

CHAPTER 8

BUILDING DESIGN FOR COMMERCIAL BUILDINGS

SECTION 801 GENERAL

801.1 Scope. The requirements contained in this chapter are applicable to commercial buildings, or portions of commercial buildings. These commercial buildings shall meet either the requirements of ASHRAE/IESNA Standard 90.1, *Energy Standard for Buildings Except for Low-Rise Residential Buildings*, or the requirements contained in this chapter.

801.2 Application. The requirements in Sections 802, 803, 804 and 805 shall each be satisfied on an individual basis. Where one or more of these sections is not satisfied, compliance for that section(s) shall be demonstrated in accordance with the applicable provisions of ASHRAE/IESNA 90.1.

Exception: Buildings conforming to Section 806, provided Sections 802.1.2, 802.3, 803.2.1 or 803.3.1 as applicable, 803.2.2 or 803.3.2 as applicable, 803.2.3 or 803.3.3 as applicable, 803.2.8 or 803.3.6 as applicable, 803.2.9 or 803.3.7 as applicable, 804, 805.2, 805.3, 805.4, 805.6 and 805.7 are each satisfied.

SECTION 802 BUILDING ENVELOPE REQUIREMENTS

802.1 General. Walls, roof assemblies, floors, glazing and slabs on grade which are part of the building envelope for buildings where the window and glazed door area is not greater than 50 percent of the gross area of above-grade walls shall meet the requirements of Sections 802.2.1 through 802.2.9, as applicable. Buildings with more glazing shall meet the applicable provisions of ASHRAE/IESNA 90.1.

802.1.1 Classification of walls. Walls associated with the building envelope shall be classified in accordance with Section 802.1.1.1, 802.1.1.2 or 802.1.1.3.

802.1.1.1 Above-grade walls. Above-grade walls are those walls covered by Section 802.2.1 on the exterior of the building and completely above grade or walls that are more than 15 percent above grade.

802.1.1.2 Below-grade walls. Below-grade walls covered by Section 802.2.8 are basement or first-story walls associated with the exterior of the building that are at least 85 percent below grade.

802.1.1.3 Interior walls. Interior walls covered by Section 802.2.9 are those walls not on the exterior of the building and that separate conditioned and unconditioned space.

802.1.2 Moisture control. All framed walls, floors and ceilings not ventilated to allow moisture to escape shall be provided with an approved vapor retarder having a permeance rating of 1 perm (5.7×10^{-11} kg/Pa · s · m²) or less, when

tested in accordance with the desiccant method using Procedure A of ASTM E 96. The vapor retarder shall be installed on the warm-in-winter side of the insulation.

Exceptions:

1. Buildings located in Climate Zones 1 through 3 as indicated in Figure 301.1 and Table 301.1.
2. In construction where moisture or its freezing will not damage the materials.
3. Where other approved means to avoid condensation in unventilated framed wall, floor, roof and ceiling cavities are provided.

802.2 Criteria. The building envelope components shall meet each of the applicable requirements in Tables 802.2(1), 802.2(2), and 802.2(3) based on the percentage of wall that is glazed. The percentage of wall that is glazed shall be determined by dividing the aggregate area of rough openings for glazing (windows and glazed doors) in all above-grade walls associated with the building envelope by the total gross area of all above-grade exterior walls that are a part of the building envelope. In buildings with multiple types of building envelope construction, each building envelope construction type shall be evaluated separately. Where Table 802.2(1), 802.2(2), or 802.2(3) does not list a particular construction type, the applicable provisions of ASHRAE/IESNA 90.1 shall be used in lieu of Section 802.

802.2.1 Above-grade walls. The minimum thermal resistance (*R*-value) of the insulating material(s) installed in the wall cavity between the framing members and continuously on the walls shall be as specified in Table 802.2(1), 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 802.2(1). "Mass walls" shall include walls weighing at least (1) 35 pounds per square foot (170 kg/m²) of wall surface area or (2) 25 pounds per square foot (120 kg/m²) of wall surface area if the material weight is not more than 120 pounds per cubic foot (1,900 kg/m³).

802.2.2 Opaque doors. Opaque doors (doors having less than 50 percent glass area) shall meet the applicable requirements for doors as specified in Table 802.2(1) and be considered as part of the gross area of above-grade walls that are part of the building envelope.

802.2.3 Windows and glass doors. The maximum solar heat gain coefficient (SHGC) and thermal transmittance (*U*-factor) of window assemblies and glass doors located in the building envelope shall be as specified in Table 802.2(2), based on the window projection factor.

The window projection factor shall be determined in accordance with Equation 8-1.

$PF = A/B$ (Equation 8-1)

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, or an area-weighted PF value shall be calculated and used for all windows and glass doors.

TABLE 802.2(1)
BUILDING ENVELOPE REQUIREMENTS – OPAQUE ELEMENTS

| CLIMATE ZONE | 1 | 2 | 3 | 4 except Marine | 5 and Marine 4 | 6 | 7 | 8 |
|---|------------------------|------------------------|-------------------------|------------------------|------------------------|-----------------------|-----------------------|-----------------------|
| Roofs | | | | | | | | |
| Insulation entirely above deck | R-15 ci | R-15 ci | R-15 ci | R-15 ci | R-20 ci | R-20 ci | R-25 ci | R-25 ci |
| Metal buildings (with R-5 thermal blocks ^{a,b}) | R-19 + R-10 | R-19 | R-19 | R-19 | R-19 | R-19 | R-19 + R-10 | R-19 + R-10 |
| Attic and other | R-30 | R-30 | R-30 | R-30 | R-30 | R-30 | R-38 | R-38 |
| Walls, Above Grade | | | | | | | | |
| Mass | NR | NR | R-5.7 ci ^{c,e} | R-5.7 ci ^c | R-7.6 ci | R-9.5 ci | R-11.4 ci | R-13.3 ci |
| Metal building ^b | R-13 | R-13 | R-13 | R-13 | R-13 + R-13 | R-13 + R-13 | R-13 + R-13 | R-13 + R-13 |
| Metal framed | R-13 | R-13 | R-13 | R-13 | R-13 + R-3.8 ci | R-13 + R-3.8 ci | R-13 + R-7.5 ci | R-13 + R-7.5 ci |
| Wood framed and other | R-13 | R-13 | R-13 | R-13 | R-13 | R-13 | R-13 | R-13 + R-7.5 ci |
| Walls, Below Grade | | | | | | | | |
| Below grade wall ^d | NR | NR | NR | NR | NR | NR | R-7.5 ci | R-7.5 ci |
| Floors | | | | | | | | |
| Mass | NR | R-5 ci | R-5 ci | R-10 ci | R-10 ci | R-10 ci | R-15 ci | R-15 ci |
| Joist/Framing | NR | R-19 | R-19 | R-19 | R-19 | R-30 | R-30 | R-30 |
| Slab-on-Grade Floors | | | | | | | | |
| Unheated Slabs | NR | NR | NR | NR | NR | NR | NR | R-10 for 24 in. below |
| Heated Slabs | R-7.5 for 12 in. below | R-7.5 for 12 in. below | R-7.5 for 12 in. below | R-7.5 for 12 in. below | R-7.5 for 24 in. below | R-10 for 36 in. below | R-10 for 36 in. below | R-10 for 48 in. below |
| Opaque Doors | | | | | | | | |
| Swinging | U – 0.70 | U – 0.70 | U – 0.70 | U – 0.70 | U – 0.70 | U – 0.70 | U – 0.70 | U – 0.50 |
| Roll-up or sliding | U – 1.45 | U – 1.45 | U – 1.45 | U – 1.45 | U – 1.45 | U – 0.50 | U – 0.50 | U – 0.50 |

For SI: 1 inch = 25.4 mm.

ci – Continuous Insulation

NR – No Requirement

a. Thermal blocks are a minimum R-5 of rigid insulation, which extends 1-inch beyond the width of the purlin on each side, perpendicular to the purlin.

b. Assembly descriptions can be found in Table 802.2(3)

c. R-5.7 ci may be substituted with concrete block walls complying with ASTM C90, ungrouted or partially grouted at 32 in. or less on center vertically and 48 in. or less on center horizontally, with ungrouted cores filled with material having a maximum thermal conductivity of 0.44 Btu-in./h-² F.

d. When heated slabs are placed below grade, below grade walls must meet the exterior insulation requirements for perimeter insulation according to the heated slab-on-grade construction.

e. Insulation is not required for mass walls in Climate Zone 3A located below the “Warm-Humid” line, and in Zone 3B.

**TABLE 802.2(2)
BUILDING ENVELOPE REQUIREMENTS**

| CLIMATE ZONE | 1 | 2 | 3 | 4 except Marine | 5 and Marine 4 | 6 | 7 | 8 |
|---|------|------|------|-----------------------|----------------------|------|------|------|
| Windows (40% maximum) | | | | | | | | |
| Factory-assembled glazed fenestration products | | | | | | | | |
| <i>U</i> -Factor | 1.20 | 0.75 | 0.65 | 0.40 | 0.35 | 0.35 | 0.35 | 0.35 |
| SHGC | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | NR | NR |
| Site-built glazed products | | | | | | | | |
| <i>U</i> -Factor | 1.20 | 0.75 | 0.65 | 0.50 | 0.45 | 0.45 | 0.45 | 0.45 |
| SHGC: PF < 0.25 | 0.25 | 0.25 | 0.25 | 0.40 | 0.40 | 0.40 | NR | NR |
| SHGC: 0.25 < PF < 0.5 | 0.33 | 0.33 | 0.33 | NR | NR | NR | NR | NR |
| SHGC: PF ≥ 0.5 | 0.40 | 0.40 | 0.40 | NR | NR | NR | NR | NR |
| Skylights (3% maximum) | | | | | | | | |
| Glass | | | | | | | | |
| <i>U</i> -Factor | 1.60 | 1.05 | 0.90 | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 |
| SHGC | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | NR | NR |
| Plastic | | | | | | | | |
| <i>U</i> -Factor | 1.90 | 1.90 | 1.30 | 1.30 | 1.30 | 0.90 | 0.90 | 0.60 |
| SHGC | 0.35 | 0.35 | 0.35 | 0.62 | 0.62 | 0.62 | NR | NR |

NR = No requirement.

PF = Projection factor (See Section 802.2.3)

802.2.4 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 802.2(1), based on construction materials used in the roof assembly.

Exception: Continuously insulated roof assemblies where the thickness of insulation varies 1 inch (25.4 mm) or less and where the area weighted *U*-factor is equivalent to the same assembly with the *R*-value specified in Table 802.2(1).

802.2.5 Skylights. Skylights located in the building envelope shall be limited to 3 percent of the gross roof assembly area and shall have a maximum thermal transmittance (*U*-factor) and SHGC of the skylight assembly as specified in Table 802.2(2).

802.2.6 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 802.2(1), based on construction materials used in the floor assembly.

802.2.7 Slabs on grade. 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 802.2(1). 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.

802.2.8 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 802.2(1), and shall extend to a depth of 10 feet (3048 mm) below the outside finish ground level, or to the level of the floor, whichever is less.

802.2.9 Interior walls. The minimum thermal resistance (*R*-value) of the insulating material installed in the wall cavity or continuously on the interior walls shall be the same as that specified for above-grade walls in Table 802.2(1).

802.3 Air leakage. The requirements for air leakage shall be as specified in Sections 802.3.1 through 802.3.7.

802.3.1 Window and door assemblies. The air leakage of window and sliding or swinging door assemblies that are part of the building envelope shall be determined in accordance with AAMA/WDMA 101/I.S.2 or AAMA/WDMA 101/I.S.2/NAFS-02, or NFRC 400 by an accredited, independent laboratory, and labeled and certified by the manufacturer and shall not exceed the values in Section 402.4.2.

Exception: Site-constructed windows and doors that are weatherstripped or sealed in accordance with Section 802.3.3.

802.3.2 Curtain wall, storefront glazing and commercial entrance doors. Curtain wall, storefront glazing and commercial-glazed swinging entrance doors and revolving doors shall be tested for air leakage at 1.57 pounds per square foot (psf) (75 Pa) in accordance with ASTM E 283. For curtain walls and storefront glazing, the maximum air leakage rate shall be 0.3 cubic feet per minute per square foot (cfm/ft²) (5.5 m³/h × m²) of fenestration area. For commercial glazed swinging entrance doors and revolving doors, the maximum air leakage rate shall be 1.00 cfm/ft² (18.3 m³/h × m²) of door area when tested in accordance with ASTM E 283.

802.3.3 Sealing of the building envelope. Openings and penetrations in the building envelope shall be sealed with caulking materials or closed with gasketing systems compatible with the construction materials and location. Joints and seams shall be sealed in the same manner or taped or covered with a moisture vapor-permeable wrapping material. Sealing materials spanning joints between construction materials shall allow for expansion and contraction of the construction materials.

802.3.4 Outdoor air intakes and exhaust openings. Stair and elevator shaft vents and other outdoor air intakes and ex-

haust openings integral to the building envelope shall be equipped with not less than a Class I motorized, leakage-rated damper with a maximum leakage rate of 4 cfm/ft² (6.8 L/s · m²) at 1.0 inch water gauge (w.g.) (1250 Pa) when tested in accordance with AMCA 500D.

Exception: Gravity (nonmotorized) dampers are permitted to be used in buildings less than three stories in height above grade.

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

802.3.6 Vestibules. A door that separates conditioned space from the exterior 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.

Exceptions:

1. Buildings in Climate Zones 1 and 2 as indicated in Figure 301.1 and Table 301.1.
2. Doors not intended to be used as a building entrance door, such as doors to mechanical or electrical equipment rooms.
3. Doors opening directly from a guestroom or dwelling unit.

**TABLE 802.2(3)
METAL BUILDING ASSEMBLY DESCRIPTIONS**

| ROOFS | DESCRIPTION | REFERENCE |
|--------------|--|-----------------------------|
| R-19 + R-10 | Filled cavity roof Thermal blocks are a minimum, R-5 of rigid insulation, which extends 1 in. beyond the width of the purlin on each side, perpendicular to the purlin This construction is R-10 insulation batts draped perpendicularly over the purlins, with enough looseness to allow R-19 batt to be laid above it, parallel to the purlins. Thermal blocks are then placed above the purlin/batt, and the roof deck is secured to the purlins. In the metal building industry, this is known as the “sag and bag” insulation system. | ASHRAE/IESNA 90.1 Table A-2 |
| R-19 | Standing seam with single insulation layer Thermal blocks are a minimum R-5 of rigid insulation, which extends 1 in. beyond the width of the purlin on each side, perpendicular to the purlin. This construction R-19 insulation batts draped perpendicularly over the purlins. Thermal blocks are then placed above the purlin/batt, and the roof deck is secured to the purlins. | ASHRAE/IESNA 90.1 Table A-2 |
| WALLS | | |
| R-13 | Single insulation layer The first layer of R-13 insulation batts is installed continuously perpendicular to the girts and is compressed as the metal skin is attached to the girts. | ASHRAE/IESNA 90.1 Table A-9 |
| R-13 + R-13 | Double insulation layer The first layer of R-13 insulation batts is installed continuously perpendicular to the girts, and is compressed as the metal skin is attached to the girts. The second layer of R-13 insulation batts is installed within the framing cavity. | ASHRAE/IESNA 90.1 Table A-9 |

For SI: 1 inch = 25.4 mm.

4. Doors that open directly from a space less than 3,000 square feet (298 m²) in area.
5. Revolving doors.
6. Doors used primarily to facilitate vehicular movement or material handling and adjacent personnel doors.

802.3.7 Recessed luminaires. When installed in the building envelope, recessed luminaires shall meet one of the following requirements:

1. Type IC rated, manufactured with no penetrations between the inside of the recessed fixture and ceiling cavity and sealed or gasketed to prevent air leakage into the unconditioned space.
2. Type IC or non-IC rated, installed inside a sealed box constructed from a minimum 0.5-inch-thick (12.7 mm) gypsum wallboard or constructed from a preformed polymeric vapor barrier, or other air-tight assembly manufactured for this purpose, while maintaining required clearances of not less than 0.5 inch (12.7 mm) from combustible material and not less than 3 inches (76 mm) from insulation material.
3. Type IC rated, in accordance with ASTM E 283 admitting no more than 2.0 cubic feet per minute (cfm) (0.944 L/s) of air movement from the conditioned space to the ceiling cavity. The luminaire shall be tested at 1.57 psf (75 Pa) pressure difference and shall be labeled.

SECTION 803 BUILDING MECHANICAL SYSTEMS

803.1 General. This section covers the design and construction of mechanical systems and equipment serving the building heating, cooling or ventilating needs.

803.1.1 Compliance. Compliance with Section 803 shall be achieved by meeting either Section 803.2 or 803.3.

803.2 Simple HVAC systems and equipment. This section applies to buildings served by unitary or packaged HVAC equipment listed in Tables 803.2.2(1) through 803.2.2(5), 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.

This section does not apply to fan systems serving multiple zones, nonunitary or nonpackaged HVAC equipment and systems or hydronic or steam heating and hydronic cooling equipment and distribution systems that provide cooling or heating and heating which are covered by Section 803.3.

803.2.1 Calculation of heating and cooling loads. Design loads shall be determined in accordance with the procedures described in the ASHRAE *Fundamentals Handbook*. Heating and cooling loads shall be adjusted to account for load reductions that are achieved when 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.

803.2.1.1 Equipment and system sizing. Heating and cooling equipment and systems capacity shall not exceed the loads calculated in accordance with Section 803.2.1. A single piece of equipment providing both heating and cooling must satisfy this provision for one function with the capacity for the other function as small as possible, within available equipment options.

803.2.2 HVAC equipment performance requirements. Equipment shall meet the minimum efficiency requirements of Tables 803.2.2(1), 803.2.2(2), 803.2.2(3), 803.2.2(4) and 803.2.2(5), when tested and rated in accordance with the applicable test procedure. The efficiency shall be verified through data furnished by the manufacturer or through certification under an approved certification program. Where multiple rating conditions or performance requirements are provided, the equipment shall satisfy all stated requirements.

803.2.3 Temperature and humidity controls. Requirements for temperature and humidity controls shall be as specified in Sections 803.2.3.1 through 803.2.3.3.

803.2.3.1 Temperature controls. Each heating and cooling system shall have at least one solid-state programmable thermostat. The thermostat shall have the capability to set back or shut down the system based on day of the week and time of day, and provide a readily accessible manual override that will return to the presetback or shutdown schedule without reprogramming.

Exceptions:

1. HVAC systems serving hotel/motel guest rooms.
2. Packaged terminal air conditioners, packaged terminal heat pumps and room air conditioner systems.

803.2.3.2 Heat pump supplementary heat. Heat pumps having supplementary electric-resistance heat shall have controls that, except during defrost, prevent supplemental heat operation when the heat pump can meet the heating load.

803.2.3.3 Humidity controls. When humidistats are installed, they shall have the capability to prevent the use of fossil fuel or electric power to achieve a humidity below 60 percent when the system controlled is cooling, and above 30 percent when the system controlled is heating.

Exceptions:

1. Systems serving spaces where specific humidity levels are required to satisfy process needs, such as computer rooms, museums, surgical suites and buildings with refrigerating systems, such as supermarkets, refrigerated warehouses and ice arenas.
2. Systems where humidity is removed as the result of the use of a desiccant system with energy recovery.
3. Reheat systems utilizing site-recovered (including condenser heat) or site-solar energy sources.

TABLE 803.2.2(1)
UNITARY AIR CONDITIONERS AND CONDENSING UNITS,
ELECTRICALLY OPERATED, MINIMUM EFFICIENCY REQUIREMENTS

| EQUIPMENT TYPE | SIZE CATEGORY | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY ^b | TEST PROCEDURE ^a |
|--|-------------------------------------|---|---|-----------------------------|
| Air conditioners, Air cooled | < 65,000 Btu/h ^d | Split system | 10.0 SEER | ARI 210/240 |
| | | Single package | 9.7 SEER | |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | Split system and single package | 10.3 EER ^c | |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Split system and single package | 9.7 EER ^c | ARI 340/360 |
| | ≥ 240,000 Btu/h and < 760,000 Btu/h | Split system and single package | 9.5 EER ^c 9.7 IPLV ^c | |
| ≥ 760,000 Btu/h | Split system and single package | 9.2 EER ^c 9.4 IPLV ^c | | |
| Air conditioners, Water and evaporatively cooled | < 65,000 Btu/h | Split system and single package | 12.1 EER | ARI 210/240 |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | Split system and single package | 11.5 EER ^c | ARI 340/360 |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Split system and single package | 11.0 EER ^c | |
| | ≥ 240,000 Btu/h | Split system and single package | 11.0 EER ^c 10.3 IPLV ^c | |

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

- a. Chapter 10 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.
- c. Deduct 0.2 from the required EERs and IPLVs for units with a heating section other than electric resistance heat.
- d. Single-phase air-cooled air conditioners < 65,000 Btu/h are regulated by the National Appliance Energy Conservation Act of 1987 (NAECA), SEER values are those set by NAECA.

803.2.4 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 803.3.3.7.

803.2.5 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*.

803.2.5.1 Energy recovery ventilation systems. Individual fan systems that have both a design supply air capacity of 5,000 cfm (2.36 m³/s) or greater and a minimum outside air supply of 70 percent or greater of the design supply air quantity shall have an energy recovery system that provides a change in the enthalpy of the outdoor air supply of 50 percent or more of the difference between the outdoor air and return air at design conditions. Provision shall be made to bypass or control the energy recovery system to permit cooling with outdoor air where cooling with outdoor air is required.

Exceptions: 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 with a total exhaust rate of 15,000 cfm (7.08 m³/s) or less.
3. Laboratory fume hood systems with a total exhaust rate greater than 15,000 cfm (7.08 m³/s) that include at least one of the following features:
 - 3.1 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.
 - 3.2 Direct makeup (auxiliary) air supply equal to at least 75 percent of the exhaust rate, heated no warmer than 2°F (Δ1.1°C) below room set point, cooled to no cooler than 3°F (Δ1.7°C) above room set point, no humidification added, and no simultaneous heating and cooling used for dehumidification control.
4. Systems serving spaces that are not cooled and are heated to less than 60°F (15.5°C).
5. Where more than 60 percent of the outdoor heating energy is provided from site-recovered or site solar energy.
6. Heating systems in climates with less than 3600 HDD.

7. Cooling systems in climates with a 1 percent cooling design wet-bulb temperature less than 64°F (17.7°C).
8. Systems requiring dehumidification that employ series-style energy recovery coils wrapped around the cooling coil.

803.2.6 Cooling with outdoor air. Supply air economizers shall be provided on each cooling system as shown in Table 803.2.6(1).

Economizers shall be capable of operating at 100-percent outside air, even if additional mechanical cooling is required to meet the cooling load of the building. Where a single room or space is supplied by multiple air systems, the aggregate capacity of those systems shall be used in applying this requirement.

gate capacity of those systems shall be used in applying this requirement.

Exceptions:

1. Where the cooling equipment is covered by the minimum efficiency requirements of Table 803.2.2(1) or 803.2.2(2) and meets or exceeds the minimum cooling efficiency requirement (EER) by the percentages shown in Table 803.2.6(2).
2. Systems with air or evaporatively cooled condensers and which serve spaces with open case refrigeration or that require filtration equipment in order to meet the minimum ventilation requirements of Chapter 4 of the *International Mechanical Code*.

**TABLE 803.2.2(2)
UNITARY AND APPLIED HEAT PUMPS, ELECTRICALLY OPERATED, MINIMUM EFFICIENCY REQUIREMENTS**

| EQUIPMENT TYPE | SIZE CATEGORY | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY ^b | TEST PROCEDURE ^a |
|---------------------------------------|--|---------------------------------|---|-----------------------------|
| Air cooled (Cooling mode) | < 65,000 Btu/h ^d | Split system | 10.0 SEER | ARI 210/240 |
| | | Single package | 9.7 SEER | |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h | Split system and single package | 10.1 EER ^c | ARI 340/360 |
| | ≥ 135,000 Btu/h and < 240,000 Btu/h | Split system and single package | 9.3 EER ^c | |
| | ≥ 240,000 Btu/h | Split system and single package | 9.0 EER ^c 9.2 IPLV ^c | |
| Water source (Cooling mode) | < 17,000 Btu/h | 86°F entering water | 11.2 EER | ARI/ASHRAE-13256-1 |
| | ≥ 17,000 Btu/h and < 135,000 Btu/h | 86°F entering water | 12.0 EER | ARI/ASHRAE-13256-1 |
| Groundwater source (Cooling mode) | < 135,000 Btu/h | 59°F entering water | 16.2 EER | ARI/ASHRAE-13256-1 |
| Ground source (Cooling mode) | < 135,000 Btu/h | 77°F entering water | 13.4 EER | ARI/ASHRAE 13256-1 |
| Air cooled (Heating mode) | < 65,000 Btu/h ^d (Cooling capacity) | Split system | 6.8 HSPF | ARI 210/240 |
| | | Single package | 6.6 HSPF | |
| | ≥ 65,000 Btu/h and < 135,000 Btu/h (Cooling capacity) | 47°F db/43°F wb outdoor air | 3.2 COP | ARI 340/360 |
| ≥ 135,000 Btu/h (Cooling capacity) | 47°F db/43°F wb outdoor air | 3.1 COP | | |
| Water source (Heating mode) | < 135,000 Btu/h (Cooling capacity) | 68°F entering water | 4.2 COP | ARI/ASHRAE-13256-1 |
| Groundwater source (Heating mode) | < 135,000 Btu/h (Cooling capacity) | 50°F entering water | 3.6 COP | ARI/ASHRAE-13256-1 |
| Ground Source (Heating mode) | < 135,000 Btu/h (Cooling capacity) | 32°F entering water | 3.1 COP | ARI/ASHRAE-13256-1 |

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. Chapter 10 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

b. IPLVs and Part load rating conditions are only applicable to equipment with capacity modulation.

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

d. Single-phase air-cooled heat pumps < 65,000 Btu/h are regulated by the National Appliance Energy Conservation Act of 1987 (NAECA), SEER and HSPF values are those set by NAECA.

TABLE 803.2.2(3)
PACKAGED TERMINAL AIR CONDITIONERS AND
PACKAGED TERMINAL HEAT PUMPS

| EQUIPMENT TYPE | SIZE CATEGORY (INPUT) | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY ^b | TEST PROCEDURE ^a |
|--|-----------------------|---------------------------------|---------------------------------|-----------------------------|
| PTAC (Cooling mode) New construction | All capacities | 95°F db outdoor air | 12.5 - (0.213 · Cap/1000) EER | ARI 310/380 |
| PTAC (Cooling mode) Replacements ^c | All capacities | 95°F db outdoor air | 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 | |
| PTHP (Cooling mode) Replacements ^c | All capacities | 95°F db outdoor air | 10.8 - (0.213 · Cap/1000) EER | |
| PTHP (Heating mode) New construction | All capacities | — | 3.2 - (0.026 · Cap/1000) COP | |
| PTHP (Heating mode) Replacements ^c | All capacities | — | 2.9 - (0.026 · Cap/1000) 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. Chapter 10 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
- b. Cap means the rated cooling capacity of the product in Btu/h. If the unit’s capacity is less than 7,000 Btu/h, use 7,000 Btu/h in the calculation. If the unit’s capacity is greater than 15,000 Btu/h, use 15,000 Btu/h in the calculation.
- c. Replacement units must 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) high and less than 42 inches (1067 mm) wide.

TABLE 803.2.2(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 ^{d, e} | TEST PROCEDURE ^a |
|--------------------------------------|-----------------------|---------------------------------|---|---------------------------------------|
| 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 ^c | 80% E _t ^f | ANSI Z21.47 |
| Warm 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 ^b | 81% E _t ^g | UL 727 |
| Warm air duct furnaces, gas fired | All capacities | Maximum capacity ^b | 80% E _c | ANSI Z83.8 |
| Warm air unit heaters, gas fired | All capacities | Maximum capacity ^b | 80% E _c | ANSI Z83.8 |
| Warm air unit heaters, oil fired | All capacities | Maximum capacity ^b | 80% E _c | UL 731 |

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

- a. Chapter 10 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_c = 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 803.2.2(5)
BOILERS, GAS- AND OIL-FIRED, MINIMUM EFFICIENCY REQUIREMENTS**

| EQUIPMENT TYPE ^f | SIZE CATEGORY (INPUT) | SUBCATEGORY OR RATING CONDITION | MINIMUM EFFICIENCY ^{c, d, e} | TEST PROCEDURE ^a |
|-------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|-----------------------------|
| Boilers, Gas fired | < 300,000 Btu/h | Hot water | 80% AFUE | DOE 10 CFR Part 430 |
| | | Steam | 75% AFUE | |
| | ≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h | Minimum capacity ^b | 75% E _t | H.I. HBS |
| | | >2,500,000 Btu/h ^f | Hot water | |
| Boilers, Oil fired | < 300,000 Btu/h | — | 80% AFUE | DOE 10 CFR Part 430 |
| | | ≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h | Minimum capacity ^b | |
| | > 2,500,000 Btu/h ^f | Hot water | 83% E _c | H.I. HBS |
| | | Steam | 83% E _c | |
| Boilers, Oil fired (Residual) | ≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h | Minimum capacity ^b | 78% E _t | H.I. HBS |
| | | Hot water | 83% E _c | |
| | > 2,500,000 Btu/h ^f | Steam | 83% E _c | |

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

- a. Chapter 10 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
- b. Minimum ratings as provided for and allowed by the unit's controls.
- c. E_c = Combustion efficiency (100 percent flue losses). See reference document for detailed information.
- d. E_t = Thermal efficiency. See reference document for detailed information.
- e. Alternative test procedures used at the manufacturer's option are ASME PTC-4.1 for units greater than 5,000,000 Btu/h input, or ANSI Z21.13 for units greater than or equal to 300,000 Btu/h and less than or equal to 2,500,000 Btu/h input.
- f. 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.

**TABLE 803.2.6(1)
ECONOMIZER REQUIREMENTS**

| CLIMATE ZONES | ECONOMIZER REQUIREMENT |
|--------------------------------|--|
| 1A, 1B, 2A, 3A, 4A, 7, 8 | No Requirement |
| 2B, 3B, 3C, 4B, 4C, 5B, 5C, 6B | Economizers on All Cooling Systems ≥ 65,000 Btu/h |
| 5A, 6A | Economizers on All Cooling Systems ≥ 135,000 Btu/h |

For SI: 1 British thermal unit per hour = 0.293 W.

**TABLE 803.2.6(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 |

803.2.7 Shutoff dampers. Outdoor air supply and exhaust ducts shall be provided with automatic means to reduce and shut off airflow.

Exceptions:

- 1. Systems serving areas designed for continuous operation.
- 2. Individual systems with a maximum 3,000 cfm (1416 L/s) airflow rate.
- 3. Systems with readily accessible manual dampers.
- 4. Where restricted by health and life safety codes.

803.2.8 Duct and plenum insulation and sealing. All supply and return air ducts and plenums shall be insulated with a minimum of R-5 insulation when located in unconditioned spaces and with a minimum of R-8 insulation when located outside the building. When 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. When located within equipment.
- 2. When the design temperature difference between the interior and exterior of the duct or plenum does not exceed 15°F (Δ8°C).

All joints, longitudinal and transverse seams and connections in ductwork, shall be securely fastened and sealed with welds, gaskets, mastics (adhesives), mastic-plus-em-

bedded-fabric systems or tapes. Tapes and mastics used to seal ductwork shall be listed and labeled in accordance with UL 181A and shall be marked “181A-P” for pressure-sensitive tape, “181A-M” for mastic or “181A-H” for heat-sensitive tape. Tapes and mastics used to seal flexible air ducts and flexible air connectors shall comply with UL 181B and shall be marked “181B-FX” for pressure-sensitive tape or “181B-M” for mastic. Duct connections to flanges of air distribution system equipment shall be sealed and mechanically fastened. Unlisted duct tape is not permitted as a sealant on any metal ducts.

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

803.2.8.1.1 High- and medium-pressure duct systems. All ducts and plenums operating at a static pressures greater than 2 inches w.g. (500 Pa) shall be insulated and sealed in accordance with Section 803.2.8. Ducts operating at a static pressures in excess of 3 inches w.g. (750 Pa) shall be leak tested in accordance with Section 803.3.6. Pressure classifications specific to the duct system shall be clearly indicated on the construction documents in accordance with the *International Mechanical Code*.

803.2.8.1.2 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 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 w.g. (500 Pa) pressure classification.

803.2.9 Piping insulation. All piping serving as part of a heating or cooling system shall be thermally insulated in accordance with Section 803.3.7.

803.3 Complex HVAC systems and equipment. This section applies to buildings served by HVAC equipment and systems not covered in Section 803.2.

803.3.1 Calculation of heating and cooling loads. Design loads shall be determined in accordance with Section 803.2.1.

803.3.1.1 Equipment and system sizing. Heating and cooling equipment and system capacity shall not exceed the loads calculated in accordance with Section 803.2.1.

Exceptions:

1. 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.
2. 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.

803.3.2 HVAC equipment performance requirements. Equipment shall meet the minimum efficiency requirements of Tables 803.3.2(1) through 803.3.2(6) and Table 803.2.2(5), when tested and rated in accordance with the applicable test procedure. 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 demonstrate that the combined efficiency of the specified components meets the requirements herein.

Where unitary or prepackaged equipment is used in a complex HVAC system and is not covered by Section 803.3.2, the equipment shall meet the applicable requirements of Section 803.2.2.

Exception: Equipment listed in Table 803.3.2(2) not designed for operation at ARI Standard test conditions of 44°F (7°C) leaving chilled water temperature and 85°F (29°C) entering condenser water temperature shall have a minimum full load COP and IPLV rating as shown in Tables 803.3.2(3) through 803.3.2(5) as applicable. The table values are only applicable over the following full load design ranges:

**TABLE 803.3.2(1)
CONDENSING UNITS, ELECTRICALLY OPERATED, MINIMUM EFFICIENCY REQUIREMENTS**

| EQUIPMENT TYPE | SIZE CATEGORY | MINIMUM EFFICIENCY ^b | TEST PROCEDURE ^a |
|---|-----------------|---------------------------------|-----------------------------|
| Condensing units, air cooled | ≥ 135,000 Btu/h | 10.1 EER 11.2 IPLV | ARI 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 10 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.

Leaving Chilled
 Water Temperature: 40 to 48°F (4 to 9°C)
 Entering Condenser
 Water Temperature: 75 to 85°F (24 to 29°C)
 Condensing Water
 Temperature Rise: 5 to 15°F (Δ3 to Δ8°C)

Chillers designed to operate outside of these ranges are not covered by this code.

803.3.3 HVAC system controls. Each heating and cooling system shall be provided with thermostatic controls as required in Sections 803.3.3.1 through 803.3.3.8.

803.3.3.1 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 (15.2 m); and,
2. The perimeter system heating and cooling supply is controlled by a thermostat(s) located within the zone(s) served by the system.

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

**TABLE 803.3.2(2)
 WATER CHILLING PACKAGES, MINIMUM EFFICIENCY REQUIREMENTS**

| EQUIPMENT TYPE | SIZE CATEGORY | MINIMUM EFFICIENCY ^b | TEST PROCEDURE ^a |
|--|---------------------------|---------------------------------|-----------------------------|
| Air cooled, with condenser, Electrically operated | < 150 tons | 2.80 COP 2.80 IPLV | ARI 550/590 |
| | ≥ 150 tons | 2.50 COP 2.50 IPLV | |
| Air cooled, without condenser, Electrically operated | All capacities | 3.10 COP 3.10 IPLV | ARI 550/590 |
| Water cooled, Electrically operated, Positive displacement (reciprocating) | All capacities | 4.20 COP 4.65 IPLV | |
| Water cooled, Electrically operated, Positive displacement (rotary screw and scroll) | < 150 tons | 4.45 COP 4.50 IPLV | ARI 550/590 |
| | ≥ 150 tons and < 300 tons | 4.90 COP 4.95 IPLV | |
| | ≥ 300 tons | 5.50 COP 5.60 IPLV | |
| Water cooled, Electrically operated, centrifugal | < 150 tons | 5.00 COP 5.00 IPLV | ARI 550/590 |
| | ≥ 150 tons and < 300 tons | 5.55 COP 5.55 IPLV | |
| | ≥ 300 tons | 6.10 COP 6.10 IPLV | |
| Air cooled, absorption single effect | All capacities | 0.60 COP | ARI 560 |
| Water cooled, absorption single effect | All capacities | 0.70 COP | |
| Absorption double effect, indirect-fired | All capacities | 1.00 COP 1.05 IPLV | |
| Absorption double effect, direct-fired | All capacities | 1.00 COP 1.00 IPLV | |

For SI: 1 ton = 3.517 kW. °C = [(°F) - 32]/1.8.

a. Chapter 10 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

b. The chiller equipment requirements do not apply for chillers used in low temperature applications where the design leaving fluid temperature is less than or equal to 40°F.

803.3.3.2 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 (Δ2.8°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.

803.3.3.3 Off-hour controls. Each zone shall be provided with thermostatic setback controls that are con-

trolled 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.

803.3.3.3.1 Thermostatic setback capabilities. Thermostatic setback controls shall have the capability to set back or temporarily operate the system to

**TABLE 803.3.2(3)
COPs AND IPLVs FOR NONSTANDARD CENTRIFUGAL CHILLERS < 150 TONS**

| CENTRIFUGAL CHILLERS < 150 TONS COP _{std} = 5.4 | | | | | | | | |
|---|---|------------------------|-----------------------|-------------|-----------|-----------|-----------|-----------|
| Leaving chilled water temperature (°F) | Entering condenser water temperature (°F) | Lift ^a (°F) | Condenser flow rate | | | | | |
| | | | 2 gpm/ton | 2.5 gpm/ton | 3 gpm/ton | 4 gpm/ton | 5 gpm/ton | 6 gpm/ton |
| | | | Required COP and IPLV | | | | | |
| 46 | 75 | 29 | 6.00 | 6.27 | 6.48 | 6.80 | 7.03 | 7.20 |
| 45 | 75 | 30 | 5.92 | 6.17 | 6.37 | 6.66 | 6.87 | 7.02 |
| 44 | 75 | 31 | 5.84 | 6.08 | 6.26 | 6.53 | 6.71 | 6.86 |
| 43 | 75 | 32 | 5.75 | 5.99 | 6.16 | 6.40 | 6.58 | 6.71 |
| 42 | 75 | 33 | 5.67 | 5.90 | 6.06 | 6.29 | 6.45 | 6.57 |
| 41 | 75 | 34 | 5.59 | 5.82 | 5.98 | 6.19 | 6.34 | 6.44 |
| 46 | 80 | 34 | 5.59 | 5.82 | 5.98 | 6.19 | 6.34 | 6.44 |
| 40 | 75 | 35 | 5.50 | 5.74 | 5.89 | 6.10 | 6.23 | 6.33 |
| 45 | 80 | 35 | 5.50 | 5.74 | 5.89 | 6.10 | 6.23 | 6.33 |
| 44 | 80 | 36 | 5.41 | 5.66 | 5.81 | 6.01 | 6.13 | 6.22 |
| 43 | 80 | 37 | 5.31 | 5.57 | 5.73 | 5.92 | 6.04 | 6.13 |
| 42 | 80 | 38 | 5.21 | 5.48 | 5.64 | 5.84 | 5.95 | 6.04 |
| 41 | 80 | 39 | 5.09 | 5.39 | 5.56 | 5.76 | 5.87 | 5.95 |
| 46 | 85 | 39 | 5.09 | 5.39 | 5.56 | 5.76 | 5.87 | 5.95 |
| 40 | 80 | 40 | 4.96 | 5.29 | 5.47 | 5.67 | 5.79 | 5.86 |
| 45 | 85 | 40 | 4.96 | 5.29 | 5.47 | 5.67 | 5.79 | 5.86 |
| 44 | 85 | 41 | 4.83 | 5.18 | 5.40 | 5.59 | 5.71 | 5.78 |
| 43 | 85 | 42 | 4.68 | 5.07 | 5.28 | 5.50 | 5.62 | 5.70 |
| 42 | 85 | 43 | 4.51 | 4.94 | 5.17 | 5.41 | 5.54 | 5.62 |
| 41 | 85 | 44 | 4.33 | 4.80 | 5.05 | 5.31 | 5.45 | 5.53 |
| 40 | 85 | 45 | 4.13 | 4.65 | 4.92 | 5.21 | 5.35 | 5.44 |
| Condenser ΔT ^b | | | 14.04 | 11.23 | 9.36 | 7.02 | 5.62 | 4.68 |

For SI: °C = [(°F) - 32] / 1.8, 1 gallon per minute = 3.785 L/min., 1 ton = 12,000 British thermal unit per hour = 3.517 kW.

- a. Lift = Entering condenser water temperature (°F) - Leaving chilled water temperature (°F).
- b. Condenser ΔT = Leaving condenser water temperature (°F) - Entering condenser water temperature (°F).

$$K_{adj} = 6.1507 - 0.30244(X) + 0.0062692(X)^2 - 0.000045595(X)$$

where: X = Condenser ΔT + Lift

$$COP_{adj} = K_{adj} \times COP_{std}$$

maintain zone temperatures down to 55°F (13°C) or up to 85°F (29°C).

803.3.3.3.2 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.

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

Exception: Individual supply systems with a design airflow rate of 3,000 cfm (1416 L/s) or less.

803.3.3.5 Economizers. Supply air economizers shall be provided on each cooling system according to Table 803.2.6(1). Economizers shall be capable of operating at

**TABLE 803.3.2(4)
COPs AND IPLVs FOR NONSTANDARD CENTRIFUGAL CHILLERS ≥ 150 TONS, ≤ 300 TONS**

| CENTRIFUGAL CHILLERS ≥ 150 Tons, ≤ 300 Tons COP _{std} = 5.55 | | | | | | | | |
|--|---|------------------------|-----------------------|-------------|-----------|-----------|-----------|-----------|
| Leaving chilled water temperature (°F) | Entering condenser water temperature (°F) | Lift _a (°F) | Condenser flow rate | | | | | |
| | | | 2 gpm/ton | 2.5 gpm/ton | 3 gpm/ton | 4 gpm/ton | 5 gpm/ton | 6 gpm/ton |
| | | | Required COP and IPLV | | | | | |
| 46 | 75 | 29 | 6.17 | 6.44 | 6.66 | 6.99 | 7.23 | 7.40 |
| 45 | 75 | 30 | 6.08 | 6.34 | 6.54 | 6.84 | 7.06 | 7.22 |
| 44 | 75 | 31 | 6.00 | 6.24 | 6.43 | 6.71 | 6.90 | 7.05 |
| 43 | 75 | 32 | 5.91 | 6.15 | 6.33 | 6.58 | 6.76 | 6.89 |
| 42 | 75 | 33 | 5.83 | 6.07 | 6.23 | 6.47 | 6.63 | 6.75 |
| 41 | 75 | 34 | 5.74 | 5.98 | 6.14 | 6.36 | 6.51 | 6.62 |
| 46 | 80 | 34 | 5.74 | 5.98 | 6.14 | 6.36 | 6.51 | 6.62 |
| 40 | 75 | 35 | 5.65 | 5.90 | 6.05 | 6.26 | 6.40 | 6.51 |
| 45 | 80 | 35 | 5.65 | 5.90 | 6.05 | 6.26 | 6.40 | 6.51 |
| 44 | 80 | 36 | 5.56 | 5.81 | 5.97 | 6.17 | 6.30 | 6.40 |
| 43 | 80 | 37 | 5.46 | 5.73 | 5.89 | 6.08 | 6.21 | 6.30 |
| 42 | 80 | 38 | 5.35 | 5.64 | 5.8 | 6.00 | 6.12 | 6.20 |
| 41 | 80 | 39 | 5.23 | 5.54 | 5.71 | 5.91 | 6.03 | 6.11 |
| 46 | 85 | 39 | 5.23 | 5.54 | 5.71 | 5.91 | 6.03 | 6.11 |
| 40 | 80 | 40 | 5.10 | 5.44 | 5.62 | 5.83 | 5.95 | 6.03 |
| 45 | 85 | 40 | 5.10 | 5.44 | 5.62 | 5.83 | 5.95 | 6.03 |
| 44 | 85 | 41 | 4.96 | 5.33 | 5.55 | 5.74 | 5.86 | 5.94 |
| 43 | 85 | 42 | 4.81 | 5.21 | 5.42 | 5.66 | 5.78 | 5.86 |
| 42 | 85 | 43 | 4.63 | 5.08 | 5.31 | 5.56 | 5.69 | 5.77 |
| 41 | 85 | 44 | 4.45 | 4.93 | 5.19 | 5.46 | 5.60 | 5.69 |
| 40 | 85 | 45 | 4.24 | 4.77 | 5.06 | 5.35 | 5.50 | 5.59 |
| Condenser ΔT _b | | | 14.04 | 11.23 | 9.36 | 7.02 | 5.62 | 4.68 |

For SI: °C = [(°F) - 32] / 1.8, 1 gallon per minute = 3.785 L/min., 1 ton = 12,000 British thermal unit per hour = 3.517 kW.

- a. Lift = Entering condenser water temperature (°F) - Leaving chilled water temperature (°F).
- b. Condenser ΔT = Leaving condenser water temperature (°F) - Entering condenser water temperature (°F).

$$K_{adj} = 6.1507 - 0.30244(X) + 0.0062692(X)^2 - 0.000045595(X)$$

where: X = Condenser ΔT + Lift COP_{adj} = K_{adj} x COP_{std}

100 percent outside air, even if additional mechanical cooling is required to meet the cooling load of the building.

Exceptions:

1. Systems utilizing water economizers that are capable of cooling supply air by direct or indirect evaporation or both and providing 100 percent of the expected system cooling load at outside air temperatures of 50°F (10°C) dry bulb/45°F (7°C) wet bulb and below.

2. Where the cooling equipment is covered by the minimum efficiency requirements of Table 803.2.2(1), 803.2.2(2), or 803.3.2(1) and meets or exceeds the minimum EER by the percentages shown in Table 803.2.6(2)
3. Where the cooling equipment is covered by the minimum efficiency requirements of Table 803.3.2(2) and meets or exceeds the minimum integrated part load value (IPLV) by the percentages shown in Table 803.2.6(2).

**TABLE 803.3.2(5)
COPs AND IPLVs FOR NONSTANDARD CENTRIFUGAL CHILLERS > 300 TONS**

| CENTRIFUGAL CHILLERS > 300 Tons COP _{std} = 6.1 | | | | | | | | |
|---|---|------------------------|-----------------------|-------------|-----------|-----------|-----------|-----------|
| Leaving chilled water temperature (°F) | Entering condenser water temperature (°F) | Lift ^a (°F) | Condenser flow rate | | | | | |
| | | | 2 gpm/ton | 2.5 gpm/ton | 3 gpm/ton | 4 gpm/ton | 5 gpm/ton | 6 gpm/ton |
| | | | Required COP and IPLV | | | | | |
| 46 | 75 | 29 | 6.80 | 7.11 | 7.35 | 7.71 | 7.97 | 8.16 |
| 45 | 75 | 30 | 6.71 | 6.99 | 7.21 | 7.55 | 7.78 | 7.96 |
| 44 | 75 | 31 | 6.61 | 6.89 | 7.09 | 7.40 | 7.61 | 7.77 |
| 43 | 75 | 32 | 6.52 | 6.79 | 6.98 | 7.26 | 7.45 | 7.60 |
| 42 | 75 | 33 | 6.43 | 6.69 | 6.87 | 7.13 | 7.31 | 7.44 |
| 41 | 75 | 34 | 6.33 | 6.60 | 6.77 | 7.02 | 7.18 | 7.30 |
| 46 | 80 | 34 | 6.33 | 6.60 | 6.77 | 7.02 | 7.18 | 7.30 |
| 40 | 75 | 35 | 6.23 | 6.50 | 6.68 | 6.91 | 7.06 | 7.17 |
| 45 | 80 | 35 | 6.23 | 6.50 | 6.68 | 6.91 | 7.06 | 7.17 |
| 44 | 80 | 36 | 6.13 | 6.41 | 6.58 | 6.81 | 6.95 | 7.05 |
| 43 | 80 | 37 | 6.02 | 6.31 | 6.49 | 6.71 | 6.85 | 6.94 |
| 42 | 80 | 38 | 5.90 | 6.21 | 6.40 | 6.61 | 6.75 | 6.84 |
| 41 | 80 | 39 | 5.77 | 6.11 | 6.30 | 6.52 | 6.65 | 6.74 |
| 46 | 85 | 39 | 5.77 | 6.11 | 6.30 | 6.52 | 6.65 | 6.74 |
| 40 | 80 | 40 | 5.63 | 6.00 | 6.20 | 6.43 | 6.56 | 6.65 |
| 45 | 85 | 40 | 5.63 | 6.00 | 6.20 | 6.43 | 6.56 | 6.65 |
| 44 | 85 | 41 | 5.47 | 5.87 | 6.10 | 6.33 | 6.47 | 6.55 |
| 43 | 85 | 42 | 5.30 | 5.74 | 5.98 | 6.24 | 6.37 | 6.46 |
| 42 | 85 | 43 | 5.11 | 5.60 | 5.86 | 6.13 | 6.28 | 6.37 |
| 41 | 85 | 44 | 4.90 | 5.44 | 5.72 | 6.02 | 6.17 | 6.27 |
| 40 | 85 | 45 | 4.68 | 5.26 | 5.58 | 5.90 | 6.07 | 6.17 |
| Condenser ΔT ^b | | | 14.04 | 11.23 | 9.36 | 7.02 | 5.62 | 4.68 |

For SI: °C = [(°F) - 32] / 1.8, 1 gallon per minute = 3.785 L/min., 1 ton = 12,000 British thermal unit per hour = 3.517 kW.

- Lift = Entering condenser water temperature (°F) - Leaving chilled water temperature (°F).
- Condenser ΔT = Leaving condenser water temperature (°F) - Entering condenser water temperature (°F).

$$K_{adj} = 6.1507 - 0.030244(X) + 0.0062692(X)^2 - 0.000045595(X)$$

where: X = Condenser ΔT + Lift

$$COP_{adj} = K_{adj} \times COP_{std}$$

TABLE 803.3.2(6)
PERFORMANCE REQUIREMENTS FOR HEAT REJECTION EQUIPMENT

| EQUIPMENT TYPE | TOTAL SYSTEM HEAT REJECTION CAPACITY AT RATED CONDITIONS | SUBCATEGORY OR RATING CONDITION | PERFORMANCE REQUIRED ^{a, b} | TEST PROCEDURE ^c |
|---------------------------------------|--|--|--------------------------------------|--------------------------------|
| Propeller or axial fan cooling towers | All | 95°F entering water 85°F leaving water 75°F wb outdoor air | ≥ 38.2 gpm/hp | CTI ATC-105 and CTI STD-201 |
| Centrifugal fan cooling towers | All | 95°F entering water 85°F leaving water 75°F wb outdoor air | ≥ 20.0 gpm/hp | CTI ATC-105 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 (69 COP) | ARI 460 |

For SI: °C = [(°F) - 32] / 1.8, 1 British thermal unit per hour = 0.2931 W, 1 gallon per minute per horsepower = 0.846 L/s · kW.
wb = wet-bulb temperature, °F

- a. For purposes of this table, cooling tower performance is defined as the maximum flow rating of the tower units (gpm) divided by the fan nameplate rated motor power units (hp).
- b. For purposes of this table, air-cooled condenser performance is defined as the heat rejected from the refrigerant units (Btu/h) divided by the fan nameplate rated motor power units (hp).
- c. Chapter 10 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

803.3.3.6 Variable air volume (VAV) fan control. Individual VAV fans with motors of 25 horsepower (18.8 kW) or greater shall be:

1. Driven by a mechanical or electrical variable speed drive; or
2. The fan motor 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 air flow when static pressure set point equals one-third of the total design static pressure, based on manufacturer’s certified fan data.

803.3.3.7 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 803.3.3.7.1 through 803.3.3.7.3. 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 input design capacity shall include either a multistaged or modulating burner.

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

803.3.3.7.2 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 (Δ8.3°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 (Δ16.7°C) apart.

803.3.3.7.3 Hydronic (water loop) heat pump systems. 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. For Climate Zones 3 through 8 as indicated in Figure 301.1 and Table 301.1, if a closed-circuit cooling tower is used, 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. 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. If an open-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. 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.

Exception: Where a system loop temperature optimization controller is installed and can determine the most efficient operating temperature based on real time conditions of demand and capacity, dead

bands of less than 20°F ($\Delta 11.1^{\circ}\text{C}$) shall be permitted.

803.3.3.7.4 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.

803.3.3.7.5 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.

803.3.3.8 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 temperature 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 803.3.2(1) through 803.3.2(6).

803.3.4 Requirements for complex mechanical systems serving multiple zones. Sections 803.3.4.1 through 803.3.4.3 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*.

Exceptions: The following define when individual zones or when 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, re-cooled 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 zone(s) 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.

803.3.4.1 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.

803.3.4.2 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.

803.3.4.3 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.

803.3.5 Ventilation. Ventilation shall be in accordance with Section 803.2.5.

803.3.6 Duct and plenum insulation and sealing. All ducts and plenums shall be insulated and sealed in accordance with Section 803.2.8.

Ducts designed to operate at static pressures in excess of 3 inches w.g. (746 Pa) 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 8-2.

$$CL = F \times P^{0.65} \quad \text{(Equation 8-2)}$$

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.

803.3.7 Piping insulation. All piping serving as part of a heating or cooling system shall be thermally insulated in accordance with Table 803.3.7.

Exceptions:

1. Factory-installed piping within HVAC equipment tested and rated in accordance with a test procedure referenced by this code.
2. Piping that conveys fluids that have a design operating temperature range between 55°F (13°C) and 105°F (41°C).
3. Piping that conveys fluids that have not been heated or cooled through the use of fossil fuels or electric power.
4. Runout piping not exceeding 4 feet (1219 mm) in length and 1 inch (25 mm) in diameter between the control valve and HVAC coil.

803.3.8 HVAC system completion. Prior to the issuance of a certificate of occupancy, the design professional shall provide evidence of system completion in accordance with Sections 803.3.8.1 through 803.3.8.3.

803.3.8.1 Air system 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 25 hp (18.6 kW) and larger.

**TABLE 803.3.7
MINIMUM PIPE INSULATION^a
(thickness in inches)**

| FLUID | NOMINAL PIPE DIAMETER | |
|-------------------------------------|-----------------------|--------|
| | ≤1.5" | > 1.5" |
| Steam | 1½ | 3 |
| Hot water | 1 | 2 |
| Chilled water, brine or refrigerant | 1 | 1½ |

For SI: 1 inch = 25.4 mm, British thermal unit per inch/h · ft² · °F = W per 25 mm/K · m²

a. Based on insulation having a conductivity (*k*) not exceeding 0.27 Btu per inch/h · ft² · °F.

803.3.8.2 Hydronic system balancing. Individual hydronic heating and cooling coils shall be equipped with means for balancing and pressure test connections.

803.3.8.3 Manuals. The construction documents shall require that an operating and maintenance manual be provided to the building owner by the mechanical contractor. The manual shall include, at least, the following:

1. Equipment capacity (input and output) and required maintenance actions.
2. Equipment operation and maintenance manuals.
3. HVAC system control 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 programming comments.
4. A complete written narrative of how each system is intended to operate.

803.3.9 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 of heat rejection, and the design service water heating load exceeds 1,000,000 Btu/h.

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.

803.3.10 Energy recovery ventilation systems. Individual fan systems that have both a design supply air capacity of 5,000 cfm (2.36 m³/s) or greater and a minimum outside air supply of 70 percent or greater of the design supply air quantity shall have an energy recovery system that provides a change in the enthalpy of the outdoor air supply of 50 percent or more of the difference between the outdoor air and return air at design conditions. Provision shall be made to bypass or control the energy recovery system to permit cooling with outdoor air where cooling with outdoor air is required.

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 with a total exhaust rate of 15,000 cfm (7.08 m³/s) or less.
3. Laboratory fume hood systems with a total exhaust rate greater than 15,000 cfm (7.08 m³/s) that include at least one of the following features:
 - 3.1. 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.
 - 3.2. Direct makeup (auxiliary) air supply equal to at least 75 percent of the exhaust rate, heated no warmer than 2°F (Δ1.1°C) below room set point, cooled to no cooler than 3°F (Δ1.7°C) above room set point, no humidification added, and no simultaneous heating and cooling used for dehumidification control.
4. Systems serving spaces that are not cooled and are heated to less than 60°F (15.5°C).
5. Where more than 60 percent of the outdoor heating energy is provided from site-recovered or site solar energy.
6. Heating systems in climates with less than 3600 HDD.
7. Cooling systems in climates with a 1 percent cooling design wet-bulb temperature less than 64°F (17.7°C).
8. Systems requiring dehumidification that employ series-style energy recovery coils wrapped around the cooling coil.

SECTION 804 SERVICE WATER HEATING

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

804.2 Service water-heating equipment performance efficiency. Water-heating equipment and hot water storage tanks shall meet the requirements of Table 804.2. The efficiency shall be verified through data furnished by the manufacturer or through certification under an approved certification program.

804.3 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).

804.4 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.

804.5 Pipe insulation. For automatic-circulating hot water systems, piping shall be insulated with 1 inch (25 mm) of insulation having a conductivity not exceeding 0.27 Btu per inch/h

× ft² × °F (1.53 W per 25 mm/m² × K). The first 8 feet (2438 mm) of piping in noncirculating 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 × ft² × °F (1.53 W per 25 mm/m² × K).

804.6 Hot water system controls. Automatic-circulating hot water system pumps or heat trace shall be arranged to be conveniently turned off automatically or manually when the hot water system is not in operation.

804.7 Pools. Pools shall be provided with energy conserving measures in accordance with Sections 804.7.1 through 804.7.3.

804.7.1 Pool heaters. All pool heaters shall be equipped with a readily accessible on-off switch to allow shutting off the heater without adjusting the thermostat setting. Pool heaters fired by natural gas shall not have continuously burning pilot lights.

804.7.2 Time switches. Time switches that can automatically turn off and on heaters and pumps according to a preset schedule shall be installed on swimming pool heaters and pumps.

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.

804.7.3 Pool covers. Heated pools shall be equipped with a vapor retardant pool cover on or at the water surface. Pools heated to more than 90°F (32°C) shall have a pool cover with a minimum insulation value of R-12.

Exception: Pools deriving over 60 percent of the energy for heating from site-recovered energy or solar energy source.

SECTION 805 ELECTRICAL POWER AND LIGHTING SYSTEMS

805.1 General. This section covers lighting system controls, the connection of ballasts, the maximum lighting power for interior applications, and minimum acceptable lighting equipment for exterior applications.

Exception: Lighting within dwelling units.

805.2 Lighting controls. Lighting systems shall be provided with controls as required in Sections 805.2.1, 805.2.2, 805.2.3 and 805.2.4.

805.2.1 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 must be continuously lighted.

- Lighting in stairways or corridors that are elements of the means of egress.

805.2.2 Additional controls. Each area that is required to have a manual control shall have additional controls that meet the requirements of Sections 805.2.2.1 and 805.2.2.2.

Exceptions:

- Areas that have only one luminaire.

- Areas that are controlled by an occupant-sensing device.
- Corridors, storerooms, restrooms or public lobbies.
- Guestrooms (See Section 805.2.3).

805.2.2.1 Light reduction controls. Each area that is required to have a manual control shall also allow the occu-

**TABLE 804.2
MINIMUM PERFORMANCE OF WATER-HEATING EQUIPMENT**

| EQUIPMENT TYPE | SIZE CATEGORY (input) | SUBCATEGORY OR RATING CONDITION | PERFORMANCE REQUIRED ^{a, b} | TEST PROCEDURE |
|---------------------------------------|---|---------------------------------|---|---------------------|
| Water heaters, Electric | ≤ 12 kW | Resistance | 0.93 - 0.00132V, 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 - 0.00132V, EF | DOE 10 CFR Part 430 |
| Storage water heaters, Gas | ≤ 75,000 Btu/h | ≥ 20 gal | 0.62 - 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 ^c | ≥ 4,000 (Btu/h)/gal and < 2 gal | 0.62 - 0.0019V, 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 and Oil | | ≥ 4,000 Btu/h/gal and ≥ 10 gal | $80\% E_t$ $(Q / 800 + 110\sqrt{V})$ SL, Btu/h | |
| Pool heaters, Gas and Oil | All | — | 78% E_t | ASHRAE 146 |
| Unfired storage tanks | All | — | ≤ 6.5 Btu/h · ft ² | (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.

partment 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.

Exceptions:

1. Areas that have only one luminaire.
2. Areas that are controlled by an occupant-sensing device.
3. Corridors, storerooms, restrooms or public lobbies.
4. Guestrooms (see Section 805.2.3).
5. Spaces that use less than 0.6 watts per square foot (6.5 W/m²).

805.2.2.2 Automatic lighting shutoff. Buildings larger than 5,000 square feet (465 m²) shall be equipped with an automatic control device to shut off lighting in those areas. This automatic control device shall function on either:

1. A scheduled basis, using time-of-day, with an independent program schedule that controls the interior lighting in areas that do not exceed 25,000 square feet (2323 m²) and are not more than one floor; or
2. An unscheduled basis by occupant intervention.

805.2.2.2.1 Occupant override. Where an automatic time switch control device is installed to comply with Section 805.2.2.2, Item 1, it shall incorporate an override switching device that:

1. Is readily accessible.
2. Is located so that a person using the device can see the lights or the area controlled by that switch, or so that the area being lit is annunciated.
3. Is manually operated.
4. Allows the lighting to remain on for no more than 2 hours when an override is initiated.
5. Controls an area not exceeding 5,000 square feet (465 m²).

Exceptions:

1. In malls and arcades, auditoriums, single-tenant retail spaces, industrial facilities and arenas, where captive-key override is utilized, override time may exceed 2 hours.
2. In malls and arcades, auditoriums, single-tenant retail spaces, industrial facilities and arenas, the area controlled may not exceed 20,000 square feet (1860 m²).

805.2.2.2.2 Holiday scheduling. If an automatic time switch control device is installed in accordance with Section 805.2.2.2, Item 1, it shall incorporate an automatic holiday scheduling feature that turns off all loads for at least 24 hours, then resumes the normally scheduled operation.

Exception: Retail stores and associated malls, restaurants, grocery stores, churches and theaters.

805.2.3 Guestrooms. Guestrooms in hotels, motels, boarding houses or similar buildings shall have at least one master switch at the main entry door that controls all permanently wired luminaires and switched receptacles, except those in the bathroom(s). Suites shall have a control meeting these requirements at the entry to each room or at the primary entry to the suite.

805.2.4 Exterior lighting controls. Automatic switching or photocell controls shall be provided for all exterior lighting not intended for 24-hour operation. Automatic time switches shall have a combination seven-day and seasonal daylight program schedule adjustment, and a minimum 4-hour power backup.

805.3 Tandem wiring. 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 other 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.

805.4 Exit signs. Internally illuminated exit signs shall not exceed 5 Watts per side.

805.5 Interior lighting power requirements. A building complies with this section if its total connected lighting power calculated under Section 805.5.1 is no greater than the interior lighting power calculated under Section 805.5.2.

805.5.1 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 determined in accordance with Sections 805.5.1.1 through 805.5.1.4.

Exceptions: The connected power associated with the following lighting equipment is not included in calculating total connected lighting power.

1. Specialized medical, dental and research lighting.
2. Professional sports arena playing field lighting.
3. Display lighting for exhibits in galleries, museums and monuments.

4. Guestroom lighting in hotels, motels, boarding houses or similar buildings.
5. Emergency lighting automatically off during normal building operation.

805.5.1.1 Screw lamp holders. The wattage shall be the maximum labeled wattage of the luminaire.

805.5.1.2 Low-voltage lighting. The wattage shall be the specified wattage of the transformer supplying the system.

805.5.1.3 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.

805.5.1.4 Line-voltage lighting track and plug-in busway. The wattage shall be the greater of the wattage of the luminaires determined in accordance with Sections 805.5.1.1 through 805.5.1.3 or 30 W/linear foot (98W/lin m).

805.5.2 Interior lighting power. The interior lighting power shall be calculated using Section 805.5.2.1 or 805.5.2.2 as applicable.

805.5.2.1 Entire building method. Under this approach, the interior lighting power (Watts) is the value from Table 805.5.2 for the building type times the floor area of the entire building. The interior lighting power (Watts) shall not be increased by the allowances contained in the footnotes of Table 805.5.2 when using the entire building method.

805.5.2.2 Tenant area or portion of building method. The total interior lighting power (Watts) is the sum of all interior lighting powers for all areas in the building covered in this permit. The interior lighting power is the floor area for each area type listed in Table 805.5.2 times the value from Table 805.5.2 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 area type as listed in Table 805.5.2. When this method is used to calculate the total interior lighting power for an entire building, each area type shall be treated as a separate area.

805.6 Exterior lighting. When the power for exterior lighting is supplied through the energy service to the building, all exterior lighting, other than low-voltage landscape lighting, shall have a source efficacy of at least 45 lumens per Watt.

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

805.7 Electrical energy consumption. 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 806 TOTAL BUILDING PERFORMANCE

806.1 General. The proposed design complies with this section where annual energy costs of the proposed design as deter-

mined in accordance with Section 806.3 do not exceed those of the standard design as determined in accordance with Section 806.4.

806.2 Analysis procedures. Sections 806.2.1 through 806.2.8 shall be applied in determining total building performance.

806.2.1 Energy analysis. Annual (8,760 hours) energy costs for the standard design and the proposed design shall each be determined using the same approved energy analysis simulation tool.

806.2.2 Climate data. The climate data used in the energy analysis shall cover 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.

806.2.3 Energy rates. The annual energy costs shall be estimated using energy rates published by the serving energy supplier and which would apply to the actual building or *DOE State-Average Energy Prices* published by DOE's Energy Information Administration and which would apply to the actual building.

806.2.4 Nondepletable energy. 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. The analysis and performance of any nondepletable energy system shall be determined in accordance with accepted engineering practice using approved methods.

806.2.5 Building operation. Building operation shall be simulated for a full calendar year (8,760 hours). 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 of occupancy, illumination, receptacle loads, thermostat settings, mechanical ventilation, HVAC equipment availability, service hot water usage, and any process loads.

806.2.6 Simulated loads. The following systems and loads shall be modeled in determining total building performance: heating systems, cooling systems, fan systems, lighting power, receptacle loads, and process loads that exceed 1.0 W/ft² (W/0.0929 m²) of floor area of the room or space in which the process loads are located.

Exception: Systems and loads serving required emergency power only.

806.2.7 Service water-heating systems. Service water-heating systems that are other than combined service hot water/space-heating systems shall be omitted from the energy analysis provided all requirements in Section 804 have been met.

806.2.8 Exterior lighting. Exterior lighting systems shall be the same as in the standard and proposed designs.

806.3 Determining energy costs for the proposed design. Building systems and loads shall be simulated in the Proposed design in accordance with Sections 806.3.1 and 806.3.2.

**TABLE 805.5.2
INTERIOR LIGHTING POWER**

| BUILDING OR AREA TYPE | ENTIRE BUILDING (W/ft²) | TENANT AREA OR PORTION OF BUILDING (W/ft²) |
|---|---|--|
| Auditorium | Not Applicable | 1.8 |
| Automotive facility | 0.9 | Not Applicable |
| Bank/financial institution ^a | Not Applicable | 1.5 |
| Classroom/lecture hall ^b | Not Applicable | 1.4 |
| Convention, conference or meeting center ^a | 1.2 | 1.3 |
| Corridor, restroom, support area | Not Applicable | 0.9 |
| Courthouse/town hall | 1.2 | Not Applicable |
| Dining ^a | Not Applicable | 0.9 |
| Dormitory | 1.0 | Not Applicable |
| Exercise center ^a | 1.0 | 0.9 |
| Exhibition hall | Not Applicable | 1.3 |
| Grocery store ^c | 1.5 | 1.6 |
| Gymnasium playing surface | Not Applicable | 1.4 |
| Hotel function ^a | 1.0 | 1.3 |
| Industrial work, < 20-foot ceiling height | Not Applicable | 1.2 |
| Industrial work, ≥ 20-foot ceiling height | Not Applicable | 1.7 |
| Kitchen | Not Applicable | 1.2 |
| Library ^a | 1.3 | 1.7 |
| Lobby—hotel ^a | Not Applicable | 1.1 |
| Lobby—other ^a | Not Applicable | 1.3 |
| Mall, arcade, or atrium | Not Applicable | 0.6 |
| Medical and clinical care ^{b, d} | 1.2 | 1.2 |
| Motel | 1.0 | Not Applicable |
| Multifamily | 0.7 | Not Applicable |
| Museum ^b | 1.1 | 1.0 |
| Office ^b | 1.0 | 1.1 |
| Parking garage | 0.3 | Not Applicable |
| Penitentiary | 1.0 | Not Applicable |
| Police/fire station | 1.0 | Not Applicable |
| Post office | 1.1 | Not Applicable |
| Religious worship ^a | 1.3 | 2.4 |
| Restaurant ^a | 1.6 | 0.9 |
| Retail sales, wholesale showroom ^c | 1.5 | 1.7 |
| School | 1.2 | Not Applicable |
| Storage, industrial and commercial | 0.8 | 0.8 |
| Theaters—motion picture | 1.2 | 1.2 |
| Theaters—performance ^a | 1.6 | 2.6 |
| Transportation | 1.0 | Not Applicable |
| Other | 0.6 | 1.0 |

For SI: 1 foot = 304.8 mm, 1 Watts per square foot = W/0.0929 m².

a. Where lighting equipment is specified to be installed for decorative appearances 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 decorative lighting equipment or 1.0 W/ft² times the area of the space that the decorative lighting equipment is in shall be added to the interior lighting power determined in accordance with this line item.

(Continued)

TABLE 805.5.2(Continued)
INTERIOR LIGHTING POWER

- b. Where lighting equipment is specified to be installed to meet requirements of visual display terminals as the primary viewing task, the smaller of the actual wattage of the lighting equipment or 0.35 W/ft^2 times the area of the space that the lighting equipment is in shall be added to the interior lighting power determined in accordance with this line item.
- c. 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 1.6 W/ft^2 times the area of the specific display, or 3.9 W/ft^2 times the actual case or shelf area for displaying and selling fine merchandise such as jewelry, fine apparel and accessories, or china and silver, shall be added to the interior lighting power determined in accordance with this line item.
- d. Where lighting equipment is specified to be installed, the smaller of the actual wattage of the lighting equipment, or 1.0 W/ft^2 times the area of the emergency, recovery, medical supply and pharmacy space shall be added to the interior lighting power determined in accordance with this line item.

806.3.1 HVAC and service water-heating equipment. All HVAC and service water-heating equipment shall be simulated in the proposed design using capacities, rated efficiencies and part-load performance data for the proposed equipment as provided by the equipment manufacturer.

806.3.2 Features not documented at time of permit. If any feature of the proposed design is not included in the building permit application, the energy performance of that feature shall be assumed to be that of the corresponding feature used in the calculations required in Section 806.4.

806.4 Determining energy costs for the standard design. Sections 806.4.1 through 806.4.7 shall be used in determining the annual energy costs of the Standard design.

806.4.1 Equipment efficiency. The space-heating, space-cooling, service water-heating, and ventilation systems and equipment shall meet, but not exceed, the minimum efficiency requirements of Sections 803 and 804.

806.4.2 HVAC system capacities. HVAC system capacities in the standard design shall be established such that no smaller number of unmet heating and cooling load hours and no larger heating and cooling capacity safety factors are provided than in the proposed design.

806.4.3 Envelope. The performance of elements of the thermal envelope of the standard design shall be determined in accordance with the requirements of Section 802.2 as applicable.

806.4.4 Identical characteristics. The heating/cooling system zoning, the orientation of each building feature, the number of floors and the gross envelope areas of the standard design shall be the same as those of the proposed design except as modified by Section 806.4.5 or 806.4.6.

Exception: Permanent fixed or movable external shading devices for windows and glazed doors shall be excluded from the standard design.

806.4.5 Window area. The window area of the standard design shall be the same as the proposed design, or 35 percent of the above-grade wall area, whichever is less, and shall be distributed in a uniform pattern equally over each building facade.

806.4.6 Skylight area. The skylight area of the standard design shall be the same as the proposed design, or 3 percent of the gross area of the roof assembly, whichever is less.

806.4.7 Interior lighting. The lighting power for the standard design shall be the maximum allowed in accordance

with Section 805.5. Where the occupancy of the building is not known, the lighting power density shall be 1.5 Watts per square foot (16.1 W/m^2).

806.5 Documentation. The energy analysis and supporting documentation shall be prepared by a registered design professional where required by the statutes of the jurisdiction in which the project is to be constructed. The information documenting compliance shall be submitted in accordance with Sections 806.5.1 through 806.5.4

806.5.1 Annual energy use and associated costs. The annual energy use and costs by energy source of the standard design and the proposed design shall be clearly indicated.

806.5.2 Energy-related features. A list of the energy-related features that are included in the proposed design and on which compliance with the provisions of the code are claimed shall be provided to the code official. This list shall include and prominently indicate all features that differ from those set forth in Section 806.4 and used in the energy analysis between the standard design and the proposed design.

806.5.3 Input and output report(s). 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.

806.5.4 Written explanation(s). An explanation of any error or warning messages appearing in the simulation tool output shall be provided in a written, narrative format.

