000 Btu/h (140 690 W) cooling capacity and 600,000 Btu/h (175 860 W) heating capacity.
2. Systems included in Section C403.3 that serve dwelling units and sleeping units in hotels, motels, boarding houses or similar 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. At a minimum, 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 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 (0.74 kW), fan speed shall be adjusted to meet design flow conditions.

**Exception:** Fans with fan motors of 1 hp (0.74 kW) or less.

\*\*

**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:**

1. Pumps with pump motors of 5 hp (3.7 kW) or less.
2. Where throttling results in no greater than five 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; and
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 control systems shall be tested to document that control devices, components, equipment, and systems are calibrated, 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. 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 pass the final mechanical inspection until such time as the *code official* has received a letter of transmittal from the *building* owner acknowledging that the *building* owner 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* 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 controls system maintenance and calibration information, including wiring diagrams, schematics, and control sequence descriptions. Desired or field-determined setpoints shall be permanently recorded on control drawings at control devices or, for digital control systems, in system programming instructions.
5. A narrative of how each system is intended to operate, including recommended setpoints.

**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 and shall include:

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 which 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 Section C408.3.

**C408.3.1 Functional testing.** Testing shall ensure that control hardware and software are calibrated, adjusted, programmed and in proper working condition in accor-

dance with the construction documents and manufacturer's installation instructions. The construction documents shall state the party who will conduct the required functional testing. Where required by the code official, an approved party independent from the design or construction of the project shall be responsible for the functional testing and shall provide documentation to the code official certifying that the installed lighting controls meet the provisions of Section C405.

Where occupant sensors, time switches, programmable schedule controls, photosensors or daylighting controls are installed, the following procedures shall be performed:

1. Confirm that the placement, sensitivity and time-out adjustments for occupant sensors yield acceptable performance.
2. Confirm that the time switches and programmable schedule controls are programmed to turn the lights off.
3. Confirm that the placement and sensitivity adjustments for photosensor controls reduce electric light based on the amount of usable daylight in the space as specified.

\*\*