CHAPTER 5

COMMERCIAL ENERGY EFFICIENCY

SECTION 501
GENERAL

501.1 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 ANSI/ASHRAE/IESNA Standard 90.1-2007, *Energy Standard for Buildings Except for Low-Rise Residential Buildings,* or the requirements contained in this chapter.

501.2 Application. The *commercial building* project shall comply with the requirements in Sections 502 (Building envelope requirements), 503 (Building mechanical systems), 504 (Service water heating) and 505 (Electrical power and lighting systems) in its entirety. As an alternative the *commercial building* project shall comply with the requirements of ANSI/ASHRAE/IESNA 90.1-2007 in its entirety. *Commercial building* projects utilizing the alternative compliance path of ANSI/ASHRAE/IESNA 90.1-2007 must follow all applicable provisions listed in Section 501.2.1.

501.2.1 Applicable provisions.

1. All instances of the term *building official* in ASHRAE/IESNA 90.1-2007 shall be replaced with the terms *code official* or other authority having jurisdiction.
2. ASHRAE/IESNA 90.1-2007 *Section 5.1.4.1 United States Locations*. Delete the exception clause and replace with the following:

   Adjustments may be made only in the following cases:

   a. Winter heating design temperatures for projects either:
      i. Located at an elevation of 1,500 feet or higher or
      ii. located in Caledonia, Essex or Orleans counties.
      iii. Adjustments shall be made as listed in the National Climate Data Center for the specific weather station: http://cdo.ncdc.noaa.gov/climatenormals/clim81_supp/CLIM81_Sup_02.pdf.
   b. As approved by *code official* or other authority having jurisdiction.
3. ASHRAE/IESNA 90.1-2007 *Section 5 Building Envelope*. All envelope requirements shall comply with the following tables in the *2011 Vermont Commercial Building Energy Standards* (CBES):
   i. *Table 502.1(1), Building Envelope Requirements-Opaque Assemblies and Element*,
   ii. *Table 502.1(2), Building Envelope Requirements-Metal Building Assembly Descriptions*,
   iii. *Table 502.1(3), Assembly U-Factors for Metal Building Roofs*,
   iv. *Table 502.1.(4), Assembly U-Factors for Metal Building Walls* and
   v. *Table 502.3, Building Envelope Requirements: Fenestration*.
4. ASHRAE/IESNA 90.1-2007 *Section 5.5.3.1 Roof Insulation*. Delete section in its entirety and replace with *Section 502.2.1 Roof Assembly of the 2011 Vermont CBES*.
5. ASHRAE/IESNA 90.1-2007 *Section 5.4.3 Air Leakage*. Delete section in its entirety and replace with *Section 502.4 Air Leakage of the 2011 Vermont CBES*.
6. ASHRAE/IESNA 90.1-2007 *Section 6.2 Compliance Path(s)*. Add new section as follows:
   a. Section 6.2.3 Electric Resistance Space Heating. Building heating with electrical resistance units, including baseboard radiation, heat pump reheat coils, duct coils, boilers, domestic hot water heaters and coils in terminal units and air systems is prohibited.

      Exceptions to Section 6.2.3:

      1. Areas, such as stairways, that are not permitted to be penetrated with piping or duct and no other method of heating is possible.
      2. Replacement of existing electrical resistance unit.
      3. Special conditions of occupancy or use that require electrical resistance heat to maintain health, safety or environmental conditions.
      4. Limited areas where a practical application of resistance electrical heat is demonstrated (e.g. small interior space such as a rest room which is distant from the distribution system, hazardous material storerooms, stairwell or other means of emergency egress).
      5. Domestic hot water heaters less than 5 kW in total unit input capacity.
7. ASHRAE/IESNA 90.1-2007 *Section 6.3.2(d) Criteria*. Delete "an electric resistance heater."
8. ASHRAE/IESNA 90.1-2007 *Section 6.4.3.5 Heat Pump Auxiliary Heat Control*. Delete section in its entirety and replace with *Section 503.2.4.1.1 Heat Pump Supplementary Heat of the 2001 Vermont CBES*.
9. ASHRAE/IESNA 90.1-2007 *Section 6.4.3.9 Ventilation Controls for High-Occupancy Areas*. Add *exception (e)*: Ventilation needs for process loads.

10. ASHRAE/IESNA 90.1-2007 *Section 6.7.2.4 System Commissioning*. Delete section I in its entirety and replace with *Section 503.2.10 Systems Performance, Verification and Completion of the 2011 Vermont CBES*.
11. ASHRAE/IESNA 90.1-2007 *Section 6.5.1 Economizers*. Delete section in its entirety and replace with *Section 503.3.1 Economizers of the 2011 Vermont CBES*.
12. ASHRAE/IESNA 90.1-2007 *Section 6.5.6.2 Heat Recovery for Service Water Heating*. Add exception (c): If compliance with Section 6.5.6.2 will be detrimental to chiller operating efficiency due to conflicts with optimized chiller head pressure control.
13. ASHRAE/IESNA 90.1-2007 *Section 7.1 General*. Add *new* section as follows:
    a. Section 7.1.1.4 Electrical Water Heating Limitation. Individual electric service water heating units shall be limited to a maximum of 5 kW total power input.

       Exception: Instantaneous electric water heaters used to serve emergency showers and emergency eye wash stations.
14. ASHRAE/IESNA 90.1-2007 *Table 7.8 Performance Requirements for Water Heating Equipment*. Change first row size category to ≤ 5 kW and delete entire second row for electric water heaters >12 kW.
15. ASHRAE/IESNA 90.1-2007 *Table 9.5.1 Lighting Power Densities Using the Building Area Method*. Delete table in its entirety and replace with *Table 505.5.2(1) of the 2011 Vermont CBES*.
16. ASHRAE/IESNA 90.1-2007 *Table 9.6.1 Lighting Power Densities Using the Space-by-Space Method*. Delete table in its entirety and replace with *Table 505.5.2(2) of the 2011 Vermont CBES*.
17. ASHRAE/IESNA 90.1-2007 *Section 9.6.2.b Additional Interior Lighting Power*. Delete equation for Additional Interior Lighting Power Allowance and replace with the following (definitions for retail areas shall remain unchanged):
    a. Additional Interior Lighting Power Allowance = 500 watts + (Retail Area 1 × 0.6 W/ft^2) + (Retail Area 2 × 0.6W/ft^2) + (Retail Area 3 × 1.4 W/ft^2) + (Retail Area 4 × 2.5 W/ft^2).
18. ASHRAE/IESNA 90.1-2007 *Section 10.4.1 Electric Motors*. Delete entire section and replace with *Section 505.8 Electric Motors of the 2011 Vermont CBES*.
19. ASHRAE/IESNA 90.1-2007 *Table 10.8 Minimum Nominal Efficiency for General Purpose Design A and Design B Motors*. Delete table in its entirety and replace with *Table 505.8(1) of the 2011 Vermont CBES*.

501.3 Certificate of compliance. 21 V.S.A. §268 requires certification that both the design and the construction of a commercial building is in compliance with the CBES.

Certification shall be issued by a completed and signed certificate permanently affixed to the outside of the heating or cooling equipment, to the electrical service panel and located inside the building, or in a visible location in the immediate vicinity of one of these three areas. Copies of the signed certification documents shall be sent to the local town clerk and to the Vermont Department of Public Service.

SECTION 502
BUILDING ENVELOPE REQUIREMENTS

502.1 General (Prescriptive).

502.1.1 Insulation and fenestration criteria. The *building thermal envelope* shall meet the requirements of Tables 502.1(1) and 502.3. Commercial buildings or portions of commercial buildings enclosing Group R occupancies shall use the *R*-values from the "Group R" column of Table 502.1(1). Commercial buildings or portions of commercial buildings enclosing occupancies other than Group R shall use the *R*-values from the "All other" column of Table 502.1(1). Buildings with a vertical fenestration area or skylight area that exceeds that allowed in Table 502.3 shall comply with the building envelope provisions of ASHRAE/IESNA 90.1-2007, as modified by Section 502.1.1.

502.1.2 *U*-factor alternative. An assembly with a *U*-factor, *C*-factor, or *F*-factor equal or less than that specified in Table 502.1(1) shall be permitted as an alternative to the *R*-value in Table 502.1(1). Commercial buildings or portions of commercial buildings enclosing Group R occupancies shall use the *U*-factor, *C*-factor, or *F*-factor from the "Group R" column of Table 502.1(1). Commercial buildings or portions of commercial buildings enclosing occupancies other than Group R shall use the *U*-factor, *C*-factor or *F*-factor from the "All other" column of Table 502.1(1).

502.2 Specific insulation requirements (Prescriptive). Opaque assemblies shall comply with Table 502.1(1).

502.2.1 Roof assembly. The minimum thermal resistance (*R*-value) of the insulating material installed either between the roof framing or continuously on the roof assembly shall be as specified in Table 502.1(1), based on construction materials used in the roof assembly. Skylight curbs shall be insulated to the level of roofs with insulation entirely above deck or R-5, whichever is less.

Mechanical curbs shall be insulated to the level of roofs with insulation entirely above deck or R-5, whichever is less.

Exceptions:

1. Continuously insulated roof assemblies where the area-weighted *U*-factor is equivalent to the same assembly with the *R*-value specified in Table 502.1(1).
2. Unit skylight curbs included as a component of a skylight assembly tested in accordance with NFRC 100 and 200 shall not require additional insulation.

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

502.2.2 Classification of walls. Walls associated with the building envelope shall be classified in accordance with Section 502.2.2.1 or 502.2.2.2.

502.2.2.1 Above-grade walls. Above-grade walls are those walls covered by Section 502.2.3 on the exterior of the building and completely above grade or walls that are more than 15 percent above grade.

502.2.2.2 Below-grade walls. Below-grade walls covered by Section 502.2.4 are basement or first-story walls associated with the exterior of the building that are at least 85 percent below grade.

502.2.3 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 502.1(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 502.1(1). "Mass walls" shall include walls weighing at least (1) 35 pounds per square foot (170 kg/m^2) of wall surface area or (2) 25 pounds per square foot (120 kg/m^2) of wall surface area if the material weight is not more than 120 pounds per cubic foot (1900 kg/m^3).

502.2.4 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 502.1(1), and shall extend to a depth of 10 feet (3048 mm) below the outside finished ground level, or to the level of the floor, whichever is less.

502.2.5 Floors over outdoor air or unconditioned space. The minimum thermal resistance (*R*-value) of the insulating material installed either between the floor framing or continuously on the floor assembly shall be as specified in Table 502.1(1), based on construction materials used in the floor assembly.

"Mass floors" shall include floors weighing at least (1) 35 pounds per square foot (170 kg/m^2) of floor surface area or (2) 25 pounds per square foot (120 kg/m^2) of floor surface area if the material weight is not more than 120 pounds per cubic foot (1,900 kg/m^3).

502.2.6 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 502.1(1). The insulation shall be placed on the outside of the foundation or on the inside of a 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.

502.2.7 Opaque doors. Opaque doors (doors having less than 50 percent glass area) shall meet the applicable requirements for doors as specified in Table 502.1(1) and be considered as part of the gross area of above-grade walls that are part of the building envelope.

502.3 Fenestration (Prescriptive). Fenestration shall comply with Table 502.3.

502.3.1 Maximum area. The vertical fenestration area (not including opaque doors) shall not exceed the percentage of the gross wall area specified in Table 502.3. The skylight area shall not exceed the percentage of the gross roof area specified in Table 502.3.

502.3.2 Maximum *U*-factor and SHGC. For vertical fenestration, the maximum *U*-factor and solar heat gain coefficient (SHGC) shall be as specified in Table 502.3, based on the window projection factor. For skylights, the maximum *U*-factor and solar heat gain coefficient (SHGC) shall be as specified in Table 502.3.

The window projection factor shall be determined in accordance with Equation 5-1.

$$PF = A/B \qquad \textbf{(Equation 5-1)}$$

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 502.1(1)
BUILDING ENVELOPE REQUIREMENTS–OPAQUE ASSEMBLIES AND ELEMENTS[a,b]

COMPONENT	MAXIMUM OVERALL *U*-FACTOR[a]		MINIMUM *R*-VALUES	
	All other	Group R	All other	Group R
Roofs				
Insulation entirely above deck	U-0.032		R-30ci	
Metal buildings[c, d]	U-0.049		See Table 502.1(2) and Table 502.1(3) for assembly descriptions and assembly *U*-factors	
Attic and other	U-0.027		R-38	
Walls, Above grade				
Mass	U-0.080	U-0.071	R-13.3ci	R-15.2ci
Metal building[c]	U-0.054		R-11 + R-13ci or R-19.5ci	
Metal framed	U-0.064		R-13 + R-7.5ci or R-13ci	
Wood-framed and other	U-0.051		R-13 + R-7.5ci or R-20 + R-3.8ci or R-23 or R-15ci	
Walls, Below grade[e]				
Below-grade wal1	C-0.092		R-10ci	
Floors				
Mass	U-0.064	U-0.057	R-12.5ci	R-14.6ci
Joist/framing-metal	U-0.038	U-0.032	R-30	R-38[f]
Joist/framing—wood and other	U-0.033		R-30	
Slab-on-grade floors				
Unheated slabs	F-0.480	F-0.450	R-10 for 48 in. below	R-15 for 48 in. below
Heated slabs[g]	F-0.550		R-10 for entire slab	
Opaque doors				
Swinging	U-0.37		N/A	
Roll-up or sliding	U-0.20		N/A	
Upward-acting, sectional	N/A		R-10	

For SI: 1 inch = 25.4 mm, ci = continuous insulation.

a. *U*-Factors include overall *F*-Factors and *C*-Factors.

b. For all envelope categories except metal building walls and metal building roofs, the use of opaque assembly *U*-factors, *C*-factors and *F*-factors from ASHRAE 90.1-2007 Appendix A, including Addendum "G", shall be permitted, provided the construction complies with the applicable construction details from such appendix. Alternatively, assembly *U*-factors for metal buildings shall be determined following ASHRAE 90.1-2007 Appendix A9 methodology.

c. Refer to Table 502.1(3) for metal building roof assembly *U*-factors and Table 502.1(4) for metal building wall assembly *U*-factors.

d. A minimum R-3 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly *U*-factor.

e. Where heated slabs are placed below grade, below-grade walls shall comply with the exterior insulation requirements for heated slabs.

f. Steel floor joist systems shall be R-38 minimum for residential structures.

g. Insulation placed under entire heated slab and around perimeter.

TABLE 502.1(2)
BUILDING ENVELOPE REQUIREMENTS–METAL BUILDING ASSEMBLY DESCRIPTIONS

BUILDING ENVELOPE REQUIREMENTS-METAL BUILDING ASSEMBLY DESCRIPTIONS	DESCRIPTION	REFERENCE
ROOFS		
Single layer plus continuous insulation (See Table 502.1(3) for qualifying assemblies)	The first rated *R*-value of insulation is for insulation installed perpendicular to and draped over purlins and then compressed when the metal roof panels are attached. A minimum R-3 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly *U*-factor. The second rated *R*-value is for continuous insulation (e.g., insulation boards or blankets), it is assumed that the insulation is installed below the purlins and is uninterrupted by framing members. Insulation exposed to the conditioned space or semiheated space shall have a facing, and all insulation seams shall be continuously sealed to provide a continuous air barrier.	ANSI/ASHRAE/IESNA 90.1-2007 including Addendum "G" Section A2.3.2
Double layer plus continuous insulation (See Table 502.1(3) for qualifying assemblies)	The first rated *R*-value of insulation is for insulation installed perpendicular to and draped over purlins. The second rated *R*-value of insulation is for unfaced insulation installed above the first layer and parallel to the purlins and then compressed when the metal roof panels are attached. A minimum R-3 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly *U*-factor. The third rated *R*-value is for continuous insulation (e.g., insulation boards or blankets), it is assumed that the insulation is installed below the purlins and is uninterrupted by framing members. Insulation exposed to the conditioned space or semiheated space shall have a facing, and all insulation seams shall be continuously sealed to provide a continuous air barrier.	ANSI/ASHRAE/IESNA 90.1-2007 including Addendum "G" Section A2.3.2
Liner system (Ls) (See Table 502.1(3) for qualifying assemblies)	A continuous membrane installed below the purlins and uninterrupted by framing members. Uncompressed, unfaced insulation rests on top of the membrane between the purlins. For multilayer installations, the last rated *R*-value of insulation is for unfaced insulation draped over purlins and then compressed when the metal roof panels are attached. A minimum R-3 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly *U*-factor.	ANSI/ASHRAE/IESNA 90.1-2007 including Addendum "G" Section A2.3.2
Filled Cavity (Fc) (See Table 502.1(3) for Qualifying Assemblies)	The first rated R-value of insulation is for faced insulation installed parallel to the purlins. The second rated R-value of insulation is for unfaced insulation installed above the first layer, parallel to and between the purlins and compressed when the metal roof panels are attached. The face of the first layer of insulation is of sufficient width to be continuously sealed to the top flange of the purlins and to accommodate the full thickness of the second layer of insulation. A supporting structure retains the bottom of the first layer at the prescribed depth required for the full thickness of the second layer of insulation being installed above it. A minimum R-5 thermal spacer block between the purlins and the metal roof panels is required, unless compliance is shown by the overall assembly U-factor.	ANSI/ASHRAE/IESNA 90.1-2007 including Addendum "G" Section A2.3.2

(continued)

TABLE 502.1(2)–continued
BUILDING ENVELOPE REQUIREMENTS–METAL BUILDING ASSEMBLY DESCRIPTIONS

BUILDING ENVELOPE REQUIREMENTS-METAL BUILDING ASSEMBLY DESCRIPTIONS	DESCRIPTION	REFERENCE
WALLS		
R-11 + R-13ci	The first rated *R*-Value of insulation is for insulation compressed between metal wall panels and the steel structure. The second rated *R*-value is for continuous insulation (e.g., insulation boards). It is assumed that the insulation boards are installed on the inside of the girts and uninterrupted by the framing members. Insulation exposed to the conditioned space or semi-heated space shall have a facing, and all insulation seams shall be continuously sealed to provide a continuous air barrier.	ANSI/ASHRAE/IESNA 90.1-2007 including Addendum "G" Section A3.2.2
R-19.5ci	The rated R-value is for continuous insulation (e.g., insulation boards). It is assumed that the insulation boards are installed on the inside of the girts and uninterrupted by the framing members. Insulation exposed to the conditioned space or semi-heated space shall have a facing, and all insulation seams shall be continuously sealed to provide a continuous air barrier.	ANSI/ASHRAE/IESNA 90.1-2007 including Addendum "G" Section A3.2.2

TABLE 502.1(3)
ASSEMBLY *U*-FACTORS FOR METAL BUILDING ROOFS

INSULATION SYSTEM	RATED *R*-VALUE OF INSULATION	OVERALL *U*-FACTOR FOR ENTIRE BASE ROOF ASSEMBLY	OVERALL *U*-FACTOR FOR ASSEMBLY OF BASE ROOF PLUS CONTINUOUS INSULATION (UNINTERRUPTED BY FRAMING)					
			Rated *R*-Value of Continuous Insulation					
Standing Seam Roofs with Thermal Spacer Blocks[a]			R-6.5	R-13	R-19.5	R-26	R-32.5	R-39
Single layer[b]	None	—	—	—	0.049	0.037	0.030	0.025
	R-10	—	—	0.046	0.035	0.029	0.024	0.021
	R-11	—	—	0.045	0.035	0.028	0.024	0.021
	R-13	—	—	0.044	0.034	0.028	0.024	0.020
	R-16	—	—	0.043	0.033	0.027	0.023	0.020
	R-19	—	—	0.040	0.031	0.026	0.022	0.020
Double layer[b]	R-10 + R-10	—	—	0.041	0.032	0.027	0.023	0.020
	R-10 + R-11	—	—	0.041	0.032	0.027	0.023	0.020
	R-11 + R-11	—	—	0.040	0.032	0.026	0.023	0.020
	R-10 + R13	—	—	0.040	0.032	0.026	0.023	0.020
	R-11 + R-13	—	—	0.040	0.032	0.026	0.022	0.020
	R-13 + R-13	—	—	0.038	0.030	0.025	0.022	0.019
	R-10 + R-19	—	—	0.038	0.030	0.025	0.022	0.019
	R-11 + R-19	—	0.049	0.037	0.030	0.025	0.022	0.019
	R-13 + R-19	—	0.047	0.036	0.029	0.025	0.021	0.019
	R-16 + R-19	—	0.046	0.035	0.029	0.024	0.021	0.018
	R-19 + R-19	—	0.043	0.034	0.028	0.023	0.020	0.018
Liner system[b]	R-19 + R-11 Ls	0.035	—	—	—	—	—	—
	R-25 + R-11 Ls	0.031						
	R-30 + R-11 Ls	0.029						
	R-25 + R-11+ R-11 Ls	0.026						
Filled cavity[c]	R-10 + R-19 Fc	0.057	0.042	0.033	0.027	0.023	0.020	0.018
Standing Seam Roofs without Thermal Spacer Blocks								
Liner system	R-19 + R-11 Ls	0.040	—	—	—	—	—	—
Thru-fastened Roofs without Thermal Spacer Blocks								
Liner system	*R*-19 + R-11 Ls	0.044	—	—	—	—	—	—
(Multiple *R*-values are listed in order from inside to outside)								

a. A standing seam roof clip that provides a minimum 1.5 in. distance between the top of the purlins and the underside of the metal roof panels is required.
b. A minimum R-3 thermal spacer block is required.
c. A minimum R-5 thermal spacer block is required.

TABLE 502.1(4)
ASSEMBLY *U*-FACTORS FOR METAL BUILDING WALLS

INSULATION SYSTEM	RATED *R*-VALUE OF INSULATION	OVERALL *U*-FACTORS FOR ASSEMBLY OF BASE WALL PLUS CONTINUOUS INSULATION (UNINTERRUPTED BY FRAMING)				
		Rated *R*-value of Continuous Insulation				
Single Layer		R-13	R-19.5	R-26	R-32.5	R-39
	None	—	0.049	0.037	0.030	0.025
	R-10	0.054	0.040	0.032	0.026	0.023
	R-11	0.054	0.040	0.032	0.026	0.023
	R-13	0.052	0.039	0.031	0.026	0.022
	R-16	0.051	0.039	0.031	0.026	0.022
	R-19	0.050	0.038	0.03	0.025	0.022

TABLE 502.3
BUILDING ENVELOPE REQUIREMENTS: FENESTRATION

Vertical fenestration (40% maximum of above-grade wall)	
Framing materials other than metal with or without metal reinforcement or cladding	
U-factor	0.35
Metal framing with or without thermal break	
Curtain wall/storefront *U*-factor	0.42
Entrance door *U*-factor	0.80
All other *U*-factor[a]	0.50
SHGC-all frame types	
SHGC: $PF < 0.25$	0.40
SHGC: $0.25 \leq PF < 0.5$	NR
SHGC: $PF \geq 0.5$	NR
Skylights (3% maximum)	
U-factor	0.60
SHGC	0.40

NR = No requirement.
PF = Projection factor (see Section 502.3.2).
a. All others includes operable windows, fixed windows and nonentrance doors.

502.4 Air leakage (Mandatory).

502.4.1 Air Barriers. A continuous air barrier shall be provided throughout the building thermal envelope. The air barriers shall be permitted to be located on the inside or outside of the building envelope, located within the assemblies composing the envelope, or any combination thereof. The air barrier shall comply with Sections 502.4.1.1 and 502.4.1.2.

502.4.1.1. The continuous air barrier shall be constructed to comply with all of the following:

1. The air barrier shall be continuous for all assemblies which are the thermal envelope of the building and across the joints and assemblies.
2. Air barrier joints and seams shall be sealed including sealing transitions in places and changes in materials. Air barrier penetrations shall be sealed in accordance with Section 502.4.2. The joints and seals shall be securely installed in or on the joint for its entire length so as not to dislodge, loosen or otherwise impair its ability to resist positive and negative pressure from wind, stack effect and mechanical ventilation.
3. Recessed lighting fixtures shall comply with Section 504.2.8. Where similar objects are installed which penetrate the air barrier, provisions shall be made to maintain the integrity of the air barrier.

Exception: Buildings that comply with Section 502.4.1.2.3 below are not required to comply with 1and 3 above.

502.4.1.2 Air barrier compliance options. A continuous air barrier for the opaque building envelope shall meet the requirements of one of the compliance options in Section 502.4.1.2.1, 502.4.1.2.2 or 502.4.1.2.3.

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

1. Plywood with a thickness of not less than $^3/_8$ inch (10 mm).
2. Oriented strand board having a thickness of not less than $^3/_8$ inch (10 mm).
3. Extruded polystyrene insulation board having a thickness of not less than $^1/_2$ inch (12 mm).
4. Foil-back polyisocyanurate insulation board having a thickness of not less than $^1/_2$ inch (12 mm).
5. Closed cell spray foam a minimum density of 1.5 pcf (2.4 kg/m^3) having a thickness of not less than $1^1/_2$ inches (36 mm).
6. Open cell spray foam with a density between 0.4 and 1.5 pcf (0.6 and 2.4 kg/m^3) and having a thickness of not less than 4.5 inches (113 mm).
7. Exterior or interior gypsum board having a thickness of not less than $^1/_2$ inch (12 mm).
8. Cement board having a thickness of not less than $^1/_2$ inch (12 mm).
9. Built up roofing membrane.
10. Modified bituminous roof membrane.
11. Fully adhered single-ply roof membrane.
12. A Portland cement/sand parge, or gypsum plaster having a thickness of not less than $^5/_8$ inch (16 mm).
13. Cast-in-place and precast concrete.
14. Fully grouted concrete block masonry.
15. Sheet steel or aluminum.

502.4.1.2.2 Assemblies. Assemblies of materials and components with an average air leakage not to exceed 0.04 cfm/ft^2 (0.2 L/s·m^2) under a pressure differential of 0.3 inches of water gauge (w.g.) (75 Pa) when tested in accordance with ASTM E 2357, ASTM E 1677 or ASTM E 283 shall comply with this section. Assemblies listed in items 1 through 2 shall be deemed to comply provided joints are sealed and requirements of Section 502.4.1.1 are met.

1. Concrete masonry walls coated with one application either of block filler and two applications of a paint or sealer coating;
2. A Portland cement/sand parge, stucco or plaster minimum $^1/_2$ inch (12 mm) in thickness.

502.4.1.2.3 Building Test. The completed building shall be tested and the air leakage rate of the building envelope shall not exceed 0.50 cfm/per square foot of shell area (excluding area of slab and below grade walls) at 50 Pa in accordance with ASTM E 779 or an equivalent method approved by the code official.

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

502.4.3 Fenestration. The air leakage of fenestration assemblies shall meet the provisions of Table 502.4.3. Testing shall be in accordance with the applicable reference test standard in Table 502.4.3 by an accredited independent testing laboratory labeled by the manufacturer.

Exceptions:

1. Field-fabricated fenestration assemblies that are sealed in accordance with Section 502.4.1.

2. Fenestration in buildings that comply with Section 502.4.1.2.3 are not required to meet the air leakage requirements in Table 502.4.3.

TABLE 502.4.3
MAXIMUM AIR INFILTRATION RATE FOR FENESTRATION ASSEMBLIES

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

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

502.4.4 Doors and Access Openings to Shafts, Chutes, Stairways, and Elevator Lobbies. Doors and access openings from conditioned space to shafts, chutes stairways and elevator lobbies shall either meet the requirements of Section 502.4.3 or shall be gasketed, weatherstripped, or sealed.

502.4.5 Outdoor air intakes and exhaust openings. Stairway enclosures and elevator shaft vents and other outdoor air intakes and exhaust openings integral to the building envelope shall be provided with dampers in accordance with Section 502.4.5.1 and 502.4.5.2.

502.4.5.1 Stair and shaft vents. Stair and shaft vents shall be provided with Class I motorized dampers with a maximum leakage rate of 4 cfm per square foot (6.8 L/s · Cm^2) at 1.0 inch water gauge (w.g.) (1250 Pa) when tested in accordance with AMCA 500D.

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

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

502.4.5.2 Outdoor air intakes and exhausts. Outdoor air supply and exhaust openings shall be provided with Class IA motorized dampers with a maximum leakage rate of 4 cfm per square foot (6.8 L/s · C m^2) 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.

502.4.6 Loading dock weather-seals and thermal requirements. Cargo doors and loading dock doors shall be equipped with weather-seals to restrict infiltration when vehicles are parked in the opening. If equipped with an interior dock leveler, the deck of the leveler and rear pit wall shall be insulated with a minimum of 1.5 inches of sprayed closed cell foam. The side pit walls and pit slab shall be insulated per the slab on grade standard in Table 502.1(1). The spaces between the pit wall and the deck skirts for the leveler shall be weather-stripped.

502.4.7 Vestibules. All building entrances shall be protected with an enclosed vestibule, with all doors opening into and out of the vestibule equipped with self-closing devices. Vestibules shall be designed so that in passing through the vestibule it is not necessary for the interior and exterior doors to open at the same time.

Exceptions:

1. Doors not intended to be used as a building *entrance door* by the general public, such as doors to mechanical or electrical equipment rooms.
2. Doors opening directly from a *sleeping unit* or dwelling unit.
3. Doors that open directly from a space less than 3,000 square feet (298 m^2) in area.
4. Revolving doors, where a required adjacent accessible entry has a complying vestibule enclosure.
5. Doors used primarily to facilitate vehicular movement or material handling and adjacent personnel doors.
6. Doors equipped with an alternative means to separate the conditioned space from direct communication with the building exterior or unconditioned spaces when approved by the code official.

502.4.7.1 Vestibule tempering. Where vestibule space tempering is included, a maximum temperature setting of 55°F (13°C) for heating mode shall be utilized. Mechanical cooling of vestibules is prohibited.

502.4.7.2 Vestibule construction. Vestibules meeting the requirements of Section 502.4.7.1 shall be constructed according to the building envelope requirements of Section 502.1.

502.4.7.3 Vestibule thermostatic controls. Vestibules meeting the requirements of Section 502.4.7.1 shall be zoned separately from the conditioned building. Thermostats located inside vestibules shall meet the following requirements:

1. Programmable, and

2. Tamper-proof, and
3. Placed in a location inaccessible to the general public.

Exception: Vestibule spaces served by radiant floor heating may utilize a non-programmable thermostat.

502.4.8 Recessed lighting. Recessed luminaires and any other building component installed in the *building thermal envelope* shall be sealed to limit air leakage between conditioned and unconditioned spaces. All recessed luminaires shall be IC-rated and *labeled* as having an air leakage rate of no more 2.0 cfm (0.944 L/s) when tested in accordance with ASTM E 283 at a 1.57 psf (75 Pa) pressure differential. All recessed luminaires shall be sealed with a gasket or caulk between the housing and interior wall or ceiling covering.

SECTION 503
BUILDING MECHANICAL SYSTEMS

503.1 General. Mechanical systems and equipment serving the building heating, cooling or ventilating needs shall comply with Section 503.2 (referred to as the mandatory provisions) and either:

1. Section 503.3 (Simple systems), or
2. Section 503.4 (Complex systems).

503.1.2 Electric resistance space heating. Building heating with electrical resistance units, including baseboard radiation, heat pump reheat coils, duct coils, boilers, domestic hot water heaters and coils in terminal units and air systems, is prohibited.

Exceptions:

1. Areas, such as stairways, that are not permitted to be penetrated with piping or duct and no other method of heating is possible.
2. Replacement of existing electrical resistance unit.
3. Special conditions of occupancy or use that require electrical resistance heat to maintain health, safety or environmental conditions.
4. Limited areas where a practical application of resistance electrical heat is demonstrated (e.g., small interior space such as a rest room which is distant from the distribution system, hazardous material storerooms, stairwell or other means of emergency egress).
5. Domestic hot water heaters less than 5 kW in total unit input capacity.

503.2 Provisions applicable to all mechanical systems (Mandatory).

503.2.1 Calculation of heating and cooling loads. Design loads shall be determined in accordance with the procedures described in the ASHRAE/ACCA Standard 183. The design loads shall account for the building envelope, lighting, ventilation and occupancy loads based on the project design. Heating and cooling loads shall be adjusted to account for load reductions that are achieved 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.

503.2.2 Equipment and system sizing. The output capacity of heating and cooling equipment and systems shall not exceed the loads calculated in accordance with Section 503.2.1. 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.

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.

503.2.3 HVAC equipment performance requirements. Equipment shall meet the minimum efficiency requirements of Tables 503.2.3(1), 503.2.3(2), 503.2.3(3), 503.2.3(4), 503.2.3(5), and 503.2.3(6), 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 demonstrates that the combined efficiency of the specified components meets the requirements herein.

Exception: Water-cooled centrifugal water-chilling packages listed in Table 503.2.3(6) not designed for operation at ARHI Standard 550/590 test conditions of 44°F (7°C) leaving chilled water temperature and 85°F (29°C) entering condenser water temperature with 3 gpm/ton (0.054 I/s.kW) condenser water flow shall have maximum full load and NPLV ratings adjusted using the following equations:

Adjusted maximum full load kW/ton rating = [full load kW/ton from Table 503.2.3(6)]/K_{adj}

Adjusted maximum NPLV rating = [IPLV from Table 503.2.3(6)]/K_{adj}

where:

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

X = DT_{std} + LIFT

DT_{std} = {24+[full load kW/ton from Table 503.2.3(6)] × 6.83}/Flow

Flow = Condenser water flow (GPM)/Cooling Full Load Capacity (tons)

LIFT = CEWT – CLWT (°F)

CEWT = Full Load Condenser Entering Water Temperature (°F)

CLWT = Full Load Leaving Chilled Water Temperature (°F)

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

Minimum Leaving Chilled Water Temperature: 38°F (3.3°C)

Maximum Condenser Entering Water Temperature: 102°F (38.9°C)

Condensing Water Flow: 1 to 6 gpm/ton 0.018 to 0.1076 1/s · kW) and X ≥ 39 and ≤ 60

Chillers designed to operate outside of these ranges or applications utilizing fluids or solutions with secondary coolants (e.g., glycol solutions or brines) with a freeze point of 27°F (-2.8°C) or lower for freeze protection are not covered by this code.

503.2.4 HVAC system controls. Each heating and cooling system shall be provided with thermostatic controls as required in Section 503.2.4.1, 503.2.4.2, 503.2.4.3, 503.2.4.4, 503.4.1, 503.4.2, 503.4.3 or 503.4.4.

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

Exception: Independent perimeter systems that are designed to offset only building envelope heat losses or gains or both serving one or more perimeter zones also served by an interior system provided:

1. The perimeter system includes at least one thermostatic control zone for each building exposure having exterior walls facing only one orientation (within +/- 45 degrees) (0.8 rad) for more than 50 contiguous feet (15.2 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.

503.2.4.1.1 Heat pump supplementary heat. Heat pumps having supplementary electric resistance heat are prohibited.

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

Exception: Thermostats requiring manual changeover between heating and cooling modes.

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

Exceptions:

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

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

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

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

Exceptions:

1. Gravity dampers shall be permitted in buildings less than three stories in height.
2. Gravity dampers shall be permitted for outside air intake or exhaust airflows of 300 cfm (0.14 m^3/s) or less.

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

TABLE 503.2.3(1)
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS

EQUIPMENT TYPE	SIZE CATEGORY[a]	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY[b]	TEST PROCEDURE[c]
Through-the wall air cooled	< 30,000 Btu/h	Split system and single package	12.0 SEER	AHRI 210/240
Small-duct high-velocity (air cooled)	< 65,000 Btu/h	Split system	10.0 SEER	
Air conditioners, air cooled	< 65,000 Btu/h	Split system and single package	13.0 SEER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	Split system and single package	11.0 EER 11.2 IEER[c]	AHRI 340/360
	≥ 135,000 Btu/h and < 240,000 Btu/h	Split system and single package	10.8 EER 11.0 IEER[c]	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Split system and single package	9.8 EER 9.9 IEER	
	≥ 760,000 Btu/h	Split system and single package	9.5 EER[c] 9.6 IEER[c]	
Air conditioners, Water cooled	< 65,000 Btu/h	Split system and single package	12.1 EER 12.3 IEER	AHRI 210/240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Split system and single package	11.9 EER 12.1 IEER[c]	AHRI 340/360
	≥ 135,000 Btu/h and < 240,000 Btu/h	Split system and single package	12.3 EER 12.5 IEER[c]	
	≥ 240,000 Btu/h and < 760, 000 Btu/h	Split system and single package	12.2 EER 12.4 IEER	
	≥ 760,000 Btu/h	Split system and single package	12.0 EER 12.2 IEER	
Air conditioners, evaporatively cooled	< 65,000 Btu/h	Split system and single package	12.1 EER 12.3 IEER	AHRI 210/240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Split system and single package	11.9 EER 12.1 IEER	AHRI 340/360
	≥ 135,000 Btu/h and < 240,000 Btu/h	Split system and single package	11.8 EER 12.0 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Split system and single package	11.7 EER 11.9 IEER	
	≥ 760,000 Btu/h	Split system and single package	11.5 EER 11.7 IEER	

(Continued)

TABLE 503.2.3(1)—continued
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS

EQUIPMENT TYPE	SIZE CATEGORY	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY[b]	TEST PROCEDURE[c]
Condensing units, air cooled	≥ 135,000 Btu/h	N/A	10.5 EER 11.8 IEER	AHRI 365
Condensing units, water cooled	≥ 135,000 Btu/h	N/A	13.5 EER 14.0 IEER	
Condensing units, evaporatively cooled	≥ 135,000 Btu/h	N/A	13.5 EER 14.0 IEER	

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

a. Single-phase air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

b. Integrated Energy Efficiency Ratio (IEER) expresses cooling part load efficiency.

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

TABLE 503.2.3(2)
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY[a]	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY[b]	TEST PROCEDURE[c]
Through-the-wall, air cooled (cooling mode)	< 30,000 Btu/h	Split System and single package	12.0 SEER	AHRI 210/240
Small-duct high-velocity air cooled (cooling mode)	< 65,000 Btu/h	Split system	10.0 SEER	
Air cooled, (cooling mode)	< 65,000 Btu/h[d]	Split system and single package	13.0 SEER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	Split system and single package	10.8 EER 11.0 IEER[c]	AHRI 340/360
	≥ 135,000 Btu/h and < 240,000 Btu/h	Split system and single package	10.4 EER 10.5 IEER[c]	
	≥ 240,000 Btu/h	Split system and single package	9.3 EER[c] 9.4 IEER[c]	
Water Source (cooling mode)	< 17,000 Btu/h	86ºF entering water	11.2 EER	AHRI/ASHRAE 13256-1
	≥ 17,000 Btu/h and < 135,000 Btu/h	86ºF entering water	12.0 EER	AHRI/ASHRAE 13256-1
Groundwater Source (cooling mode)	< 135,000 Btu/h	59ºF entering water	16.2 EER	AHRI/ASHRAE 13256-1
		77ºF entering water	13.4 EER	
Water-source water to water (cooling mode)	< 135,000 Btu/h	86ºF entering water	10.6 EER	AHRI/ASHRAE 13256-2
		59ºF entering water	16.3 EER	
Groundwater Source Brine to Water (cooling mode)	< 135,000 Btu/h	77ºF entering fluid	12.1 EER	

(continued)

TABLE 503.2.3(2)—continued
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY[b]	TEST PROCEDURE[a]
Air cooled (heating mode)	< 65,000 Btu/h[d] (Cooling capacity)	Split system	7.7 HSPF	AHRI 210/240
		Single package	7.7 HSPF	
	≥ 65,000 Btu/h and < 135,000 Btu/h (Cooling capacity)	47ºF db/43ºF wb Outdoor air	3.3 COP	AHRI 340/360
		17ºF db/15ºF wb Outdoor air	2.25 COP	
	≥ 135,000 Btu/h (Cooling capacity)	47°F db/43°F wb Outdoor air	3.2 COP	
		17ºF db/15ºF wb Outdoor air	2.05 COP	
Through-the-wall (air cooled, heating mode)	< 30,000 Btu/h	Split system	7.4 HSPF	AHRI 210/240
		Single package	7.4 HSPF	
Small-duct high-velocity (air cooled, heating mode)	> 65,000 Btu/h	Split system	6.8 HSPF	
Water source (heating mode)	< 135,000 Btu/h (Cooling capacity)	68ºF entering water	4.2 COP	AHRI/ASHRAE 13256-1
Groundwater source (heating mode)	< 135,000 Btu/h (Cooling capacity)	50°F entering water	3.6 COP	AHRI/ASHRAE 13256-1
Ground source (heating mode)	< 135,000 Btu/h (Cooling capacity)	32°F entering water	3.1 COP	AHRI/ASHRAE 13256-1
Water-source water to water (heating mode)	< 135,000 Btu/h	68ºF entering water	3.7 COP	AHRI/ASHRAE 13256-2
		50ºF entering water	3.1 COP	
Groundwater Source Brine to Water (heating mode)	< 135,000 Btu/h	32ºF entering fluid	2.5 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. Single-phase air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.
b. Integrated Energy Efficiency Ratio (IEER) expresses cooling part load efficiency.
c. Chapter 6 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

TABLE 503.2.3(3)
PACKAGED TERMINAL AIR CONDITIONERS, PACKAGED TERMINAL HEAT PUMPS, SINGLE-PACKAGE VERTICAL AIR CONDITIONERS, SINGLE VERTICAL HEAT PUMPS, ROOM AIR CONDITIONERS AND ROOM AIR-CONDITIONER HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY[b]		TEST PROCEDURE[a]
			Before 10/08/2012	As of 10/08/2012	
PTAC (Cooling mode) New construction	All capacities	95ºF db outdoor air	12.5 - (0.213 · Cap/1000) EER	13.8 - (0.300 · Cap/1000) EER	AHRI 310/380
PTAC (Cooling mode) Replacements[c]	All capacities	95ºF db outdoor air	10.9 - (0.213 · Cap/1000) EER	10.9 - (0.213 · Cap/1000) EER	
PTHP (Cooling mode) New construction	All capacities	95ºF db outdoor air	12.3 - (0.213 · Cap/1000) EER	14.0 - (0.300 · Cap/1000) EER	
PTHP (Cooling mode) Replacements[c]	All capacities	95ºF db outdoor air	10.8 - (0.213 · Cap/1000) EER	10.8 - (0.213 · Cap/1000) EER	
PTHP (Heating mode) New construction	All capacities	—	3.2 - (0.026 · Cap/1000) COP	3.2 - (0.026 · Cap/1000) COP	
PTHP (Heating mode) Replacements[c]	All capacities	—	2.9 - (0.026 · Cap/1000) COP	2.9 - (0.026 · Cap/1000) COP	
SPVAC (cooling mode) and SPVHP (cooling mode)	< 65,000 Btu/h	95ºF db/75°F wb outdoor air	9.0 EER	9.0 EER	AHRI 390
	≥ 65,000 Btυ/η αnδ < 135,000 Btυ/η	95ºF db/75°F wb outdoor air	8.9 EER	8.9 EER	
	[3] 135,000 Btu/h and < 240,000 Btu/h	95ºF db/75°F wb outdoor air	8.6 EER	8.6 EER	
SPVAC (heating mode)	< 65,000 Btu/h	47ºF db/43°F wb outdoor air	3.0 COP	3.0 COP	
	≥ 65,000 Btu/h and < 135,000 Btu/h	47ºF db/43°F wb outdoor air	3.0 COP	3.0 COP	
	≥ 135,000 Btu/h and < 240,000 Btu/h	47ºF db/43°F wb outdoor air	2.9 COP	2.9 COP	
Room air conditioners, with louvered slides	< 6,000 Btu/h	—	9.7 SEER	9.7 SEER	ANSI/AHAM RAC-1
	≥ 6,000 Btu/h and < 8,000 Btu/h	—	9.7 EER	9.7 EER	
	≥ 8,000 Btu/h and < 14,000 Btu/h	—	9.8 EER	9.8 EER	
	≥ 14,000 Btu/h and < 20,000 Btu/h	—	9.7 SEER	9.7 SEER	
	≥ 20,000 Btu/h	—	8.5 EER	8.5 EER	
Room air conditioners, without louvered slides	< 8,000 Btu/h	—	9.0 EER	9.0 EER	
	≥ 8,000 Btu/h and < 20,000 Btu/h	—	8.5 EER	8.5 EER	
	≥ 20,000 Btu/h	—	8.5 EER	8.5 EER	
Room air-conditioner heat pumps with louvered sides	< 20,000 Btu/h	—	9.0 EER	9.0 EER	
	≥ 20,000 Btu/h	—	8.5 EER	8.5 EER	

(Continued)

TABLE 503.2.3(3)—continued
PACKAGED TERMINAL AIR CONDITIONERS, PACKAGED TERMINAL HEAT PUMPS, SINGLE-PACKAGE VERTICAL AIR CONDITIONERS, SINGLE VERTICAL HEAT PUMPS, ROOM AIR CONDITIONERS AND ROOM AIR-CONDITIONER HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY[b]		TEST PROCEDURE[a]
			Before 10/08/2012	As of 10/08/2012	
Room air-conditioner heat pumps without louvered sides	< 14,000 Btu/h	—	8.5 EER	8.5 EER	ANSI/AHAM RAC-1
	≥ 14,000 Btu/h	—	8.0 EER	8.0 EER	
Room air conditioner casement only	All capacities	—	8.7 EER	8.7 EER	
Room air conditioner casement-slider	All capacities	—	9.5 EER	9.5 EER	

For SI: °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 6 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 503.2.3(4)
WARM AIR FURNACES AND COMBINATION WARM AIR FURNACES/AIR-CONDITIONING UNITS, WARM AIR DUCT FURNACES AND UNIT HEATERS, MINIMUM EFFICIENCY REQUIREMENTS

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY[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 air furnaces, oil fired	< 225,000 Btu/h	—	78% AFUE or 80% E_t[c]	DOE 10 CFR Part 430 or UL 727
	≥ 225,000 Btu/h	Maximum capacity[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 6 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 503.2.3(5)
BOILERS, GAS- AND OIL-FIRED, MINIMUM EFFICIENCY REQUIREMENTS

EQUIPMENT TYPE[f]	SIZE CATEGORY	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY[c, d, e]	TEST PROCEDURE
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 and 80% E_c (See Note c, d)	DOE 10 CFR Part 431
	> 2,500,000 Btu/h[f]	Hot water	80% E_c (See Note c, d)	
		Steam	80% E_c (See Note c, d)	
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]	78% E_t and 83% E_c (See Note c, d)	DOE 10 CFR Part 431
	> 2,500,000 Btu/h[a]	Hot water	83% E_c (See Note c, d)	
		Steam	83% E_c (See Note c, d)	
Boilers, Oil-fired (Residual)	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h	Minimum capacity[b]	78% E_t and 83% E_c (See Note c, d)	DOE 10 CFR Part 431
	> 2,500,000 Btu/h[a]	Hot water	83% E_c (See Note c, d)	
		Steam	83% E_c (See Note c, d)	

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

a. Chapter 6 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 less 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 503.2.3(6)
WATER CHILLING PACKAGES, EFFICIENCY REQUIREMENTS[a]

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2010		MINIMUM EFFICIENCY[c]				TEST PROCEDURE[b]
					PATH A		PATH B		
			FULL LOAD	IPLV	FULL LOAD	IPLV	FULL LOAD	IPLV	
Air-cooled chillers	< 150 tons	EER	≥ 9.562	≥ 10.416	≥ 9.562	≥ 12.500	NA[d]	NA[d]	AHRI 550/590
	≥ 150 tons	EER			≥ 9.562	≥ 12.750	NA[d]	NA[d]	
Air cooled without condenser, electrical operated	All capacities	EER	≥ 10.586	≥ 11.782	Air-cooled chillers without condensers must be rated with matching condensers and comply with the air-cooled chiller efficiency requirements				
Water cooled, electrically operated, reciprocating	All capacities	kW/ton	≤ 0.837	≤ 0.696	Reciprocating units must comply with water cooled positive displacement efficiency requirements				
Water cooled, electrically operated, positive displacement	< 75 tons	kW/ton	≤ 0.790	≤ 0.676	≤ 0.780	≤ 0.630	≤ 0.800	≤ 0.600	
	≥ 75 tons and < 150 tons	kW/ton			≤ 0.775	≤ 0.615	≤ 0.790	≤ 0.586	
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.717	≤ 0.627	≤ 0.680	≤ 0.580	≤ 0.718	≤ 0.540	
	≥ 300 tons	kW/ton	≤ 0.639	≤ 0.571	≤ 0.620	≤ 0.540	≤ 0.639	≤ 0.490	
Water cooled, electrically operated, centrifugal	< 150 tons	kW/ton	≤ 0.703	≤ 0.669	≤ 0.634	≤ 0.596	≤ 0.639	≤ 0.450	
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.634	≤ 0.596					
	≥ 300 tons and < 600 tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.576	≤ 0.549	≤ 0.600	≤ 0.400	
	≥ 600 tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.570	≤ 0.539	≤ 0.590	≤ 0.400	
Air cooled, absorption single effect	All capacities	COP	≥ 0.600	NR[e]	≥ 0.600	NR[e]	NA[d]	NA[d]	AHRI 560
Water-cooled, absorption single effect	All capacities	COP	≥ 0.700	NR[e]	≥ 0.700	NR[e]	NA[d]	NA[d]	
Absorption double effect, indirect-fired	All capacities	COP	≥ 1.000	≥ 1.050	≥ 1.000	≥ 1.050	NA[d]	NA[d]	
Absorption double effect, direct fired	All capacities	COP	≥ 1.000	≥ 1.000	≥ 1.000	≥ 1.000	NA[d]	NA[d]	

For SI: 1 ton = 3517 W, 1 British thermal unit per hour = 0.2931 W.

a. The chiller equipment requirements do not apply for chillers used in low-temperature applications where the design leaving fluid temperature is < 40°F.

b. Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

c. Compliance with this standard can be obtained by meeting the minimum requirements of Path A or B. However, both the full load and IPLV must be met to fulfill the requirements of Path A or B.

d. NA means that this requirement is not applicable and cannot be used for compliance.

e. NR means that there are no minimum requirements for this category.

503.2.5 Ventilation. Ventilation, either natural or mechanical, shall be provided in accordance with ASHRAE Standard 62.1-2007.

503.2.5.1 Outdoor air required. The minimum outdoor airflow rate shall be determined in accordance with ASHRAE Standard 62.1-2007.

Where mechanical ventilation is provided, the system shall provide the capability to reduce the outdoor air supply to the minimum required by ASHRAE Standard 62.1-2007. The design professional shall utilize ventilation rates based on the expected occupancy level of the space. Life safety maximum allowable occupancy density shall not be used as a ventilation basis of design.

503.2.5.2 Demand controlled ventilation. Demand control ventilation (DCV) is required for spaces meeting the following three criteria:

1. Spaces larger than 500 ft^2 (50 m^2) and
2. Spaces with an average occupant load of 40 people per 1000 ft^2 (93 m^2) of floor area (as established in Table 6.1 in ASHRAE 62.1-2007 and
3. Spaces served by systems with one or more of the following:
    1. An air-side economizer;
    2. Automatic modulating control of the outdoor air damper; or
    3. A design outdoor airflow greater than 3,000 cfm (1400 L/s).

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

        1. Systems with energy recovery complying with Section 503.2.6.
        2. Multiple-zone systems without direct digital control of individual zones communicating with a central control panel.
        3. System with a design outdoor airflow less than 1,200 cfm (600 L/s).
        4. Spaces where the supply airflow rate minus any makeup or outgoing transfer air requirement is less than 1,200 cfm (600 L/s).
        5. Ventilation provided for process loads only.

503.2.6 Energy recovery ventilation systems. Individual fan systems that have both a design supply air capacity of 5,000 cfm (2.36 m^3/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 that include at least one of the following features:
    2.1. Variable-air-volume hood exhaust and room supply systems capable of reducing exhaust and makeup air volume to 50 percent or less of design values.
    2.2. Direct makeup (auxiliary) air supply equal to at least 75 percent of the exhaust rate, heated no warmer than 2°F (1.1°C) below room setpoint, cooled to no cooler than 3°F (1.7°C) above room setpoint, no humidification added, and no simultaneous heating and cooling used for dehumidification control.
3. Systems serving spaces that are not cooled and are heated to less than 60°F (15.5°C).
4. Where more than 60 percent of the outdoor heating energy is provided from site-recovered or site solar energy.
5. Cooling systems in climates with a 1-percent cooling design wet-bulb temperature less than 64°F (18°C).
6. Systems requiring dehumidification that employ series-style energy recovery coils wrapped around the cooling coil.

503.2.7 Duct and plenum insulation and sealing. All supply and return air ducts and plenums shall be insulated with a minimum of R-8 insulation when located in unconditioned spaces and a minimum of R-10 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-10 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 (8°C).

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

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

503.2.7.1.1 Low-pressure duct systems. All longitudinal and transverse joints, seams and connections of supply and return ducts operating at a static pressure less than or equal to 2 inches 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.

503.2.7.1.2 Medium-pressure duct systems. All ducts and plenums designed to operate at a static pressure greater than 2 inches w.g. (500 Pa) but less than 3 inches w.g. (750 Pa) shall be insulated and sealed in accordance with Section 503.2.7. Pressure classifications specific to the duct system shall be clearly indicated on the construction documents in accordance with the *International Mechanical Code*.

503.2.7.1.3 High-pressure duct systems. Ducts designed to operate at static pressures in excess of 3 inches w.g. (746 Pa) shall be insulated and sealed in accordance with Section 503.2.7. In addition, ducts and plenums shall be leak-tested in accordance with the SMACNA *HVAC Air Duct Leakage Test Manual* with the rate of air leakage (*CL*) less than or equal to 6.0 as determined in accordance with Equation 5-2.

$$CL = F / P^{0.65} \qquad \textbf{(Equation 5-2)}$$

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.

503.2.8 Piping insulation. All piping serving as part of a heating or cooling system shall be thermally insulated in accordance with Table 503.2.8.

Exceptions:

1. Factory-installed piping within HVAC equipment tested and rated in accordance with a test procedure referenced by this code.
2. Factory-installed piping within room fan-coils and unit ventilators tested and rated according to AHRI 440 (except that the sampling and variation provisions of Section 6.5 shall not apply) and 840, respectively.
3. Piping that conveys fluids that have a design operating temperature range between 60°F (13°C) and 105°F (41°C), inclusive.
4. Piping that conveys fluids that have not been heated or cooled through the use of fossil fuels or electric power.
5. Runout piping not exceeding 4 feet (1219 mm) in length and 1 inch (25 mm) in diameter between the control valve and HVAC coil.

503.2.9 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 503.2.9.1 through 503.2.9.3. Buildings greater than 50,000 gross square feet shall also meet the requirements of Section 503.2.10.

503.2.9.1 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 10 horsepower (hp) (7.5 kW) and larger.

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

503.2.9.3 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.

503.2.10 Systems performance, verification and completion. New buildings of 50,000 gross square feet of conditioned space or greater shall meet the provisions of Sections 503.2.10.1 through 503.2.10.2.

503.2.10.1 Qualifications. The scope required by Section 503.2.10.2 shall be completed by the project commissioning authority. The commissioning authority shall:

1. Have experience as a commissioning authority on at least (3) previous projects each at least 20,000 square feet or greater, and
2. Be an independent third party entity. The commissioning authority shall not be an employee of the design team, construction team, owner or developer.

503.2.10.2 Equipment performance verification testing. Equipment performance verification testing shall demonstrate the correct installation and operation of power consumption of systems in accordance with the energy performance criteria noted in Section 503.2.10.2.1.

TABLE 503.2.8
MINIMUM PIPE INSULATION[a]
(thickness in inches)

FLUID DESIGN OPERATING TEMPERATURE RANGE (°F)	INSULATION CONDUCTIVITY		NOMINAL PIPE OR TUBE SIZE (inches)				
	Conductivity Btu · in. (h · ft^2 · °F)	Mean Rating Temperature (°F)	< 1	1 to < 1$^1/_2$	1$^1/_2$ to < 4	4 to < 8	≥ 8
Heating Systems (Steam, Steam Condensate and Hot Water)[b, c]							
> 350	0.32 - 0.34	250	2.5	3.0	3.0	4.0	4.0
251 - 350	0.29 - 0.32	200	1.5	2.5	3.0	3.0	3.0
201 - 250	0.27 - 0.30	150	1.5	1.5	2.0	2.0	2.0
141 - 200	0.25 - 0.29	125	1.0	1.0	1.0	1.5	1.5
105 - 140	0.25 - 0.28	100	0.5	0.5	1.0	1.0	1.0
Domestic and Service Hot Water Systems							
105+	0.22 - 0.28	100	0.5	0.5	1	1	1
Cooling Systems (Chilled Water, Brine and Refrigerant)[d]							
40 - 60	0.22 - 0.28	100	0.5	0.5	1.0	1.0	1.0
< 40	0.22 - 0.28	100	0.5	1.0	1.0	1.0	1.5

For SI: 1 inch = 25.4 mm.

a. For Insulation outside the stated conductivity range, the minimum thickness (T) shall be determined as follows:

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

where:

T = Minimum insulation thickness (in).

r = Actual outside radius of pipe (in).

t = Insulation thickness listed in this table for applicable fluid temperature and pipe size.

K = Conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (Btu · in/hr · ft^2 · °F).

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

b. These thicknesses are based on energy efficiency considerations only. Additional insulation is sometimes required relative to safety issues/surface temperature.

c. Piping insulation is not required between the control valve and coil on run-outs when the control valve is located within 4 feet of the coil and the pipe size is 1 inch or less.

d. These thicknesses are based on energy efficiency considerations only. Issues such as water vapor permeability or surface condensation sometimes require vapor retarders or additional insulation.

503.2.10.2.1 Equipment requiring performance verification.

1. Economizers (Section 503.3.1 and Section 503.4.1)
2. Variable Air Volume (VAV) fan control (Section 503.4.2)
3. Part Load Hydronic Controls (Section 503.4.3.4)

503.2.10.2.2 Performance verification requirements. The scope of performance verification testing shall test and record the following:

A. Economizers (Section 503.3.1)

1. Method of economizer control
2. Economizer setpoints
3. Economizer operates in full 100 percent outside air mode when enabled.
4. Economizer operates with additional mechanical cooling when 100 percent outside air mode is active.
5. When economizer is disabled, outside air dampers revert to minimum outside air mode that provides for the minimum amount of outside air necessary.

B. Variable Air Volume (VAV) fan control (Section 503.4.2) and Part Load Hydronic Controls (Section 503.4.3.4)

1. Power input (watts or kW) when system operates in full load mode
2. Power input (watts or kW) when system operates at 50 percent of design air or water flow

2.1. Verify that power input at 50 percent of design air or water flow is no greater than 30 percent of the full load power input

2.2. The 50 percent of design flow test in B.2.2.1 shall be conducted with actual reduced flow and flow measured by:

2.2.1. Hydronic flow measurement devices such as balance valves, venturi metering devices equipped

with test ports or permanent or temporary calibrated electronic flow measurement devices.

2.2.2. Airflow measurement devices such as portable direct air flow measurement (pitot tubes) or permanent calibrated electronic flow measurement station devices or summation of terminal unit air flow measurement or by fan curve extrapolation based on measured fan speed and pressures.

2.2.3. Reducing the fan or pump speed or pressure control setpoint using only manual overrides for purposes of conducting the 50 percent flow performance verification is prohibited.

2.2.4. Visually inspect and verify the pressure control device is installed in a location in accordance with Sections 503.4.2 and 503.4.3.4.

2.2.5. Where air systems utilizing a duct static pressure control device, verify the static pressure control setpoint is reset in accordance with Section 503.4.2

2.2.6. Power input units shall only be kW or watt engineering units. Amperage alone is not an acceptable unit.

2.2.7. Power input shall be permitted to be determined using kW display readout where variable speed drives are utilized.

503.2.10.2.3 Acceptance and Documentation. The commissioning authority shall submit completed, dated and signed performance verification test documents certifying the performance verification process has been successfully completed and the applicable system performance conforms to this energy code, prior to occupancy.

503.2.11 Air system design and control. Each HVAC system having a total fan system motor nameplate horsepower (hp) exceeding 5 horsepower (hp) (3.7 kW) shall meet the provisions of Sections 503.2.11.1 through 503.2.11.2.

503.2.11.1 Allowable fan floor horsepower. Each HVAC system at fan system design conditions shall not exceed the allowable fan system motor nameplate hp (Option 1) or fan system bhp (Option 2) as shown in Table 503.2.11.1(1). This includes supply fans, return/relief fans, and fan-powered terminal units associated with systems providing heating or cooling capability.

Exceptions:

1. Hospital, vivarium and laboratory systems that utilize flow control devices on exhaust and/or return to maintain space pressure relationships necessary for occupant health and safety or environmental control shall be permitted to use variable volume fan power limitation.
2. Individual exhaust fans with motor nameplate horsepower of 1 hp (0.7 kW) or less.
3. Fans exhausting air from fume hoods. (Note: If this exception is taken, no related exhaust side credits shall be taken from Table 503.2.11.1(2) and the Fume Exhaust Exception Deduction must be taken from Table 503.2.11.1(2).

503.2.11.2 Motor nameplate horsepower. For each fan, the selected fan motor shall be no larger than the first available motor size greater than the brake horsepower (bhp). The fan brake horsepower (bhp) shall be indicated on the design documents to allow for compliance verification by the *code official* or authority having jurisdiction.

Exceptions:

1. For fans less than 6 bhp, where the first available motor larger than the brake horsepower has a nameplate rating within 50 percent of the

TABLE 503.2.11.1(1)
FAN POWER LIMITATION

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

where:

CFM_S = The maximum design supply airflow rate to conditioned spaces served by the system in cubic feet per minute.

hp = The maximum combined motor nameplate horsepower.

Bhp = The maximum combined fan brake horsepower.

A = Sum of $[PD \times CFM_D / 4131]$.

where:

PD = Each applicable pressure drop adjustment from Table 503.2.11.1(2) in. w.c.

CFM_D = The design airflow through each applicable device from Table 503.2.11.1(2) in cubic feet per minute.

TABLE 503.2.11.1(2)
FAN POWER LIMITATION PRESSURE DROP ADJUSTMENT

DEVICE	ADJUSTMENT
Credits	
Fully ducted return and/or exhaust air systems	0.5 in w.c.
Return and/or exhaust airflow control devices	0.5 in w.c
Exhaust filters, scrubbers or other exhaust treatment.	The pressure drop of device calculated at fan system design condition.
Particulate filtration credit: MERV 9 thru 12	0.5 in w.c.
Particulate filtration credit: MERV 13 thru 15	0.9 in w.c.
Particulate filtration credit: MERV 16 and greater and electronically enhanced filters	Pressure drop calculated at 2x clean filter pressure drop at fan system design condition.
Carbon and other gas-phase air cleaners	Clean filter pressure drop at fan system design condition.
Heat recovery device	Pressure drop of device at fan system design condition.
Evaporative humidifier/cooler in series with another cooling coil	Pressure drop of device at fan system design conditions
Sound attenuation section	0.15 in w.c.
Deductions	
Fume hood exhaust exception (required if Section 503.2.11.1, Exception 3, is taken)	-1.0 in w.c.

bhp, selection of the next larger nameplate motor size is allowed.

2. For fans 6 bhp and larger, where the first available motor larger than the bhp has a nameplate rating within 30 percent of the bhp, selection of the next larger nameplate motor size is allowed.

503.2.12 Heating outside a building. Systems installed to provide heat outside a building shall be radiant systems. Such heating systems shall be controlled by an occupancy sensing device or a timer switch, so that the system is automatically deenergized when no occupants are present.

503.3 Simple HVAC systems and equipment (Prescriptive). This section applies to buildings served by unitary or packaged HVAC equipment listed in Tables 503.2.3(1) through 503.2.3(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 cooling and heating which are covered by Section 503.4.

503.3.1 Economizers. Each cooling system ≥ 54,000 Btu/h that has a fan shall include an air economizer meeting the requirements of Sections 503.3.1.1 through 503.4.1.4. The total capacity of all systems without economizers shall not exceed 480,000 Btu/h per building, or 20 percent of its air economizer capacity, whichever is greater.

Exceptions: Economizers are not required for the systems listed below.

1. Where more than 25 percent of the air designed to be supplied by the system is to spaces that are designed to be humidified above 35°F dew-point temperature to satisfy process needs.
2. Systems that serve residential spaces where the system capacity is less than five times the minimum requirement (< 270,000 Btu/h).
3. Systems expected to operate less than 20 hours per week.

503.3.1.1 Air Economizers.

503.3.1.1.1 Design Capacity. Air economizer systems shall be capable of modulating *outdoor air* and return air dampers to provide up to 100 percent of the design supply air quantity as *outdoor air* for cooling.

503.3.1.1.2 Control Signal. Economizer dampers shall be capable of being sequenced with the mechanical cooling equipment and shall not be controlled by mixed air temperature.

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

503.3.1.1.3 High-Limit Shutoff. All air economizers shall be capable of automatically reducing *outdoor air* intake to the design minimum *outdoor air* quantity when *outdoor air* intake will no longer reduce cooling energy usage. High-limit shutoff control types for specific climates shall be chosen from Table 503.3.1.1.3(1). High-limit shutoff control settings for these control types shall be those listed in Table 503.3.1.1.3(2).

TABLE 503.3.1.1.3(1)
HIGH-LIMIT SHUTOFF CONTROL OPTIONS FOR AIR ECONOMIZERS

ALLOWED CONTROL TYPES	PROHIBITED CONTROL TYPES
Fixed dry bulb Differential dry bulb Fixed enthalpy Electronic enthalpy[a] Differential enthalpy Dew-point and dry-bulb temperatures	None

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

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

503.3.2 Hydronic system controls. Hydronic systems of at least 300,000 Btu/h (87,930 W) design output capacity supplying heated and chilled water to comfort conditioning systems shall include controls that meet the requirements of Section 503.4.3.

503.4 Complex HVAC systems and equipment. (Prescriptive). This section applies to buildings served by HVAC equipment and systems not covered in Section 503.3.

503.4.1 Economizers. Economizer systems for complex HVAC equipment shall comply with Sections 503.4.1.1 through 503.4.1.4.

503.4.1.1 Design Capacity. Water economizer systems shall be capable of cooling supply air by indirect evaporation and providing up to 100 percent of the expected system cooling load at outdoor air temperatures of 50°F dry bulb/45°F wet bulb and below.

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

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

503.4.1.3 Integrated Economizer Control. Economizer systems shall be integrated with the mechanical cooling system and be capable of providing partial cooling even when additional mechanical cooling is required to meet the remainder of the cooling load.

Exceptions: Direct expansion systems that include controls that reduce the quantity of outdoor air required to prevent coil frosting at the lowest step of compressor unloading, provided this lowest step is no greater than 25 percent of the total system capacity.

Individual direct expansion units that have a rated cooling capacity less than 54,000 Btu/h and use non-integrated economizer controls that preclude simultaneous operation of the economizer and mechanical cooling.

503.4.1.4 Economizer Heating System Impact. HVAC system design and economizer controls shall be such that economizer operation does not increase the building heating energy use during normal operation.

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

503.4.2 Variable air volume (VAV) fan control. Individual VAV fans with motors of 10 horsepower (7.5 kW) or greater shall be:

1. Driven by a mechanical or electrical variable speed drive; or

TABLE 503.3.1.1.3(2)
HIGH-LIMIT SHUTOFF CONTROL SETTING FOR AIR ECONOMIZERS

DEVICE TYPE	REQUIRED HIGH LIMIT (ECONOMIZER OFF WHEN):	
	Equation	Description
Fixed dry bulb	TOA > 70°F	Outdoor air temperature exceeds 70°F
Differential dry	TOA > TRA	Outdoor air temperature exceeds return air temperature
Fixed enthalpy	hOA > 28 Btu/lba	Outdoor air enthalphy exceeds 28 Btu/lb of dry air
Electronic Enthalpy	(TOA, RHOA) > B	Outdoor air temperature/RH exceeds the “B” setpoint curve
Differential enthalpy	hOA > hRA	Outdoor air enthalpy exceeds return air enthalpy
Dew-point and dry bulb temperatures	DPOA > 55°F or TOA > 70°F	Outdoor air dry bulb exceeds 70°F or outside dewpoint exceeds 55°F (65 gr/lb)

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

503.4.2.1 Static Pressure Sensor Location. Static pressure sensors used to control VAV fans shall be placed in a position such that the controller setpoint is no greater than one-third the total design fan static pressure. For sensors installed downstream of major duct splits, at least one sensor shall be located on each major branch to ensure that static pressure can be maintained in each branch. Location of the static pressure sensor near the supply fan discharge would result in non-compliance.

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

503.4.3 Hydronic systems controls. The heating of fluids that have been previously mechanically cooled and the cooling of fluids that have been previously mechanically heated shall be limited in accordance with Sections 503.4.3.1 through 503.4.3.3. Hydronic heating systems comprised of multiple-packaged boilers and designed to deliver conditioned water or steam into a common distribution system shall include automatic controls capable of sequencing operation of the boilers. Hydronic heating systems comprised of a single boiler and greater than 500,000 Btu/h input design capacity shall include either a multistaged or modulating burner.

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

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

503.4.3.3 Hydronic (water loop) heat pump systems. Hydronic heat pump systems shall comply with Sections 503.4.3.3.1 through 503.4.3.3.3.

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

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

503.4.3.3.2 Heat rejection. If an open- or closed-circuit cooling tower is used, then a separate heat exchanger shall be required to isolate the cooling tower from the heat pump loop, and heat loss shall be controlled by shutting down the circulation pump on the cooling tower loop and providing an automatic valve to stop the flow of fluid.

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

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

503.4.3.4 Hydronic Variable Flow Systems. HVAC pumping systems that include control valves designed to modulate or step open and close as a function of load shall be designed for variable fluid flow and shall be capable of reducing pump flow rates to 50 percent or less of the design flow rate. Individual pumps serving variable flow systems having a pump head exceeding 100 feet and motor exceeding 50 hp shall have controls and/or devices (such as variable speed control) that will result in pump motor demand of no more than 30 percent of design wattage at 50 percent of design water flow. The controls or devices shall be controlled as a function of desired flow or to maintain a minimum required differential pressure. Differential pressure shall be measured at or near the most remote heat exchanger or the heat exchanger requiring the greatest differential pressure.

Exceptions:

1. Systems where the minimum flow is less than the minimum flow required by the equipment manufacturer for the proper operation of equipment served by the system, such as chillers, and where total pump system power is 75 hp or less.
2. Systems that include no more than three control valves.

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

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

503.4.3.6 Chilled- and Hot-Water Temperature Reset Controls. Chilled- and hot-water systems with a design capacity exceeding 300,000 Btu/h supplying chilled or heated water (or both) to comfort conditioning systems shall include controls that have the capability to automatically reset supply water temperatures by representative building loads (including return water temperature) or by outdoor air temperature.

Exceptions:

1. Where the supply temperature reset controls cannot be implemented without causing improper operation of heating, cooling, humidifying, or dehumidifying systems.
2. Hydronic systems, such as those required by Section 503.4.3.4 that use variable flow to reduce pumping energy.

503.4.4 Heat rejection equipment fan speed control. Each fan powered by a motor of 7.5 hp (5.6 kW) or larger shall have the capability to operate that fan at two-thirds of full speed or less, and shall have controls that automatically change the fan speed to control the leaving fluid 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 503.2.3(1) and 503.2.3(6).

503.4.5 Requirements for complex mechanical systems serving multiple zones. Sections 503.4.5.1 through 503.4.5.4 shall apply to complex mechanical systems serving multiple zones. Supply air systems serving multiple zones shall be VAV systems which, during periods of occupancy, are designed and capable of being controlled to reduce primary air supply to each *zone* to one of the following before reheating, recooling or mixing takes place:

1. Thirty percent of the maximum supply air to each *zone*.
2. Three hundred cfm (142 L/s) or less where the maximum flow rate is less than 10 percent of the total fan system supply airflow rate.
3. The minimum ventilation requirements of ASHRAE Standard 62.1-2007.

Exception: 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, recooled or mixed is no greater than the volume of outside air required to meet the minimum ventilation requirements of ASHRAE Standard 62.1-2007.
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.

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

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

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

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

Exceptions:

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

503.4.6 Heat recovery for service water heating. Condenser heat recovery shall be installed for heating or reheating of service hot water provided the facility operates 24 hours a day, the total installed heat capacity of water-cooled systems exceeds 6,000,000 Btu/hr 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.
3. If compliance with Section 503.4.6 will be detrimental to chiller operating efficiency due to conflicts with optimized chiller head pressure control.

503.4.7 Hot gas bypass limitation. Cooling systems shall not use hot gas bypass or other evaporator pressure control systems unless the system is designed with multiple steps of unloading or continuous capacity modulation. The capacity of the hot gas bypass shall be limited as indicated in Table 503.4.7.

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

TABLE 503.4.7
MAXIMUM HOT GAS BYPASS CAPACITY

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

For SI: 1 Btu/h = 0.29 watts.

SECTION 504
SERVICE WATER HEATING
(Mandatory)

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

504.1.1 Electrical water heating limitation. Individual electric service water heating units shall be limited to a maximum of 5 kW total power input.

Exception: Instantaneous electric water heaters used to serve emergency showers and emergency eye wash stations.

504.2 Service water-heating equipment performance efficiency. Water-heating equipment and hot water storage tanks shall meet the requirements of Table 504.2. The efficiency shall be verified through data furnished by the manufacturer or through certification under an *approved* certification program.

504.3 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).

504.4 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.

504.5 Pipe insulation. The following piping shall be insulated to levels shown in Section 503, Table 503.2.8.

1. Recirculating system piping, including the supply and return piping of a circulating tank type water heater.
2. The first 8 feet of outlet piping for a constant temperature nonrecirculating storage system.
3. The inlet pipe between the storage tank and a heat trap in a nonrecirculating storage system.
4. Pipes that are externally heated (such as heat trace or impedance heating).

504.6 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.

504.7 Pools. Pools shall be provided with energy conserving measures in accordance with Sections 504.7.1 through 504.7.3.

504.7.1 Time switches. Time switches that can automatically turn heaters and pumps off and on 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.

504.7.2 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 or LPG shall not have continuously burning pilot lights.

504.7.3 Covers. Heated pools, hot tubs and spas shall be provided with a vapor retardant cover. Hot tubs and spas capable of being heated to more than 90°F (32°C) shall be provided with a cover having a minimum insulation value of R-12.

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

TABLE 504.2
MINIMUM PERFORMANCE OF WATER-HEATING EQUIPMENT

EQUIPMENT TYPE	SIZE CATEGORY (input)	SUBCATEGORY OR RATING CONDITION	PERFORMANCE REQUIRED[a, b]	TEST PROCEDURE
Water heaters, Electric	≤ 5 kW	Resistance	0.97 - 0.00132*V*, EF	DOE 10 CFR Part 430
	≤ 24 amps and ≤ 250 volts	Heat pump	0.93 - 0.00132*V*, EF	DOE 10 CFR Part 430
Storage water heaters, Gas	≤ 75,000 Btu/h	≥ 20 gal	0.67 - 0.0019*V*, EF	DOE 10 CFR Part 430
	> 75,000 Btu/h and ≤ 155,000 Btu/h	< 4,000 Btu/h/gal	80% E_t $\left(Q / 800 + 110\sqrt{V}\right)$SL, Btu/h	ANSI Z21.10.3
	> 155,000 Btu/h	< 4,000 Btu/h/gal	80% E_t $\left(Q / 800 + 110\sqrt{V}\right)$ 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 - 0.0019*V*, 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 $\left(Q / 800 + 110\sqrt{V}\right)$ SL, Btu/h	
Storage water heaters, Oil	≤ 105,000 Btu/h	≥ 20 gal	0.59 - 0.0019*V*, EF	DOE 10 CFR Part 430
	> 105,000 Btu/h	< 4,000 Btu/h/gal	78% E_t $\left(Q / 800 + 110\sqrt{V}\right)$ 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 - 0.0019*V*, 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 $\left(Q / 800 + 110\sqrt{V}\right)$ SL, Btu/h	
Hot water supply boilers, Gas and Oil	≥ 300,000 Btu/h and <12,500,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	80% E_t	ANSI Z21.10.3
Hot water supply boilers, Gas	≥ 300,000 Btu/h and <12,500,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal	80% E_t $\left(Q / 800 + 110\sqrt{V}\right)$ SL, Btu/h	
Hot water supply boilers, Oil	> 300,000 Btu/h and <12,500,000 Btu/h	> 4,000 Btu/h/gal and > 10 gal	78% E_t $\left(Q / 800 + 110\sqrt{V}\right)$ SL, Btu/h	
Pool heaters, Gas and Oil	All	—	78% E_t	ASHRAE 146
Heat pump pool heaters	All	—	4.0 COP	AHRI 1160
Unfired storage tanks	All	—	Minimum insulation requirement R-12.5 $(h \cdot ft^2 \cdot °F)/Btu$	(none)

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

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

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

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

SECTION 505
ELECTRICAL POWER AND LIGHTING SYSTEMS
(Mandatory)

505.1 General (Mandatory). 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: Dwelling units within commercial buildings shall not be required to comply with Sections 505.2 through 505.5 provided that not less than 50 percent of the permanently installed light fixtures, other than low-voltage lighting, shall be fitted for, and contain only, high efficacy lamps.

505.2 Lighting controls (Mandatory). Lighting systems shall be provided with controls as required in Sections 505.2.1, 505.2.2, 505.2.3 and 505.2.4.

505.2.1 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.
2. Lighting in stairways or corridors that are elements of the means of egress.

505.2.2 Additional controls. Each area that is required to have a manual control shall have additional controls that meet the requirements of Sections 505.2.2.1 and 505.2.2.2.

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

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

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. *Sleeping unit* (see Section 505.2.3).
5. Spaces that use less than 0.6 watts per square foot (6.5 W/m^2).

505.2.2.2 Automatic lighting shutoff. Buildings larger than 5,000 square feet (465 m^2) 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 m^2) and are not more than one floor; or
2. An occupant sensor that shall turn lighting off within 30 minutes of an occupant leaving a space; or
3. A signal from another control or alarm system that indicates the area is unoccupied.

Exception: The following shall not require an automatic control device:

1. *Sleeping unit* (see Section 505.2.3).
2. Lighting in spaces where patient care is directly provided.
3. Spaces where an automatic shutoff would endanger occupant safety or security.

505.2.2.2.1 Occupant override. Where an automatic time switch control device is installed to comply with Section 505.2.2.2, 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 m^2).

Exceptions:

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

505.2.2.2.2 Holiday scheduling. If an automatic time switch control device is installed in accordance with Section 505.2.2.2, 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, places of religious worship and theaters.

505.2.2.3 Daylight zone control. Daylight zones, as defined by this code, shall be provided with individual controls that control the lights independent of general area lighting. Contiguous daylight zones adjacent to vertical fenestration are allowed to be controlled by a single controlling device provided that they do not include zones facing more than two adjacent cardinal orientations (i.e., north, east, south, west). Daylight zones under skylights more than 15 feet (4572 mm) from the perimeter shall be controlled separately from daylight zones adjacent to vertical fenestration.

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

505.2.3 Sleeping unit controls. *Sleeping unit*s 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.

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

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

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

Exceptions:

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

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

505.5 Interior lighting power requirements (Prescriptive). A building complies with this section if its total connected lighting power calculated under Section 505.5.1 is no greater than the interior lighting power calculated under Section 505.5.2.

505.5.1 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 505.5.1.1 through 505.5.1.4.

Exceptions:

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

12. Lighting integral to both open and glass-enclosed refrigerator and freezer cases.
13. Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions.
14. Furniture mounted supplemental task lighting that is controlled by automatic shutoff.

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

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

505.5.1.3 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.

505.5.1.4 Line-voltage lighting track and plug-in busway. The wattage shall be:

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

505.5.2 Interior lighting power. The total interior lighting power allowance (watts) is determined according to Table 505.5.2(1) using the Building Area Method, or Table 505.5.2(2) using the Space-by-Space Method, for all areas in the building covered in this permit. For the Building Area Method, the interior lighting power allowance is the floor area for each building area type listed in Table 505.5.2(1) times the value from Table 505.5.2(1) for that area. For the purposes of this method, an "area" shall be defined as all contiguous spaces that accommodate or are associated with a single building area type as *listed* in Table 505.5.2(1). When this method is used to calculate the total interior lighting power for an entire building, each building area type shall be treated as a separate area. For the Space-by-Space Method, the interior lighting power allowance shall be determined by multiplying the floor area of each space times the value for the space type in Table 505.5.2(2) that most closely represents the proposed use of the space, and then summing the lighting power allowances for all spaces. Trade-offs among spaces within the building are permitted.

TABLE 505.5.2(1)
INTERIOR LIGHTING POWER ALLOWANCES
BUILDING AREA METHOD

LIGHTING POWER DENSITY	
Building Area Type	**LPD (W/ft^2)**
Automotive Facility	0.9
Convention Center	1.2
Court House	1.2
Dining: Bar Lounge/Leisure	1.3
Dining: Cafeteria/Fast Food	1.4
Dining: Family	1.6
Dormitory	1.0
Exercise Center	1.0
Fire Station	0.8
Gymnasium	1.1
Healthcare—clinic	1.0
Hospital	1.2
Hotel	1.0
Library	1.3
Manufacturing Facility	1.3
Motel	1.0
Motion Picture Theater	1.2
Multifamily	0.7
Museum	1.1
Office	0.9
Parking Garage	0.3
Penitentiary	1.0
Performing Arts Theater	1.6
Police Station	1.0
Post Office	1.1
Religious Building	1.3
Retail	1.4
School/University	1.2
Sports Arena	1.1
Town Hall	1.1
Transportation	1.0
Warehouse	0.6
Workshop	1.4

TABLE 505.5.2(2)
INTERIOR LIGHTING POWER ALLOWANCES—
SPACE-BY-SPACE METHOD

COMMON SPACE-BY-SPACE TYPES	LPD (w/ft^2)
Atrium – First 40 feet in height	0.03 per ft. ht.
Atrium – Above 40 feet in height	0.02 per ft. ht.
Audience/seating area—permanent	
For auditorium	0.9
For performing arts theater	2.6
For motion picture theater	1.2
Classroom/Lecture/training	1.30
Conference/meeting/multipurpose	1.2
Corridor/transition	0.7
Dining area	
Bar/lounge/leisure dining	1.40
Family dining area	1.40
Dressing/fitting room performing arts theater	1.1
Electrical/mechanical	1.10
Food preparation	1.20
Laboratory for classrooms	1.3
Laboratory for medical/industrial/research	1.8
Lobby	1.10
Lobby for performing arts theater	3.3
Lobby for motion picture theater	1.0
Locker room	0.80
Lounge recreation	0.8
Office—enclosed	1.1
Office—open plan	1.0
Restroom	1.0
Sales area	1.6[a]
Stairway	0.70
Storage	0.8
Workshop	1.60
Courthouse/police station/penetentiary	
Courtroom	1.90
Confinement cells	1.1
Judge chambers	1.30
Penitentiary audience seating	0.5
Penitentiary classroom	1.3
Penitentiary dining	1.1
BUILDING SPECIFIC SPACE-BY-SPACE TYPES	**LPD (w/ft^2)**
Automotive – service/repair	0.70
Bank/office – banking activity area	1.5
Convention center	
Exhibit Space	1.50
Audience/Seating Area	0.90
Dormitory living quarters	1.10
Gymnasium/fitness center	
Fitness area	0.9
Gymnasium Audience/Seating	0.40
Playing Area	1.40

(continued)

Table 505.5.2(2)—continued
INTERIOR LIGHTING POWER
ALLOWANCES—SPACE-BY-SPACE METHOD

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

(continued)

Table 505.5.2(2)—continued
INTERIOR LIGHTING POWER ALLOWANCES—SPACE-BY-SPACE METHOD

COMMON SPACE-BY-SPACE TYPES	LPD (W/ft^2)
Sports arena	
Audience seating	0.4
Court sports area – Class 4	0.7
Court sports area – Class 3	1.2
Court sports area – Class 2	1.9
Court sports area – Class 1	3.0
Ring sports area	2.7
Transportation	
Air/Train/Bus Baggage Area	1.00
Airport Concourse	0.60
Terminal – Ticket Counter	1.50
Warehouse	
Fine Material Storage	1.40
Medium/Bulky Material	0.60

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

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

Calculate the additional lighting power as follows:

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

where:

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

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

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

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

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

505.6 Exterior lighting. (Mandatory). 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 comply with Sections 505.6.1 and 505.6.2.

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

505.6.1 Exterior building grounds lighting. All exterior building grounds luminaires that operate at greater than 100 watts shall contain lamps having a minimum efficacy of 60 lumens per watt unless the luminaire is controlled by a motion sensor or qualifies for one of the exceptions under Section 505.6.2. Appropriate exterior lighting designs including maximum exterior illuminance levels and cut-off exterior fixtures may be required by the District Environmental Commission for Act 250 projects.

505.6.2 Exterior building lighting power. The total exterior lighting power allowance for all exterior building applications is the sum of the base site allowance plus the individual allowances for areas that are to be illuminated and are permitted in Table 505.6.2(2) for the applicable lighting *zone*. Tradeoffs are allowed only among exterior lighting applications listed in Table 505.6.2(2), Tradable Surfaces section. The lighting zone for the building exterior is determined from Table 505.6.2(1) unless otherwise specified by the local jurisdiction. Exterior lighting for all applications (except those included in the exceptions to Section 505.6.2) shall comply with the requirements of Section 505.6.1.

Exceptions: Lighting used for the following exterior applications is exempt when equipped with a control device independent of the control of the nonexempt lighting:

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

TABLE 505.6.2(1)
EXTERIOR LIGHTING ZONES

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

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

Exception: Housing for the elderly with fuel-fired heating systems, with centrally operated air conditioning systems, or without air-conditioning systems.

TABLE 505.6.2(2)
INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS

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

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

505.8 Electric motors. Electric motors shall comply with the requirements of the Energy Independence and Security Act of 2007, as shown in Table 505.8(1). Motors that are not included in the scope of the Energy Independence and Security Act of 2007 have no performance requirements in this section.

505.9 Electric power distribution. Electrical distribution systems shall be designed for the efficient distribution of electrical energy from the service entrance to the point of use.

Exception: Emergency power systems.

505.10 Voltage drop.

505.10.1 Feeders. Feeder conductors shall be sized for a maximum voltage drop of 2 percent at design load.

505.10.2 Branch Circuits. Branch circuit conductors shall be sized for a maximum voltage drop of 3 percent at design load.

TABLE 505.8(1)
MINIMUM NOMINAL EFFICIENCY FOR GENERAL PURPOSE DESIGN A AND DESIGN B MOTORS RATED 600 VOLTS OR LESS[a]

MINIMUM NOMINAL FULL LOAD EFFICIENCY (%)						
NUMBER OF POLES	Open Drip-proof Motors			Totally Enclosed Fan-cooled Motors		
	2	4	6	2	4	6
Synchronous Speed (RPM)	3600	1800	1200	3600	1800	1200
Motor Horsepower						
1	77	85.5	82.5	77	85.5	82.5
1.5	84	86.5	86.5	84	86.5	87.5
2	85.5	86.5	87.5	85.5	86.5	88.5
3	85.5	89.5	88.5	86.5	89.5	89.5
5	86.5	89.5	89.5	88.5	89.5	89.5
7.5	88.5	91	90.2	89.5	91.7	91
10	89.5	91.7	91.7	90.2	91.7	91
15	90.2	93	91.7	91	92.4	91.7
20	91	93	92.4	91	93	91.7
25	91.7	93.6	93	91.7	93.6	93
30	91.7	94.1	93.6	91.7	93.6	93
40	92.4	94.1	94.1	92.4	94.1	94.1
50	93	94.5	94.1	93	94.5	94.1
60	93.6	95	94.5	93.6	95	94.5
75	93.6	95	94.5	93.6	95.4	94.5
100	93.6	95.4	95	94.1	95.4	95
125	94.1	95.4	95	95	95.4	95
150	94.1	95.8	95.4	95	95.8	95.8
200	95	95.8	95.4	95.4	96.2	95.8
250	95	95.8	95.4	95.8	96.2	95.8
300	95.4	95.8	95.4	95.8	96.2	95.8
350	95.4	95.8	95.4	95.8	96.2	95.8
400	95.8	95.8	95.8	95.8	96.2	95.8
450	95.8	96.2	96.2	95.8	96.2	95.8
500	95.8	96.2	96.2	95.8	96.2	95.8

a. Nominal efficiencies shall be established in accordance with NEMA Standard MG1. Design A and Design B are National Electric Manufacturers Association (NEMA) design class designations for fixed frequency small and medium AC squirrel-cage induction motors.

505.11 Transformers. Single-phase and three-phase dry-type and liquid-filled distribution transformers shall be selected based on its rating as described in Sections 505.11.1 and 503.11.2.

Exceptions:

1. Liquid-filled transformers below 10 kVA or dry-type transformers below 15 kVA.
2. All rectifier transformers and transformers designed for high-harmonic autotransformers.
3. Nondistribution transformers such as UPS transformers.
4. Special impedance, regulation and harmonic transformers
5. Sealed and nonventilated transformers.
6. Retrofit transformers, machine tool transformers or welding transformers.
7. Grounding or testing transformers.
8. Where the loading on the subject transformer can be demonstrated to be such that a different transformer would consume less energy.
9. Dry-type transformers below 15 kVA covered in Item 1 above.
10. Drive transformers, both ac and dc.
11. Transformers with tap ranges greater than 15 percent or frequency other than 60 Hz.

505.11.1 Dry-type transformers. Dry-type transformers shall comply with the minimum efficiencies in Table 505.11(1) as tested in accordance with 10 C.F.R. Part 431 ("Test Procedures for Distribution Transformers").

505.11.2 Liquid-filled transformers. Liquid-filled transformers shall comply with the minimum efficiencies in Table 505.11.2 as tested in accordance with NEMA Standard TP 1-2002.

TABLE 505.11(1)
NEMA PREMIUM EFFICIENCY LEVELS FOR DRY-TYPE DISTRIBUTION TRANSFORMERS

SINGLE-PHASE		THREE-PHASE	
kVA	Efficiency (%)	kVA	Efficiency (%)
15	98.39%	15	97.90%
25	98.60%	30	98.25%
37.5	98.74%	45	98.39%
50	98.81%	75	98.60%
75	98.95%	112.5	98.74%
100	99.02%	150	98.81%
167	99.09%	225	98.95%
250	99.16%	300	99.02%
333	99.23%	500	99.09%
		750	99.16%
		1000	99.23%

TABLE 505.11(2)
NEMA CLASS 1 EFFICIENCY LEVELS FOR LIQUID-FILLED DISTRIBUTION TRANSFORMERS

REFERENCE CONDITION	TEMPERATURE		% OF NAMEPLATE LOAD
Load Loss	55°C		50%
No Load Loss	20°C		50%
kVA	Efficiency (%)	kVA	Efficiency (%)
10	98.4%	15	98.1%
15	98.6%	30	98.4%
25	98.7%	45	98.6%
37.5	98.8%	75	98.7%
50	98.9%	112.5	98.8%
75	99.0%	150	98.9%
100	99.0%	225	99.0%
167	99.1%	300	99.0%
250	99.2%	500	99.1%
333	99.2%	750	99.2%
500	99.3%	1000	99.2%
667	99.4%	1500	99.3%
883	99.4%	2000	99.4%