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 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.

Exception: Buildings conforming to Section 506, provided Sections 502.4, 503.2, 504, 505.2, 505.3, 505.4, 505.6 and 505.7 are each satisfied.

SECTION 502
BUILDING ENVELOPE REQUIREMENTS

502.1 General.

502.1.1 Insulation and fenestration criteria. The *building thermal envelope* opaque assemblies shall meet the requirements of Table 502.1.1 and Section 502.2. Fenestration shall meet the requirements of Section 502.3. Values from tables shall be based on the climate zone specified in Chapter 3. Commercial buildings or portions of commercial buildings enclosing Group R occupancies shall use the *R*-values from the "Group R" column of Table 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 Section 502.1.3, Simplified trade-off approach or Section 506.1, Whole Building Approach.

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 502.1.2 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 502.1.2. Commercial buildings or portions of commercial buildings enclosing occupancies other than Group R shall use the *U*-factor, *C*-factor or *F*-factor from the "All other" column of Table 502.1.2. Appendix A of ASHRAE 90.1-2010 shall be used for determining values for opaque assemblies.

502.1.3 Simplified trade-off approach. Buildings may demonstrate compliance with the thermal performance standards of this section by using the Simplified Trade-off Approach (STA). The STA is an analytical method to determine if the energy performance of a proposed building's envelope is at least equivalent to a similar building meeting the prescriptive path approach. Information and criteria for demonstrating compliance using the STA path using COMcheck software is available at www.bcd.oregon.gov.

TABLE 502.1.1
BUILDING ENVELOPE REQUIREMENTS - OPAQUE ASSEMBLIES

CLIMATE ZONE	5 AND MARINE 4	
	All other	Group R
Roofs		
Insulation entirely above deck	R-20ci	R-20ci
Metal buildings (with R-3.5 thermal blocks[a, b])	R-13 + R-13	R-19
Attic and other	R-38	R-38
Walls, Above Grade		
Mass	R-11.4ci	R-13.3ci
Metal building[b]	R-13 + R-5.6ci	R-13 + R-5.6ci
Metal framed	R-13 + R-7.5ci	R-13 + R-7.5ci
Wood framed and other	R-13 + R-3.8ci or R-21	R-13 +R-3.8ci or R-21
Walls, Below Grade		
Below grade wall[d]	R-7.5ci	R-7.5ci
Floors		
Mass	R-10ci	R-12.5ci
Joist/Framing (steel/wood)	R-30	R-30
Slab-on-Grade Floors		
Unheated slabs	NR	R-10 for 24 in. below
Heated slabs	R-15 for 24 in. below	R-15 for 24 in. below
Opaque Doors		
Swinging	U-0.70	U-0.70
Roll-up or sliding	U-0.50	U-0.50

For SI: 1 inch = 25.4 mm.
ci = Continuous insulation. NR = No requirement.
a. Thermal spacer blocks are required.
b. Assembly descriptions can be found in Table 502.2(2).
c. When heated slabs are placed below grade, below-grade walls must meet the exterior insulation requirements for perimeter insulation according to the heated slab-on-grade construction.

TABLE 502.1.2
BUILDING ENVELOPE REQUIREMENTS
OPAQUE ELEMENT, MAXIMUM *U*-FACTORS

CLIMATE ZONE	5 AND MARINE 4	
	All other	Group R
Roofs		
Insulation entirely above deck	U-0.048	U-0.048
Metal buildings[c]	U-0.055	U-0.055
Attic and other	U-0.027	U-0.027
Walls, Above Grade		
Mass[b]	U-0.150[c]	U-0.090
Metal building	U-0.069	U-0.069
Metal framed	U-0.064	U-0.064
Wood framed and other	U-0.064	U-0.064
Walls, Below Grade		
Below-grade wall[a]	C-0.119	C-0.119
Floors		
Mass	U-0.074	U-0.064
Joist/Framing	U-0.033	U-0.033
Slab-on-Grade Floors		
Unheated slabs	F-0.730	F-0.540
Heated slabs[a]	F-0.860	F-0.860

a. When heated slabs are placed below-grade, below grade walls must meet the *F*-factor requirements for perimeter insulation according to the heated slab-on-grade construction.

b. Exception: Integral insulated concrete block walls complying with ASTM C90 with all cores filled and meeting both of the following: 1) At least 50 percent of cores must be filled with vermiculite or equivalent fill insulation, and 2) the structure encloses one of the following uses: gymnasiums, auditorium, church chapel, arena, kennel, manufacturing plant, indoor swimming pool, pump station, water and waste water treatment facility, storage facility, restroom/concessions, mechanical/electrical structures, storage area, warehouse (storage and retail), motor vehicle service facility.

c. R-3.5 spacer blocks required for all metal roof assemblies; see Table 502.2(2).

502.2 Specific insulation requirements. Opaque assemblies constructed in accordance with Section 502.2 shall comply with *R*-values as specified in 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.

Exception: Continuously insulated roof assemblies where the thickness of insulation varies 1 inch (25 mm) or less and where the area-weighted *U*-factor is equivalent to the same assembly with the *R*-value specified in Table 502.1.1.

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

502.2.1.1 Roof curbs. Portions of curb skylights and equipment above the roof deck shall be insulated with minimum R-5 insulation.

Exception: Skylight curbs included as a component of an NFRC 100 rated assembly shall not be required to be insulated.

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 con-tinuously 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.

TABLE 502.2(2)
METAL BUILDING ASSEMBLY DESCRIPTIONS[a]

ROOFS	DESCRIPTION
R-19	Standing seam roof with single fiberglass insulation layer. This construction is R-19 faced fiberglass insulation batts draped perpendicular over the purlins. A minimum R-3.5 thermal spacer block is placed above the purlin/batt, and the roof deck is secured to the purlins.
R-13 + R-13 R-13 + R-19	Standing seam roof with two fiberglass insulation layers. The first *R*-value is for faced fiberglass insulation batts draped over purlins. The second *R*-value is for unfaced fiberglass insulation batts installed parallel to the purlins. A minimum R-3.5 thermal spacer block is placed above the purlin/batt, and the roof deck is secured to the purlins.
WALLS	
R-13 + R-5.6ci R-19 + R-5.6 ci	The first *R*-value is for faced fiberglass insulation batts installed perpendicular and compressed between the metal wall panels and the steel framing. The second rated *R*-value is for continuous rigid insulation installed between the metal wall panel and steel framing, or on the interior of the steel framing.

a. ASHRAE 90.1-2010, Table A3.2 reference for *U*-factors and alternate assemblies.

502.3 Fenestration. Fenestration shall comply with Table 502.3.

TABLE 502.3
BUILDING ENVELOPE REQUIREMENTS: FENESTRATION

CLIMATE ZONE	5 AND MARINE 4
Vertical fenestration (30% maximum of above-grade wall)	
Fenestration type	***U*-factor**
Framing materials other than metal with or without metal reinforcement or cladding	
Fixed, operable, and doors with greater than 50% glazing	0.35
Metal framing with or without thermal break	
Fixed: including curtain wall/storefront	0.45
Entrance door	0.80
All other[a]	0.46
SHGC-all frame types	0.40
Skylights (3% maximum of roof area)	
U-factor	0.60
SHGC	0.40

a. All others includes operable windows, and non-entrance doors with greater than 50-percent glazing.

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 and skylights, the maximum *U*-factor and solar heat gain coefficient (SHGC) shall be as specified in Table 502.3.

Exception: Buildings complying with STA approach in accordance with Section 502.1.3.

502.4 Air leakage. The thermal envelope of buildings shall comply with Sections 502.4.1 through 502.4.7.

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

1. The air barrier shall be continuous for all assemblies that are the thermal envelope of the building and across the joints and assemblies.
2. Air barrier joints and seams shall be sealed, including sealing transitions in places and changes in materials. Air barrier penetrations shall be sealed in accordance with Section C502.4.2. 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 are not required to comply with Items 1 and 3.

502.4.1.2 Air barrier compliance options. A continuous air barrier for the opaque building envelope shall comply with 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 per square foot (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. Orientated 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 with 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 per square foot (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 and 2 shall be deemed to comply provided joints are sealed and requirements of Section C502.4.1.1 are met.

1. Concrete or 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 0.40 cfm per square foot at a pressure differential of 0.3 inches water gauge (2.0 L/s · m^2 at 75 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 Air leakage of fenestration and doors. The air leakage of fenestration assemblies and doors and access openings from conditioned space to shafts, chutes, stairways and elevator lobbies 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 and 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.
3. Doors and access panels that are continuously gasketed, weatherstripped or sealed.
4. Door openings required to comply with Section 714 or 715.4 of the *Building Code*; or doors and door openings required by the *Building Code* to comply with UL 1784.

502.4.4 Outdoor air intakes and exhaust openings. Stair and elevator shaft vents and other ventilation openings integral to the building envelope shall be equipped with not less than a Class I motorized, leakage- rated damper with a maximum leakage rate of 4 cfm 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.

Stair and shaft vent dampers shall be capable of being automatically closed during normal building operation and interlocked to open as required by the *Building Code.*

Exceptions:

1. Mechanical systems intake, exhaust and relief openings shall comply with Section 503.2.4.5.
2. Elevator shaft vents complying with the *Oregon Elevator Specialty Code.*

TABLE 502.4.3
MAXIMUM AIR INFILTRATION RATE
FOR FENESTRATION ASSEMBLIES

FENESTRATION ASSEMBLY	MAXIMUM RATE (CFM/FT^2)	TEST PROCEDURE
Windows	0.30	AAMA/WDMA/ CSA101/I.S.2/A440 or NFRC 400
Sliding doors	0.30	
Swinging doors	0.30	
Skylights – with condensation weepage openings	0.30	
Skylights – all other	0.30	
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)

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

502.4.6 Vestibules. A door that separates conditioned space from the exterior shall be protected with an enclosed vestibule, with all doors opening into and out of the vestibule equipped with self-closing devices. Vestibules shall be designed so that in passing through the vestibule it is not necessary for the interior and exterior doors to open at the same time.

Exceptions:

1. Doors not intended to be used as a building entrance door, 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.
5. Doors used primarily to facilitate vehicular movement or material handling and adjacent personnel doors.

502.4.7 Recessed lighting. Recessed luminaires installed in the *building thermal envelope* shall be sealed to limit air leakage between conditioned and unconditioned spaces. All recessed luminaires shall be IC-rated and *labeled* as meeting ASTM E 283 when tested at 1.57 psf (75 Pa) pressure differential with no more than 2.0 cfm (0.944 L/s) of air movement from the *conditioned space* to the ceiling cavity. 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).

503.2 Provisions applicable to all mechanical systems.

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. 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.

503.2.1.1 Packaged electric equipment. Forced air unit and packaged electric equipment with a total heating capacity greater than 20,000 Btu/h (5862W) shall have a heat pump as the primary heating source.

Exception: Unstaffed equipment shelters or cabinets used solely for personal wireless service facilities.

503.2.2 Equipment and system sizing. Heating and cooling equipment and systems capacity 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), 503.2.3(6), 503.2.3(7), 503.2.3(8), 503.2.3(9) and 503.2.3(10) 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.

C503.2.3.1 Water-cooled centrifugal chilling packages. Equipment not designed for operation at AHRI Standard 550/590 test conditions of 44°F (7°C) leaving chilled-water temperature and 2.4 gpm/ton evaporator fluid flow 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 kW/ton (FL) and part load ratings requirements adjusted using Equations 4-5 and 4-6.

$$FL_{adj} = FL/K_{adj} \quad \textbf{(Equation 5-1)}$$

$$PLV_{adj} = IPLV/K_{adj} \quad \textbf{(Equation 5-2)}$$

where:

K_{adj} = A × B

FL = full-load kW/ton value as specified in Table C503.2.3(7).

FL_{adj} = maximum full-load kW/ton rating, adjusted for nonstandard conditions.

$IPLV$ = $IPLV$ value as specified in Table C503.2.3(7).

PLV_{adj} = maximum $NPLV$ rating, adjusted for nonstandard conditions.

$A = 0.00000014592 \times (LIFT)^4 - 0.0000346496 \times (LIFT)^3 + 0.00314196 \times (LIFT)^2 - 0.147199 \times (LIFT) + 3.9302$

$B = 0.0015 \times L_{vg}E_{vap} + 0.934$

$LIFT = L_{vg}Cond - L_{vg}E_{vap}$

$L_{vg}Cond$ = Full-load condenser leaving fluid temperature (°F).

$L_{vg}E_{vap}$ = Full-load evaporator leaving temperature (°F).

The FL_{adj} and PLV_{adj} values are only applicable for centrifugal chillers meeting all of the following full-load design ranges:

1. Minimum Evaporator Leaving Temperature: 36°F.
2. Maximum Condenser Leaving Temperature: 115°F.
3. 20°F ≤ LIFT ≤ 80°F.

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 that respond to temperature within the zone.

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 ther-mostatic control zone for each building expo-sure 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 sup-ply 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 shall have controls that, except during defrost, prevent supplementary heat operation when the heat pump can meet the heating load.

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

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

503.2.4.3 Optimum start controls. Each HVAC system shall have controls that vary the start-up time of the system to just meet the temperature set point at time of occupancy.

503.2.4.4 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.

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

503.2.4.4.2 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.

503.2.4.5 Shutoff dampers and controls. Outdoor air supply exhaust and relief shall be equipped with not less than Class I 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 accor-

dance with AMCA 500D, that will automatically shut when the systems or spaces served are not in use.

Exceptions:

1. Gravity dampers shall be permitted for outside air intake or exhaust airflows of 300 cfm (0.14 m^3/s) or less.
2. Relief dampers integral to packaged cooling equipment.
3. Type I grease exhaust systems.

503.2.4.6 Freeze protection and snow melt system controls. Freeze protection systems, such as heat tracing of outdoor piping and heat exchangers, including self-regulating heat tracing, shall include automatic controls capable of shutting off the systems when *outdoor air* temperatures are above 40°F (4°C) or when the conditions of the protected fluid will prevent freezing. 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.

503.2.4.7 Zone isolation controls. A system serving multiple occupancies or floors in the same building shall be independently zoned and equipped with isolation devices capable of automatically shutting off the supply of conditioned air and outside air to and from each isolated area. Each isolated area shall be controlled independently and satisfy temperature setback (see Section 503.2.4.4.1) and optimum start control requirements (see Section 503.2.4.3). The central fan system air volume shall be reduced through fan speed reduction.

Exception: A cooling system less than 240,000 Btu/h (70 kW) or a heating system with less than 300,000 Btu/h (88 kW) total capacity.

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

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE[a]
				Before 1/1/2016	As of 1/1/2016	
Air conditioners, air cooled	< 65,000 Btu/h[b]	All	Split System	13.0 SEER	13.0 SEER	AHRI 210/240
			Single Package	14.0 SEER	14.0 SEER	
Through-the-wall (air cooled)	≤ 30,000 Btu/h[b]	All	Split system	12.0 SEER	12.0 SEER	
			Single Package	12.0 SEER	12.0 SEER	
Small-duct high-velocity (air cooled)	< 65,000 Btu/h[b]	All	Split System	11.0 SEER	11.0 SEER	
Air conditioners, air cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.2 EER 11.4 IEER	11.2 EER 12.8 IEER	AHRI 340/360
		All other	Split System and Single Package	11.0 EER 11.2 IEER	11.0 EER 12.6 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	11.0 EER 12.4 IEER	
		All other	Split System and Single Package	10.8 EER 11.0 IEER	10.8 EER 12.2 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 10.1 IEER	10.0 EER 11.6 IEER	
		All other	Split System and Single Package	9.8 EER 9.9 IEER	9.8 EER 11.4 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 9.8 IEER	9.7 EER 11.2 IEER	
		All other	Split System and Single Package	9.5 EER 9.6 IEER	9.5 EER 11.0 IEER	

(continued)

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

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE[a]
				Before 1/1/2016	As of 1/1/2016	
Air conditioners, water cooled	< 65,000 Btu/h[b]	All	Split System and Single Package	12.1 EER 12.3 IEER	12.1 EER 12.3 IEER	AHRI 210/240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.1 EER 12.3 IEER	12.1 EER 13.9 IEER	AHRI 340/360
		All other	Split System and Single Package	11.9 EER 12.1 IEER	11.9 EER 13.7 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.5 EER 12.5 IEER	12.5 EER 13.9 IEER	
		All other	Split System and Single Package	12.3 EER 12.5 IEER	12.3 EER 13.7 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.4 EER 12.6 IEER	12.4 EER 13.6 IEER	
		All other	Split System and Single Package	12.2 EER 12.4 IEER	12.2 EER 13.4 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.2 EER 12.4 IEER	12.2 EER 13.5 IEER	
		All other	Split System and Single Package	12.0 EER 12.2 IEER	12.0 EER 13.3 IEER	
Air conditioners, evaporatively cooled	< 65,000 Btu/h[b]	All	Split System and Single Package	12.1 EER 12.3 IEER	12.1 EER 12.3 IEER	AHRI 210/240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.1 EER 12.3 IEER	12.1 EER 12.3 IEER	AHRI 340/360
		All other	Split System and Single Package	11.9 EER 12.1 IEER	11.9 EER 12.1 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.0 EER 12.2 IEER	12.0 EER 12.2 IEER	
		All other	Split System and Single Package	11.8 EER 12.0 IEER	11.8 EER 12.0 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.9 ERR 12.1 IERR	11.9 ERR 12.1 IEER	
		All other	Split System and Single Package	11.7 ERR 11.9 IEER	11.7 ERR 11.9 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.7 ERR 11.9 ERR	11.7 ERR 11.9 ERRT	
		All other	Split System and Single Package	11.5 ERR 11.7 ERR	11.5 ERR 11.7 ERR	
Condensing units, air cooled	≥ 135,000 Btu/h			10.5 EER 11.8 IEER	10.5 EER 11.8 IEER	AHRI 365
Condensing units, water cooled	≥ 135,000 Btu/h			13.5 EER 14.0 IEER	13.5 EER 14.0 IEER	
Condensing units, evaporatively cooled	≥ 135,000 Btu/h			13.5 EER 14.0 IEER	13.5 EER 14.0 IEER	

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 reference year version of the test procedure.

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

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

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE[a]
				Before 1/1/2016	As of 1/1/2016	
Air cooled (cooling mode)	< 65,000 Btu/h[b]	All	Split System	14.0 SEER	14.0 SEER	AHRI 210/240
			Single Packaged	14.0 SEER	14.0 SEER	
Through-the-wall, air cooled	≤ 30,000 Btu/h[b]	All	Split System	12.0 SEER	12.0 SEER	
			Single Packaged	12.0 SEER	12.0 SEER	
Single-duct high-velocity air cooled	< 65,000 Btu/h[b]	All	Split System	11.0 SEER	11.0 SEER	
Air cooled (cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	11.0 EER 12.0 IEER	AHRI 340/360
		All other	Split System and Single Package	10.8 EER 11.0 IEER	10.8 EER 11.8 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.6 EER 10.7 IEER	10.6 EER 11.6 IEER	
		All other	Split System and Single Package	10.4 EER 10.5 IEER	10.4 EER 11.4 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 9.6 IEER	9.5 EER 10.6 IEER	
		All other	Split System and Single Package	9.3 EER 9.4 IEER	9.3 EER 9.4 IEER	
Water to Air: Water Loop (cooling mode)	< 17,000 Btu/h	All	86ºF entering water	12.2 EER	12.2 EER	ISO 13256-1
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86ºF entering water	13.0 EER	13.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86ºF entering water	13.0 EER	13.0 EER	
Water to Air: Ground Water (cooling mode)	< 135,000 Btu/h	All	59ºF entering water	18.0 EER	18.0 EER	ISO 13256-1
Brine to Air: Ground Loop (cooling mode)	< 135,000 Btu/h	All	77ºF entering water	14.1 EER	14.1 EER	ISO 13256-1
Water to Water: Water Loop (cooling mode)	< 135,000 Btu/h	All	86ºF entering water	10.6 EER	10.6 EER	ISO 13256-2
Water to Water: Ground Water (Cooling Mode)	< 135,000 Btu/h	All	59ºF entering water	16.3 EER	16.3 EER	
Brine to Water: Ground Loop (cooling mode)	< 135,000 Btu/h	All	77ºF entering fluid	12.1 EER	8.2 EER	
Air cooled (heating mode)	< 65,000 Btu/hb	—	Split System	8.2 HSPF	8.2 HSPF	AHRI 210/240
		—	Single Package	8.0 HSPF	8.0 HSPF	
Through-the-wall, (air cooled, heating mode)	≤ 30,000 Btu/h[b] (cooling capacity)	—	Split System	7.4 HSPF	7.4 HSPF	
		—	Single Package	7.4 HSPF	7.4 HSPF	
Small-duct high velocity (air cooled, heating mode)	< 65,000 Btu/h[b]	—	Split System	6.8 HSPF	6.8 HSPF	

(continued)

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

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE[a]
				Before 1/1/2016	As of 1/1/2016	
Air cooled (heating mode)	≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity)	—	47ºF db/43ºF wb Outdoor Air	3.3 COP	3.3 COP	AHRI 340/360
			17ºF db/15ºF wb Outdoor Air	2.25 COP	2.25 COP	
	≥ 135,000 Btu/h (Cooling Capacity)	—	47ºF db/43ºF wb Outdoor Air	3.2 COP	3.2 COP	
			17ºF db/15ºF wb Outdoor Air	2.05 COP	2.05 COP	
Water to Air: Water Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	4.3 COP	4.3 COP	ISO 13256-1
Water to Air: Ground Water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering water	3.7 COP	3.7 COP	
Brine to Air: Ground Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	3.2 COP	3.2 COP	
Water to Water: Water Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	3.7 COP	3.7 COP	ISO 13256-2
Water to Water: Ground Water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering water	3.1 COP	3.1 COP	
Brine to Water: Ground Loop (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	2.5 COP	2.5 COP	

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

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

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

TABLE 503.2.3(3)
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED PACKAGED TERMINAL AIR CONDITIONERS,
PACKAGED TERMINAL HEAT PUMPS, SINGLE-PACKAGE VERTICAL AIR CONDITIONERS,
SINGLE VERTICAL HEAT PUMPS, ROOM AIR CONDITIONERS AND ROOM AIR-CONDITIONER HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
PTAC (cooling mode) new construction	All Capacities	95°F db outdoor air	14.0 – (0.300 × Cap/1000)[c] EER	AHRI 310/380
PTAC (cooling mode) replacements[b]	All Capacities	95°F db outdoor air	10.9 - (0.213 × Cap/1000) EER	
PTHP (cooling mode) new construction	All Capacities	95°F db outdoor air	14.0 - (0.300 × Cap/1000) EER	
PTHP (cooling mode) replacements[b]	All Capacities	95°F db outdoor air	10.8 - (0.213 × Cap/1000) EER	
PTHP (heating mode) new construction	All Capacities	—	3.2 - (0.026 × Cap/1000) COP	
PTHP (heating mode) replacements[b]	All Capacities	—	2.9 - (0.026 × Cap/1000) COP	
SPVAC (cooling mode)	< 65,000 Btu/h	95°F db/ 75°F wb outdoor air	9.0 EER	AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h	95°F db/ 75°F wb outdoor air	8.9 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95°F db/ 75°F wb outdoor air	8.6 EER	
SPVHP (cooling mode)	< 65,000 Btu/h	95°F db/ 75°F wb outdoor air	9.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	95°F db/ 75°F wb outdoor air	8.9 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95°F db/ 75°F wb outdoor air	8.6 EER	
SPVHP (heating mode)	< 65,000 Btu/h	47°F db/ 43°F wb outdoor air	3.0 COP	AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h	47°F db/ 43°F wb outdoor air	3.0 COP	
	≥ 135,000 Btu/h and < 240,000 Btu/h	47°F db/ 75°F wb outdoor air	2.9 COP	
Room air conditioners, with louvered slides	< 6,000 Btu/h	—	9.7 SEER	ANSI/AHAM RAC-1
	≥ 6,000 Btu/h and < 8,000 Btu/h	—	9.7 EER	
	≥ 8,000 Btu/h and < 14,000 Btu/h	—	9.8 EER	
	≥ 14,000 Btu/h and < 20,000 Btu/h	—	9.7 SEER	
	≥ 20,000 Btu/h	—	8.5 EER	
Room air conditioners, with louvered slides	< 8,000 Btu/h	—	9.0 EER	
	≥ 8,000 Btu/h and < 20,000 Btu/h	—	8.5 EER	
	≥ 20,000 Btu/h	—	8.5 EER	
Room air-conditioner heat pumps with louvered sides	< 20,000 Btu/h	—	9.0 EER	
	≥ 20,000 Btu/h	—	8.5 EER	
Room air-conditioner heat pumps without louvered sides	< 14,000 Btu/h	—	8.5 EER	
	≥ 14,000 Btu/h	—	8.0 EER	
Room air conditioner casement only	All capacities	—	8.7 EER	
Room air conditioner casement-slider	All capacities	—	9.5 EER	

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

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

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

b. Replacement unit shall be factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406 mm) in height and less than 42 inches (1067 mm) in width.

TABLE 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.

f. E_c = Combustion efficiency. Units shall 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 shall 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.

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TABLE 503.2.3(5)
MINIMUM EFFICIENCY REQUIREMENTS: GAS- AND OIL-FIRED BOILERS

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

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

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

a. These requirements apply to boilers with rated input of 8,000,000 Btu/h or less that are not packaged boilers and to all packaged boilers. Minimum efficiency requirements for boilers cover all capacities of packaged boilers.

b. Maximum capacity – minimum and maximum ratings as provided for and allowed by the unit's controls.

c. Includes oil-fired (residual).

TABLE 503.2.3(6)
CONDENSING UNITS, ELECTRICALLY OPERATED, MINIMUM EFFICIENCY REQUIREMENTS

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

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

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

b. IPLVs are only applicable to equipment with capacity modulation.

TABLE 503.2.3(7)
WATER CHILLING PACAKAGES – EFFICIENCY REQUIREMENTS[a, b, c]

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	BEFORE 1/1/2015		AS OF 1/1/2015		TEST PROCEDURE[c]
			Path A	Path B	Path A	Path B	
Air-Cooled Chillers	< 159 Tons	EER (Btu/W)	≥ 9.562 FL	NA[d]	≥ 10.100 FL	≥ 9.700 FL	AHRI 550/590
			≥ 12.500 IPLV		≥ 13.700 IPLV	≥ 15,800 IPLV	
	≥ 150 Tons		≥ 9.562 FL	NA[d]	≥ 10.100 FL	≥ 9.700 FL	
			≥ 12.500 IPLV		≥ 14.000 IPLV	≥ 16.100 IPLV	
Air-Cooled without Condenser, Electrically Operated	All Capacities	EER (Btu/W)	Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirements.				
Water-Cooled, Electrically Operated Positive Displacement	< 75 Tons	kW/ton	≤ 0.780 FL	≤ 0.800 FL	≤ 0.750 FL	≤ 0.780 FL	
			≤ 0.630 IPLV	≤ 0.600 IPLV	≤ 0.600 IPLV	≤ 0.500 IPLV	
	≥ 75 tons and < 150 tons		≤ 0.775 FL	≤ 0.790 FL	≤ 0.720 FL	≤ 0.750 FL	
			≤ 0.615 IPLV	≤ 0.586 IPLV	≤ 0.560 IPLV	≤ 0.490 IPLV	
	≥ 150 tons and < 300 tons		≤ 0.680 FL	≤ 0.718 FL	≤ 0.660 FL	≤ 0.680 FL	
			≤ 0.580 IPLV	≤ 0.540 IPLV	≤ 0.540 IPLV	≤ 0.440 IPLV	
	≥ 300 tons and < 600 tons		≤ 0.620 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.625 FL	
			≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.520 IPLV	≤ 0.410 IPLV	
	≥ 600 tons		≤ 0.620 FL	≤ 0.639 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.540 IPLV	≤ 0.490 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
Water-Cooled, Electrically Operated Centrifugal	≤150 Tons	kW/ton	≤ 0.780 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.695 FL	
			≤ 0.630 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤ 0.440 IPLV	
	≥ 150 tons and < 300 tons		≤ 0.634 FL	≤ 0.639 FL	≤ 0.610 FL	≤ 0.635 FL	
			≤ 0.596 IPLV	≤ 0.450 IPLV	≤ 0.550 IPLV	≤ 0.400 IPLV	
	≥ 300 tons and < 400 tons		≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.595 FL	
			≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.520 IPLV	≤ 0.390 IPLV	
	≥ 400 tons and < 600 tons		≤ 0.576 FL	≤ 0.600 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.549 IPLV	≤ 0.400 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
	≥ 600 Tons		≤ 0.570 FL	≤ 0.590 FL	≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.539 IPLV	≤ 0.400 IPLV	≤ 0.500 IPLV	≤ 0.380 IPLV	
Air-Cooled, Absorption, Single Effect	All Capacities	COP	≥ 0.600 FL	NA[d]	≥ 0.600 FL	NA[d]	AHRI 560
Water-Cooled Absorption, Single Effect	All Capacities	COP	≥ 0.700 FL	NA[d]	≥ 0.700 FL	NA[d]	
Absorption, Double-Effect, Indirect-Fired	All Capacities	COP	≥ 1.000 FL	NA[d]	≥ 1.000 FL	NA[d]	
			≥ 1.050 IPLV		≥ 1.050 IPLV		
Absorption Double-Effect Direct-Fired	All Capacities	COP	≥ 1.000 FL	NA[d]	≥ 1.000 FL	NA[d]	
			≥ 1.000 IPLV		≥ 1.050 IPLV		

a. The requirements for centrifugal chiller shall be adjusted for nonstandard rating conditions in accordance with Section 503.2.3.1 and are only applicable for the range of conditions listed in Section 503.2.3.1. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure.

b. Both the full load and IPLV requirements shall be met or exceeded to comply with this code. Where there is a Path B, compliance can be with either Path A or Path B for any application.

c. FL is the full load performance requirements and IPLV is for the part load performance requirements.

d. NA means the requirements are not applicable for Path B and only Path A can be used for compliance.

TABLE 503.2.3(8)
MINIMUM EFFICIENCY REQUIREMENTS:
HEAT REJECTION EQUIPMENT

EQUIPMENT TYPE[a]	TOTAL SYSTEM HEAT REJECTION CAPACITY AT RATED CONDITIONS	SUBCATEGORY OR RATING CONDITION[i]	PERFORMANCE REQUIRED[b, c, d, g, h]	TEST PROCEDURE[e, f]
Propeller or axial fan open circuit cooling towers	All	95°F Entering Water 85°F Leaving Water 75°F Entering wb	≥ 40.2 gpm/hp	CTI ATC-105 and CTI STD-201
Centrifugal fan open circuit cooling towers	All	95°F Entering Water 85°F Leaving Water 75°F Entering wb	≥20.0 gpm/hp	CTI ATC-105 and CTI STD-201
Propeller or axial fan closed circuit cooling towers	All	102°F Entering Water 90°F Leaving Water 75°F Entering wb	≥ 14.0 gpm/hp	CTI ATC-105S and CTI STD-201
Centrifugal closed circuit cooling towers	All	102°F Entering Water 90°F Leaving Water 75°F Entering wb	≥ 7.0 gpm/hp	CTI ATC-105S and CTI STD-201
Propeller or axial fan evaporative condensers	All	Ammonia Test Fluid 140°F entering gas temperature 96.3°F condensing temperature 75°F entering wb	≥ 134,000 Btu/h · hp	CTI ATC-106
Centrifugal fan evaporative condensers	All	Ammonia Test Fluid 140°F entering gas temperature 96.3°F condensing temperature 75°F entering wb	≥ 110,000 Btu/h · hp	CTI ATC-106
Propeller or axial fan evaporative condensers	All	R-507A Test Fluid 165°F entering gas temperature 105°F condensing temperature 75°F entering wb	≥ 157,000 Btu/h · hp	CTI ATC-106
Centrifugal fan evaporative condensers	All	R-507A Test Fluid 165°F entering gas temperature 105°F condensing temperature 75°F entering wb	≥ 135,000 Btu/h · hp	CTI ATC-106
Air-cooled condensers	All	125°F Condensing Temperature 190°F Entering Gas Temperature 15°F Subcooling 95°F Entering db	≥ 176,000 Btu/h · hp	ARI 460

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

a. The efficiencies and test procedures for both open and closed circuit cooling towers are not applicable to hybrid cooling towers that contain a combination of wet and dry heat exchange sections.

b. For purposes of this table, open circuit cooling tower performance is defined as the water flow rating of the tower at the thermal rating condition listed in Table 403.2.3(8) divided by the fan nameplate rated motor power.

c. For purposes of this table, closed circuit cooling tower performance is defined as the water flow rating of the tower at the thermal rating condition listed in Table 403.2.3(8) divided by the sum of the fan nameplate rated motor power and the spray pump nameplate rated motor power.

d. For purposes of this table, air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the fan nameplate rated motor power.

e. Chapter 6 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure. The certification requirements do not apply to field erected cooling towers.

f. Where a certification program exists for a covered product, and it includes provisions for verification and challenge of equipment efficiency ratings, then the product shall be listed in the certification program, or, where a certification program exists for a covered product, and it includes provisions for verification and challenge of equipment efficiency ratings, but the product is not listed in the existing certification program, the ratings shall be verified by an independent laboratory test report.

g. All cooling towers shall comply with the minimum efficiency listed in the table for that specific type of tower with the capacity effect of any project specific accessories and /or options included in the capacity of the cooling tower.

h. For purposes of this table, evaporative condenser performance is defined as the heat rejected at the specified rating condition in the table divided by the sum of the fan motor nameplate power and the integral spray pump nameplate power.

i. Requirements for evaporative condensers are listed with ammonia (R-717) and R-507A as test fluids in the table. Evaporative condensers intended for use with halocarbon refrigerants other than R-507A shall meet the minimum efficiency requirements listed above with R-507A as the test fluid.

TABLE 503.2.3(9)
MINIMUM EFFICIENCY AIR CONDITIONERS AND CONDENSING UNITS SERVING COMPUTER ROOMS

EQUIPMENT TYPE	NET SENSIBLE COOLING CAPACITY[a]	MINIMUMSCOP-127[b] EFFICIENCY DOWNFLOW UNITS/UPFLOW UNITS	TEST PROCEDURE
Air conditioners, air cooled	< 65,000 Btu/h	2.20 / 2.09	ANSI/ ASHRAE 127
	≥ 65,000 Btu/h and < 240,000 Btu/h	2.10 / 1.99	
	≥ 240,000 Btu/h	1.90 / 1.79	
Air conditioners, water cooled	< 65,000 Btu/h	2.60 / 2.49	
	≥ 65,000 Btu/h and < 240,000 Btu/h	2.50 / 2.39	
	≥ 240,000 Btu/h	2.40 / 2.29	
Air conditioners, water cooled with fluid economizer	< 65,000 Btu/h	2.55 / 2.44	
	≥ 65,000 Btu/h and < 240,000 Btu/h	2.45 / 2.34	
	≥ 240,000 Btu/h	2.35 / 2.24	
Air conditioners, glycol cooled (rated at 40% propylene glycol)	< 65,000 Btu/h	2.50 / 2.39	
	≥ 65,000 Btu/h and < 240,000 Btu/h	2.15 / 2.04	
	≥ 240,000 Btu/h	2.10 / 1.99	
Air conditioners, glycol cooled (rated at 40% propylene glycol) with fluid economizer	< 65,000 Btu/h	2.45 / 2.34	
	≥ 65,000 Btu/h and < 240,000 Btu/h	2.10 / 1.99	
	≥ 240,000 Btu/h	2.05 / 1.94	

a. Net sensible cooling capacity: The total gross cooling capacity less the latent cooling less the energy to the air movement system. (Total Gross – latent – Fan Power).

b. Sensible coefficient of performance (SCOP-127): a ratio calculated by dividing the net sensible cooling capacity in watts by the total power input in watts (excluding reheaters and humidifiers) at conditions defined in ASHRAE Standard 127. The net sensible cooling capacity is the gross sensible capacity minus the energy dissipated into the cooled space by the fan system.

TABLE 503.2.3(10)
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED VARIABLE REFRIGERANT FLOW AIR-TO-AIR AND APPLIED HEAT PUMP

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUB-CATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE
VRF Air Cooled, (cooling mode)	< 65,000 Btu/h	All	VRF Multi-split System	13.0 SEER	AHRI 1230
	≥ 65.000 Btu/h and < 135,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	11.0 EER 12.9 IEER	
	≥ 65.000 Btu/h and < 135,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System with Heat Recovery	10.8 EER 12.7 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	10.6 EER 12.3 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System with Heat Recovery	10.4 EER 12.1 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	9.5 EER 11.0 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System with Heat Recovery	9.3 EER 10.8 IEER	
VRF Water source (cooling mode)	< 65,000 Btu/h	All	VRF Multi-split systems 86°F entering water	12.0 EER	AHRI 1230
	< 65,000 Btu/h	All	VRF Multi-split systems with Heat Recovery 86°F entering water	11.8 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	VRF Multi-split System 86°F entering Water	12.0 EER	
	≥ 65.000 Btu/h and < 135,000 Btu/h	All	VRF Multi-split System with Heat Recovery 86°F entering water	11.8 EER	
	≥ 135.000 Btu/h	All	VRF Multi-split System 86°F entering water	10.0 EER	
	≥ 135.000 Btu/h	All	VRF Multi-split System with Heat Recovery 86°F entering water	9.8 EER	
VRF Groundwater source (cooling mode)	< 135,000 Btu/h	All	VRF Multi-split System 59°F entering water	16.2 EER	AHRI 1230
	< 135,000 Btu/h	All	VRF Multi-split System with Heat Recovery 59°F entering water	16.0 EER	
	≥ 135,000 Btu/h	All	VRF Multi-split System 59°F entering water	13.8 EER	
	≥ 135,000 Btu/h	All	VRF Multi-split System with Heat Recovery 59°F entering water	13.6 EER	
VRF Ground source (cooling mode)	< 135,000 Btu/h	All	VRF Multi-split System 77°F entering water	13.4 EER	AHRI 1230
	< 135,000 Btu/h	All	VRF Multi-split System with Heat Recovery 77°F entering water	13.2 EER	
	≥ 135,000 Btu/h	All	VRF Multi-split System 77°F entering water	11.0 EER.	
	≥ 135,000 Btu/h	All	VRF Multi-split System with Heat Recovery 77°F entering water	10.8 EER	
VRF Air Cooled (heating mode)	< 65,000 Btu/h (cooling capacity)	—	VRF Multi-split System	7.7 HSPF	AHRI 1230
	≥ 65.000 Btu/h and < 135,000 Btu/h (cooling capacity)	—	VRF Multi-split system 47°F db/43°F wb outdoor air 17°F db/157 wb outdoor air	3.3 COP 2.25 COP	
	> 135,000 Btu/h (cooling capacity)	—	VRF Multi-split System 47°F db/43°F wb outdoor air 177 db/15°F wb outdoor-air	3.2 COP 2.05 COP	
VRF Water source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	VRF Multi-split System 68°F entering water	4.2 COP	AHRI 1230
	≥ 135,000 Btu/h (cooling capacity)	—	VRF Multi-split System 68°F entering water	3.9 COP	
VRF Groundwater source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	VRF Multi-split System 50°F entering water	3.6 COP	AHRI 1230
	≥ 135,000 Btu/h (cooling capacity)	—	VRF Multi-split System 50°F entering water	3.3 COP	
VRF Ground source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	VRF Multi-split System 32°F entering water	3.1 COP	AHRI 1230
	≥ 135,000 Btu/h (cooling capacity)	—	VRF Multi-split System 32°F entering water	2.8 COP	

503.2.4.8 Separate air distribution systems. Zones with special process temperature requirements and/or humidity requirements shall be served by separate air distribution systems from those serving zones requiring only comfort conditions; or shall include supplementary control provisions so that the primary systems may be specifically controlled for comfort purposes only.

Exceptions: Zones requiring only comfort heating or comfort cooling that are served by a system primarily used for process temperature and humidity control provided that:

1. The total supply air to those comfort zones is no more than 25 percent of the total system supply air, or
2. The total conditioned floor area of the zones is less than 1,000 square feet (90 m^2).

503.2.4.9 Humidity control. If a system is equipped with a means to add or remove moisture to maintain specific humidity levels in a zone or zones, a humidity control device shall be provided.

503.2.4.9.1 The humidity control device shall be set to prevent the use of fossil fuel or electricity to produce relative humidity in excess of 30 percent. Where a humidity control device is used for dehumidification, it shall be set to prevent the use of fossil fuel or electricity to reduce relative humidity below 60 percent.

Exception: Hospitals, process needs, archives, museums, critical equipment, and other noncomfort situations with specific humidity requirements outside this range.

503.2.4.9.2 Humidity controls shall maintain a deadband of at least 10 percent relative humidity where no active humidification or dehumidification takes place.

Exception: Heating for dehumidification is provided with heat recovery or heat pumping and the mechanical cooling system efficiency is 10 percent higher than required in Section 503.2.3, HVAC equipment performance requirements.

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

503.2.5.1 Demand controlled ventilation. Demand control ventilation (DCV) is required for spaces with an average occupant load of 25 people or more per 1000 square feet (93 m^2) of floor area (as established in Table 403.3 of the *Mechanical Code*) and served by systems with one or more of the following:

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

Exceptions:

1. Spaces smaller than 500 square feet (46.5 m^2) served by single-zone systems.
2. Spaces smaller than 150 square feet (13.9 m^2) served by multiple-zone systems.
3. Systems with energy recovery complying with Section 503.2.6.
4. Spaces less than 750 square feet (69.7 m^2) where an occupancy sensor turns the fan off, closes the ventilation damper, or closes the zone damper when the space is unoccupied.

503.2.5.2 Kitchen hoods. Kitchen makeup air shall be provided as required by the *Mechanical Code*. For each kitchen with a total exhaust capacity greater than 5,000 cfm (2360 L/s), 50 percent of the required makeup air shall be (a) unheated or heated to no more than 60°F (15.55°C); and (b) uncooled or evaporatively cooled.

Exception: Where hoods are used to exhaust ventilation air that would otherwise be exhausted by other fan systems. Air transferred from spaces served by other fan systems may not be used if those systems are required to meet either Sections 503.2.5.1 or 503.2.6. Occupancy schedule of HVAC system supplying transfer air shall be similar to kitchen exhaust hood operating schedule.

503.2.5.2.1 Variable flow exhaust. Each kitchen with a total Type 1 exhaust capacity greater than 5,000 cfm (2360 L/s) shall be equipped with a demand ventilation system on at least 75 percent of the exhaust and makeup air. Such systems shall be equipped with automatic controls that reduce airflow in response to cooking appliance operation.

503.2.5.3 Enclosed parking garage ventilation controls. In Group S-2, enclosed parking garages used for storing or handling automobiles operating under their own power having ventilation exhaust rates 30,000 cfm (14 157 L/s) and greater shall employ automatic carbon monoxide sensing devices. These devices shall modulate the ventilation system to maintain a maximum average concentration of carbon monoxide of 50 parts per million during any 8-hour period, with a maximum concentration not greater than 200 parts per million for a period not exceeding 1 hour. The system shall be capable of producing a ventilation rate of 0.75 cfm per square foot (0.0038 $m^3/s \cdot m^2$) of floor area. Failure of such devices shall cause the exhaust fans to operate in the ON position.

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. Where a single room or space is supplied by multiple units, the aggregate supply (cfm) of those units shall be used in applying this requirement.

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 *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 that reduce exhaust and makeup air volume to 50 percent or less of design values during periods of reduced occupancy or system demand.
   - 2.2. Variable-air-volume hood exhaust and room supply systems that reduce exhaust and makeup air volume and/or incorporate a heat recovery system to precondition makeup air from laboratory exhaust shall meet the following:

     A + B*(E/M) = 50%

     where:

     A = Percentage that the exhaust and makeup airflow rates will be reduced from design conditions.

     B = Percentage sensible heat recovery effectiveness.

     E = Exhaust airflow rate through the heat recovery device at design conditions.

     M= Makeup air flow rate of the system at design conditions.
   - 2.3. 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. Type 1 kitchen exhaust hoods.
6. Cooling systems in climates with a 1-percent cooling design wet-bulb temperature less than 64°F (18°C).
7. Systems requiring dehumidification that employ series-style energy recovery coils wrapped around the cooling coil when the evaporative coil is located upstream of the exhaust air stream.
8. Systems exhausting toxic, flammable, paint exhaust, corrosive fumes or dust.

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-5 insulation when located in unconditioned spaces and a minimum of R-8 insulation when located outside the building. When located within a building envelope assembly, the duct or plenum shall be separated from the building exterior or unconditioned or exempt spaces by a minimum of R-8 insulation.

Exceptions:

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

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

503.2.7.1 Duct construction. Ductwork shall be constructed and erected in accordance with the *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 *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 *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 5-3.

$$CL = F \times P^{0.65} \qquad \textbf{(Equation 5-3)}$$

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 (14°C) and 105°F (41°C).
4. Runout piping not exceeding 4 feet (1219 mm) in length and 1 inch (25 mm) in diameter between the control valve and HVAC coil.

503.2.8.1 Protection of piping insulation. Piping insulation exposed to weather shall be protected from damage, including that due to sunlight, moisture, equipment maintenance, and wind, and shall provide shielding from solar radiation that can cause degradation of the material. Adhesives tape shall not be permitted as the means of protection and shall be used in accordance with manufacturer's specfications.

503.2.9 HVAC system completion.

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 *Mechanical Code*. Discharge dampers intended to modulate airflow 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. 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.
3. A complete written narrative of how each system is intended to operate.

TABLE 503.2.8
MINIMUM PIPE INSULATION THICKNESS (thickness in inches)[a, b, c]

FLUID OPERATING TEMPERATURE RANGE AND USAGE (°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
> 350	0.32 – 0.34	250	4.5	5.0	5.0	5.0	5.0
251 – 350	0.29 – 0.32	200	3.0	4.0	4.5	4.5	4.5
201 – 250	0.27 – 0.30	150	2.5	2.5	2.5	3.0	3.0
141 – 200	0.25 – 0.29	125	1.5	1.5	2.0	2.0	2.0
105 – 140	0.21 – 0.28	100	1.0	1.0	1.5	1.5	1.5
40 – 60	0.21 – 0.27	75	0.5	0.5	1.0	1.0	1.0
< 40	0.20 – 0.26	50	0.5	1.0	1.0	1.0	1.5

For SI: 1 inch = 25.4 mm.

a. For piping smaller than 1$^1/_2$ inch (38 mm) and located in partitions within conditioned spaces, reduction of these thicknesses by 1 inch (25 mm) shall be permitted (before thickness adjustment required in footnote b) but not to a thickness less that 1 inch (25 mm).

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

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

where:

T = minimum insulation thickness,

r = actual outside radius of pipe,

t = insulation thickness listed in Table 503.2.8 for applicable fluid temperature and pipe size,

K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (Btu× in./h x ft^2 × °F) and

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

c. For direct-buried heating and hot water system piping, reduction of these thicknesses by 1$^1/_2$ inches (38 mm) shall be permitted (before thickness adjustment required in footnote b but not to thicknesses less than 1 inch (25 mm).

503.2.10 Air system design and control. Each HVAC system having a total fan system motor nameplate horsepower (hp) exceeding 5 horsepower (hp) (3.7 kW) shall meet the provisions of Sections 503.2.10.1 through 503.2.10.2.

503.2.10.1 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 503.2.10.1(1). This includes supply fans, return/relief fans, and fan-powered terminal units associated with systems providing heating or cooling capability.

Exceptions:

1. Hospital 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.

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

Exceptions:

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

503.2.10.3 Large volume fan systems. Large volume fan systems shall comply with Sections 503.2.10.3.1 and 503.2.10.3.2 as applicable.

Exception: Systems where the function of the supply air is for purposes other than temperature control, such as maintaining specific humidity levels or supplying an exhaust system

503.2.10.3.1 Fan systems over 8,000 cfm (7 m^3/s) without direct expansion cooling coils that serve single zones are required to reduce airflow based on space thermostat heating and cooling demand. A two-speed motor or variable frequency drive shall reduce airflow to a maximum 60 percent of peak airflow or minimum ventilation air requirement as required by Chapter 4 of the *Mechanical Code*, whichever is greater.

503.2.10.3.2 All air-conditioning equipment and air-handling units with direct expansion cooling and a cooling capacity at AHRI conditions greater than or equal to 110,000 Btu/h (32 241W) that serve single zones shall have their supply fans controlled by two-speed motors or variable speed drives. At cooling demands less than or equal to 50 percent, the supply fan controls shall be able to reduce the airflow to no greater than the larger of the following:

1. Two-thirds of the full fan speed, or
2. The volume of outdoor air required to meet the ventilation requirements of Standard 62.1.

503.2.10.4 Series fan-powered terminal unit fan motors. Fan motors for series fan-powered terminal units shall be electronically-commutated motors and have a minimum motor efficiency of 70 percent when rated in accordance with NEMA Standard MG 1-2006 at full load rating conditions.

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

TABLE 503.2.10.1(1)
FAN POWER LIMITATION

	LIMIT	CONSTANT VOLUME	VARIABLE VOLUME
Option 1: Fan system motor nameplate hp	Allowable nameplate motor hp	hp ≤ CFMS *0.0011	hp ≤ CFMS *0.0015
Option 2: Fan system bhp	Allowable fan system bhp	bhp ≤ CFMS *0.00094 + *A*	bhp ≤CFMS *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 × CFM_D/4131].

where:

PD = Each applicable pressure drop adjustment from Table 503.2.10.1(2) in. w.c.

CFM_D = The design airflow through each applicable device from Table 503.2.10.1(2) in cubic feet per minute.

TABLE 503.2.10.1(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 2× 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.
Exhaust system serving fume hoods	0.35 in. w.c.
Laboratory and vivarium exhaust systems in high-rise buildings	0.25 in. w.c./100 ft. of vertical duct exceeding 75 feet

For SI: 1 foot = 304.8 mm.

503.2.11.1 Spot heating within enclosed spaces. Infrared *spot heating* meeting the control requirements of Section 503.2.11 shall be allowed within unconditioned and semiheated spaces without requiring the envelope to comply as a conditioned space. Spot heating shall be limited to the larger of 500 ft^2 (m^3) or 10 percent of the floor area.

503.2.12 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 503.2.12.

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

TABLE 503.2.12
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 = 0.2931 watts.

503.3 Simple HVAC systems and equipment. This section applies to 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. Supply air economizers shall be provided on each cooling system and shall be capable of providing 100-percent outdoor air, even if additional mechanical cooling is required to meet the cooling load of the building. Systems shall provide a means to relieve excess outdoor air during economizer operation to prevent overpressurizing the building. The relief air outlet shall be located to avoid recirculation into the building. Where a single room or space is supplied by multiple air systems, the aggregate capacity of those systems shall be used in applying this requirement.

Exceptions:

1. Cooling equipment less than 54,000 Btu/h (15 827 W) total cooling capacity. The total capacity of all such units without economizers shall not exceed 240,000 Btu/h (70 342 W) per building area served by one utility meter or service, or 10 percent of its total installed cooling capacity, whichever is greater. That portion of the equipment serving dwelling units and guest rooms is not included in determining the total capacity of units without economizers.
2. Economizer cooling is not required for new cooling systems serving an existing dedicated computer server room, electronic equipment room or telecom switch room in existing buildings up to a total of 600,000 Btu/h (17 586 W) of new cooling equipment.
3. Economizer cooling is not required for new cooling systems serving a new dedicated computer server room, electronic equipment room or telecom switch room in existing buildings up to a total of 240,000 Btu/h (70 344 W) of new cooling equipment.

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

503.4 Complex HVAC systems and equipment. This section applies to HVAC equipment and systems not covered in Section 503.3.

503.4.1 Economizers. Supply air economizers shall be provided on each cooling system and shall be capable of operating at 100 percent outside air, even if additional mechanical cooling is required to meet the cooling load of the building.

Exceptions:

1. Systems utilizing water economizers that are capable of cooling supply air by direct or indirect evaporation or both and providing 100 percent of the expected system cooling load at outside air temperatures of 50°F (10°C) dry bulb/45°F (7°C) wet bulb and below.
2. Cooling equipment less than 54,000 Btu/h (15 827 W) total cooling capacity. The total capacity of all such units without economizers shall not exceed 240,000 Btu/h (70 342 W) per building area served by one utility meter or service, or 10 percent of its total installed cooling capacity, whichever is greater. That portion of the equipment serving dwelling units and guest rooms is not included in determining the total capacity of units without economizers.
3. Ground-coupled heat pumps with cooling capacity of 54,000 Btu/h (15 827 W) or less.
4. Systems where internal/external zone heat recovery is used.
5. Systems used to cool any dedicated computer server room, electronic equipment room or telecom switch room having an economizer system capable of cooling air by direct and/or indirect evaporation and providing 100 percent of the expected systems cooling load at outside air temperatures of 45ºF (7°C) dry bulb and 40°F (8°C) wet bulb and below.
6. Economizer cooling is not required for new cooling systems serving an existing dedicated computer server room, electronic equipment room or telecom switch room in existing buildings up to a total of 600,000 Btu/h (175,800 W) of new cooling equipment.
7. Economizer cooling is not required for new cooling systems serving a new dedicated computer server room, electronic equipment room or telecom switch room in existing buildings up to a total of 240,000 Btu/h (70,300 W) of new cooling equipment.
8. Systems using condenser heat recovery, up to the cooling capacity used to provide condenser heat recovery.

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

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. Heat rejection equipment shall comply with this section.

1. If a closed-circuit cooling tower is used directly in the heat pump loop, either an automatic valve shall be installed to bypass all but a minimal flow of water around the tower, or lower leakage positive closure dampers shall be provided.
2. If an open-circuit tower is used directly in the heat pump loop, an automatic valve shall be installed to bypass all heat pump water flow around the tower.
3. If an open- or closed-circuit cooling tower is used in conjunction with a separate heat exchanger to isolate the cooling tower from the heat pump loop, then heat loss shall be controlled by shutting down the circulation pump on the cooling tower loop.

   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 an automatic two-position valve or be served by a dedicated pump with check valve for each heat pump.

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

1. Automatically reset the supply-water tempera-tures using zone-return water temperature, building-return water temperature, or outside air temperature as an indicator of building heating or cooling demand. The temperature shall be capable of being reset by at least 25 percent of the design supply-to-return water temperature difference; or
2. For pumping systems less than 5hp (4 kW) reduce system pump flow by at least 50 percent of design flow rate utilizing adjustable speed drive(s) on pump(s), or multiple-staged pumps where at least one-half of the total pump horsepower is capable of being automatically turned off and control valves designed to modulate or step down, and close, as a function of load, or other *approved* means.
3. For pumping systems greater than 5hp (4 kW) reduce system pump flow by at least 50 percent of design flow rate utilizing adjustable speed drive(s) on pump(s) and control valves designed to modulate or step down, and close, as a function of load, or other *approved* means.

Exception: Dedicated equipment circulation pumps designed to meet minimum flow requirements established by the manufacturer, such as boiler or chiller auxiliary circulation pumps.

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 Heating and cooling water pump control. Water circulation systems serving heating coil(s) or cooling coil(s) shall have controls that lock out pump operation when there is no demand. The pumps shall shut off based on the following outside air lock out temperatures: hot water pump whenever outside air temperature is 70°F (21°C) or higher, cooling water pump when outside air temperature is 55°F (13°C) or lower.

Exceptions:

1. Industrial process and humidity control process,
2. Hot water reheat for terminal units,
3. Hot water circulation systems used to provide multiple functions (e.g., space heating, service water heating - DHW) as an integrated system.
4. Pumps serving water side economizer functions, systems.

503.4.3.7 Tower flow turndown. Open cooling towers configured with multiple condenser water pumps shall be designed so that all cells can be run in parallel with a turndown flow that is the larger of (1) the flow produced by the smallest pump or (2) 50 percent of the design flow for the cell.

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(6) and 503.2.3(7).

503.4.5 Requirements for complex mechanical systems serving multiple zones. Sections 503.4.5.1 through 503.4.5.3 shall apply to complex mechanical systems serving multiple zones. Supply air systems serving multiple zones shall be VAV systems which, during periods of occupancy, are designed controlled to comply with all of the following:

1. Reduce primary air supply to each zone to one of the following when the zone temperature is in a 5°F (3°C) zone temperature dead band after cooling is no longer

required and before reheating, recooling or mixing takes place:

1.1 Twenty percent of the maximum supply air to each zone.

1.2 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.

1.3 The minimum ventilation requirements of Chapter 4 of the *Mechanical Code* unless increasing the volume to critical zones (zones with the highest ratio of outside air to total supply air) beyond the minimum ventilation requirements results in a decrease in overall outside air required by the HVAC system. An increase beyond minimum ventilation rates shall not be applied to more than 20 percent of the zones with reheat.

2. The volume of air that is reheated, recooled, or mixed in peak heating demand shall be less than 50 percent of the *zone* design peak supply rate.

3. Airflow between *dead band* and full heating or full cooling shall be modulated.

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 Chapter 4 of the *Mechanical Code*.

6. Zones or supply air systems with thermostatic and humidistatic controls capable of operating in sequence the supply of heating and cooling energy to the zone(s) and prevent 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 reduce the flow from one duct to a minimum before mixing of air from the other duct takes place.

503.4.5.3 Supply-air temperature reset controls. HVAC systems serving multiple zones, including dedicated outside air 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 35 percent of the difference between the design supply-air temperature and the design room air temperature. Controls that adjust the reset based on zone humidity control requirements are allowed. Zones which are expected to experience relatively constant loads, such as electronic equipment rooms or interior zones without reheat, shall be designed for the fully reset supply temperature.

Exceptions:

1. Systems that prevent reheating, recooling or mixing of heated and cooled supply air.

2. 75 percent of the energy for reheating is from site-recovered or site solar energy sources.

503.4.5.4 Heat recovery for reheat and service water heating. Where the total installed heat rejection capacity of water-cooled chillers exceeds 6,000,000 Btu/h (1 758 600 W) and the combined design reheat, dual duct heating, and service water heating load exceeds 1,000,000 Btu/h (293 100W), all the following shall apply:

1. Condenser heat recovery shall be installed for heating or preheating of service hot water, heating water for reheat, or dual-duct system heating.

2. Reheat coils and dual duct heating coils shall be hydronic; except VAV zones with design airflow less than 500 cfm (236 L/s) may have electric reheat.

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

3.1. 30 percent of the peak heat rejection load at design conditions; or

3.2. The preheating required to raise the peak service hot water draw to 85°F (29°C) plus 10 percent of the design reheat or dual-duct heating load.

Exception: Facilities that provide 25 percent of their combined design service water heating, reheat, and Dual Duct heating from site solar or site recovered energy, such as geothermal heat recovery or combined heat and power.

503.4.6 Limited use of air cooled chillers. Chilled water plants with more than 300 tons (304 814 kg) total capacity shall not have more than 100 tons (101 605 kg) provided by air-cooled chillers.

Exception: Air-cooled chillers with minimum efficiencies equal to or greater than approved water-cooled equipment.

SECTION 504
SERVICE WATER HEATING

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

504.2 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 120°F (49°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 120°F (49°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. For automatic-circulating hot water and externally heated (such as heat trace or impedance heating) systems, piping shall be insulated with 1 inch (25 mm) of insulation having a conductivity not exceeding 0.27 Btu per inch/h $ft^2 \times °F$ (1.53 W per 25 $mm/m^2 \times K$). The first 8 feet (2438 mm) of piping in noncirculating systems served by equipment without integral heat traps shall be insulated with 0.5 inch (12.7 mm) of material having a conductivity not exceeding 0.27 Btu per inch/h $\times$ $ft^2 \times °F$ (1.53 W per 25 $mm/m^2 \times K$).

504.6 Hot water system controls. Systems designed to maintain usage temperatures in hot water pipes, such as hot water recirculating systems or heat trace, shall be turned off automatically when the hot water system is not operational and shall have demand sensing controls (flow switch in cold water make-up pipe, return water aquastat temperature sensor) that turn off the system when there is no demand when the system is operational. A check valve or similar device shall be located between the circulator pump and the water heating equipment to prevent water from flowing backwards though the recirculation loop. Gravity or thermosyphon circulation loops are prohibited.

Exceptions:

1. Where public health standards require 24 hours per day operation of pumps for uses such as swimming pools, spas and hospitals.
2. Service water heating systems used to provide multiple functions (e.g., space heating and DHW) as part of an integrated system.
3. Where coupled with water heating capacity less than 100,000 Btu/h (29 kW).

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

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

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

Exceptions:

1. Where public health standards require 24-hour pump operation.

Swimming pools and spas are regulated by the Oregon Health Authority per OAR 333-062. In the event of conflict with this code, OAR 333-062 shall prevail.

2. Where pumps are required to operate solar-and waste-heat-recovery heating systems.

504.7.3 Covers. Heated pools, spas and hottubs shall be equipped with a vapor retardant cover on or at the water surface. Pools, spas and hottubs heated to more than 90°F (32°C) shall have a cover with a minimum insulation value of R-12.

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

504.7.4 Heat recovery. Heated indoor swimming pools, spas, or hot tubs with water surface area greater than 200 square feet (19 m^2) shall provide heat recovery utilizing either:

1. Compressorized dehumidification system with integral reheat and:
   a. Condensor heat recover for water heating of pool and/or service hot water, or
   b. Exhaust air heat recovery that recovers 50 percent of the total energy from the pool enclosure exhaust air stream at design heating conditions.
2. Air-to-air exchange system with variable outdoor air/exhaust and variable heat exchanger bypass, set to maintain maximum space relative humidity of 60 percent. At 50ºF dry bulb and 80-percent relative humidity outdoor conditions, the heat exchanger shall increase the total energy of the incoming outdoor air by 60 percent or shall increase the sensible energy of the outdoor air by 70 percent.

Exception: Pools, spas, or hot tubs that include system(s) that provide equivalent recovered energy on an annual basis through one of the following methods:

1. Heated by renewable energy,
2. Waste heat recovery, or
3. A combination of these system(s) sources capable of providing at least 70 percent of the heating energy required over an operating season.

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	≤ 12 kW[d]	Resistance	0.97 - 0.00132*V*, EF	DOE 10 CFR Part 430
	> 12 kW	Resistance	$(0.3 \div 27/V_m)$, %h	ANSI Z21.10.3
	≤ 24 amps and ≤ 250 volts	Heat pump	0.93 - 0.00 132*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	$80\% E_t$ $\left(Q / 800 + 110\sqrt{V}\right)$ 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	—	$82\% E_t$	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 equations for electric water heaters, V is the rated volume in gallons and V_m is the measured volume 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 shall comply with these requirements if the water heater is designed to heat water to temperatures 180°F or higher.

d. Electric water heaters with an input rating of 12kW or less that are designed to heat water to temperatures of 180°F or greater shall comply with the requirements for electric water heaters that have an input rating greater than 12kW.

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: Lighting within dwelling units where 50 percent or more of the permanently installed interior light fixtures are fitted with high-efficacy lamps.

505.2 Interior 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 Lighting controls. At least one local shutoff lighting control shall be provided for every 2,000 square feet (185.8 m^2) of lit floor area and each area enclosed by walls or floor-to-ceiling partitions. 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. Lighting systems serving areas designated as security or emergency areas that must be continuously lighted.
2. Lighting in public areas such as concourses, stairways or corridors that are elements of the means of egress with switches that are accessible only to authorized personnel.
3. Lighting for warehouses, parking garages or spaces using less than 0.5 watts per square foot (5.4 W/m^2).
4. Lighting for contiguous, single-tenant retail spaces.

505.2.1.1 Egress lighting. Egress illumination shall be controlled by a combination of listed emergency relay and occupancy sensors to shut off during periods that the building space served by the means of egress is unoccupied.

Exception: Building exits as defined in Section 1002 of the *Building Code*.

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 (dimming or multilevel switching);
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).
6. Electrical and mechanical rooms.

505.2.2.2 Automatic lighting shutoff. Buildings larger than 2,000 square feet (186 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 10,000 square feet (929 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.

Occupancy sensors in rooms that include daylight zones are required to have Manual ON activation,

An occupant sensor control device shall be installed that automatically turns lighting off within 30 minutes of all occupants leaving a space, except spaces with multi-scene control, in:

1. Classrooms and lecture halls.
2. Conference, meeting and training rooms.
3. Employee lunch and break rooms.
4. Rooms used for document copying and printing.
5. Office spaces up to 300 square feet (29 m^2).
6. Restrooms.
7. Dressing, fitting and locker rooms.

An occupant sensor control device that automatically turns lighting off within 30 minutes of all occupants leaving a space or a locally activated switch that automatically turns lighting off within 30 minutes of being activated shall be installed in all storage and supply rooms up to 1000 square feet (93 m^2).

Exception: The following shall not require an auto matic 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 2,000 square feet (185.8 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.

Exceptions:

1. Retail stores and associated malls, restaurants, grocery stores, places of religious worship, theaters and exterior lighting zones.
2. Single zone electronic time control devices and self-contained wall box preset lighting controls.

505.2.2.3 Daylight zone control. All daylight zones, as defined by this code, shall be provided with individual controls that control the lights independent of general area lighting in the nondaylight zone. In all individual daylight zones larger than 350 square feet (33 m^2), automatic daylight controls shall be provided.

Automatic daylight sensing controls shall reduce the light output of the controlled luminaires within the daylighted area by at least 50 percent, and provide an automatic OFF control, while maintaining a uniform level of illumination.

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 shall be controlled separately from daylight zones adjacent to vertical fenestration.

Exceptions:

1. Retail spaces adjacent to vertical glazing (retail spaces under overhead glazing are not exempt).
2. Display, exhibition and specialty lighting.
3. HID lamps 150 watts or less.
4. Spaces required to have occupancy sensors.

505.2.3 Sleeping unit controls. *Sleeping units* 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). Bathrooms shall have a control device installed to automatically turn off the bathroom lighting, except for night lighting not exceeding 5 watts, within 60 minutes of the occupant leaving the space.

505.2.4 Reserved.

505.3 Reserved.

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 intesrior lighting power calculated under Section 505.5.2 or 505.5.2.1.

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. *Sleeping unit* lighting in hotels, motels, boarding houses or similar buildings.
   1.2. Emergency lighting automatically off during normal building operation.
   1.3. 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.
   1.4. Lighting in interior spaces that have been specifically designated as a registered interior historic landmark.
   1.5 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 integral to both open and glass-enclosed refrigerator and freezer cases.
12. Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions.
13. 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 50W/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 method. The total interior lighting power (watts) is the sum of all interior lighting powers for all areas in the building covered in this permit. The interior lighting power is the floor area for each building area type listed in Table 505.5.2(a) times the value from Table 505.5.2(a) 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(a). 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.

505.5.2.1 Space-by-space method. The total interior connected lighting power shall not exceed the maximum power allowance calculated by multiplying the lighting power density from Table 505.5.2(b) for each space by the floor area of that space. Parking garages and exterior canopies shall be treated separately from the building for the purposes of calculating interior connected lighting power.

TABLE 505.5.2(a)
INTERIOR LIGHTING POWER ALLOWANCES

LIGHTING POWER DENSITY	
Building Area Type	**(W/ft^2)**
Automotive Facility	0.79
Convention Center	1.08
Court House	1.05
Dining: Bar Lounge/Leisure	0.99
Dining: Cafeteria/Fast Food	0.90
Dining: Family	0.89
Dormitory	1.0
Exercise Center	0.88
Gymnasium	1.00
Healthcare—clinic	0.89
Hospital	1.08
Hotel	1.0
Library	1.17
Manufacturing Facility/Data Center	1.24
Motel	1.0
Motion Picture Theater	0.83
Multifamily	0.58
Museum	1.04
Office	0.91
Parking Garage	0.25
Penitentiary	1.0
Performing Arts Theater	1.39
Police	0.89
Fire Station	0.74
Post Office	0.98
Religious Building	1.05
Retail	1.32
School/University	1.01
Sports Arena	0.78
Town Hall	0.94
Transportation	0.77
Warehouse	0.66
Workshop	1.2

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

TABLE 505.5.2(b)
SPACE-BY-SPACE METHOD MAXIMUM ALLOWABLE LIGHTING POWER DENSITY (LPD)

COMMON SPACE TYPES	LPD (W/ft²)[1]
Office-enclosed[2]	0.97
Office-open plan[2]	0.93
Conference/Meeting/Multipurpose[3]	1.11
Classroom/Lecture/Training	1.23
Lobby	0.90
For Hotel	1.10
For Performing Arts Theater	2.00
For Motion Picture Theater	0.52
Audience/Seating Area	0.79
For Gymnasium	0.40
For Exercise Center	0.40
For Convention Center	0.70
For Religious Buildings	1.53
For Sports Complex	0.40
For Performing Arts Theater	2.43
For Motion Picture Theater	1.11
For Transportation	0.46
Atrium-first three floors	0.60
Atrium-each additional floors	0.16
Lounge/Recreation	0.73
For Hospital	0.71
Dining Area[2]	—
For Hotel/Motel	0.82
For Bar Lounge/Leisure Dining	1.31
For Family Dining	0.89
Food Preparation	0.99
Laboratory	1.40
Restrooms	0.82
Dressing/Locker Room	0.52
Corridor/Transition	0.41
For Hospital	0.94
For Manufacturing Facility	0.41
Stairs-active	0.49
Active Storage	0.63
For Hospitals	0.79
Inactive Storage	0.26
For Museum	0.66
Electrical/Mechanical/Data Center	0.95
Workshop[4]	1.64
BUILDING SPECIFIC SPACE TYPES	
Courthouse/Police Station	—
Courtroom	1.72
Judges Chambers	1.17
Gymnasium/Exercise Center	—
Playing Area	1.20
Exercise Area	0.72
Fire Stations	—
Fire Station Engine Room	0.64

(continued)

TABLE 505.5.2(b)—continued
SPACE-BY-SPACE METHOD MAXIMUM ALLOWABLE LIGHTING POWER DENSITY (LPD)

Sleeping Quarters	0.27
Post Office - Sorting Area	1.01
Convention Center - Exhibit Space[3]	1.09
Library[2]	—
Card File and Cataloging	0.96
Stacks	1.47
Reading Area	1.07
Hospital	—
Emergency	2.34
Recovery	0.74
Nurse Station	0.85
Exam/Treatment Room	1.26
Pharmacy	0.99
Patient Room	0.59
Operating Room	1.92
Nursery	0.48
Medical Supply	1.23
Physical Therapy	0.80
Radiology	0.35
Laundry-Washing	0.52
Automotive - Service/Repair	0.63
Museum	—
General Exhibition	1.00
Restoration	1.58
Bank/Office - Banking Activity Area	1.31
Religious Buildings	—
Worship-pulpit, choir	1.53
Fellowship Hall	0.64
Retail	1.50
Mall Concourse	1.10
Fitting Room	1.06
Sports Arena Complex	—
Ring Sports Area	2.70
Court Sports Area	2.00
Indoor Playing Field Area	1.35
Warehouse	—
Fine Material Storage	0.95
Medium/Bulky Material Storage	0.58
Parking Garage - Garage Area	0.19
Transportation	—
Airport - Concourse	0.36
Air/Train/Bus - Baggage Area	0.76
Terminal - Ticket Counter	1.08

For SI: 1 foot = 304.8 mm, 1 square foot = 0.929 m^2, $W/m^2 = W/ft^2 \times 10.764$.

1. The watts per square foot may be increased by 2 percent per foot of ceiling height above 20 feet unless specified differently by another footnote.
2. The watts per square foot of room may be increased by 2 percent per foot of ceiling height above 9 feet.
3. Hotel banquet room, conference rooms, or exhibit hall watt per square foot of room may be increased by 2 percent per foot of ceiling height above 12 feet.
4. Spaces used specifically for manufacturing are exempt.

505.5.2.1.1 Additional lighting power for retail displays. For lighting equipment installed in retail sales area that is specifically designed and directed to highlight merchandise, one of the following may apply:

1. 0.6 watts per square foot of sales floor area not listed in 2 or 3 below; or
2. 1.4 watts per square foot of furniture, clothing, cosmetics or artwork floor area; or
3. 2.5 watts per square foot of jewelry, crystal; or china floor area.

The specified floor area for 1, 2, and 3 above, and the adjoining circulation paths shall be identified and specified on building plans. Calculate the additional power allowance by multiplying the above LPDs by the sales floor area for each department excluding major circulation paths. The total additional lighting power allowance is the sum of allowances sales categories, 1, 2, or 3. This additional lighting power shall only be used for retail display lighting in the applicable space, and shall not be used to increase lighting power allowance with other spaces or general lighting system within the space and shall be controlled separately from the space general lighting system.

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. No incandescent or mercury vapor lighting sources shall be used for exterior building lighting.

Exceptions:

1. Incandescent lighting used in or around swimming pools, water features, or other locations subject to the requirements of Article 680 of the *Electrical Code*.
2. Incandescent luminaires controlled by motion sensors with total power less than 150 watts.

505.6.2 Exterior building lighting power. The total exte-rior 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.

505.6.3 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 retain programming and the time setting during loss of power for a period of at least 10 hours. Lighting designated to operate more than 2000 hours per year for uncovered parking areas shall be equipped with motion sensors that will reduce the luminaire power by 33 percent or turn off one-third the luminaires when no activity is detected.

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.

SECTION 506
WHOLE BUILDING APPROACH

506.1 Whole Building Approach (WBA). Applicants shall demonstrate that the whole building annual energy consumption will not exceed that used by a similar building using similar forms of energy design in accordance with the prescriptive requirements of this code. Compliance under this section allows tradeoffs between building components using an 8,760 - hour annual building simulation. Information and criteria for demonstrating compliance using the WBA is available at http://www.bcd.oregon.gov.

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 not classified as lighting zone 1, 2 or 4.
4	High-activity commercial districts in major metropolitan areas as designated by the local land use planning authority

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) and food service	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 and roof paths[a]	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.

a. Roof lighting: larger of either total roof area or total access/maintenance walkway path length.

SECTION 507
OTHER EQUIPMENT

507.1 Distribution transformers.

507.1.1 Energy efficiency. All distribution transformers shall meet the minimum efficiency levels specified in Tables 507.1 and 507.2. All other terms and provisions of National Electrical Manufacturers Association (NEMA) Standard TP 1-1996, *Guide for Determining Energy Efficiency for Distribution Transformers*, shall apply to distribution transformers. These requirements shall apply to transformers within the scope of TP 1-1996.

Exceptions:

1. Liquid-filled transformers below 10 kVA.
2. Dry-type transformers below 15 kVA.
3. Drive transformers designed only to operate electronic variable speed AC and DC drives.
4. Rectifier transformers designed only to power rectifier circuits that have nameplate ratings for fundamental frequency and RMS.
5. High harmonic transformers with a *K*-rating of K-4 or greater that are designed to supply loads with higher than normal harmonic current levels. A licensed engineer shall submit verification of need for harmonic current control.
6. Autotransformers in which the primary and secondary windings are not electrically isolated, and in which secondary voltage is derived from at least a portion of the primary winding as specified by a licensed engineer.
7. Nondistribution transformers, such as those designed as an integral part of an uninterruptible power system (UPS).
8. Transformers with special impedance outside the following ranges: 1.5 percent to 7.0 percent for 15 kVA - 150 kVA units, 3.0 percent to 8.0 percent for 167 kVA - 500 kVA units, and 5.0 percent to 8.0 percent for 667 kVA -2500 kVA units.
9. Voltage regulating transformers with load tap changing gear.
10. Sealed transformers that are designed to remain hermetically sealed and nonventilated transformers designed to prevent airflow through the transformer.
11. Replacement of an existing transformer where a qualified TP-1 transformer will not fit in the space provided.
12. Transformers feeding circuits dedicated to machine tools and/or welders.
13. Transformers with tap ranges greater than 15 percent or with frequencies other than 50 to 60 Hz.
14. Grounding transformers that only provide a system ground reference point, or testing transformers that are part of, or supply power to electrical test equipment.

TABLE 507.1
NEMA CLASS 1 EFFICIENCY LEVELS FOR LIQUID-FILLED DISTRIBUTION TRANSFORMERS[1]

SINGLE PHASE		THREE PHASE	
kVa	**Efficiency**	**kVa**	**Efficiency**
10	98.3%	15	98.0%
15	98.5%	30	98.3%
25	98.7%	45	98.5%
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%	1,000	99.2%
667	99.4%	1,500	99.3%
833	99.4%	2,000	99.4%
		2,500	99.4%

1. Efficiency is calculated per conditions stated in NEMA Standard TP 1-1996.

507.1.2 Testing. All distribution transformers shall be tested in accordance with National Electrical Manufacturers Association (NEMA) TP 2-1998, *Standard Test Method for measuring the Energy Consumption of Distribution Transformers*.

507.1.3 Labeling. All distribution transformers shall be labeled in accordance with National Electrical Manufacturers Association (NEMA) TP 3-2000, *Standard for the Labeling of Distribution Transformer Efficiency.*

507.1.4 Alterations. Replacement of existing equipment shall meet the requirements of this section.

TABLE 507.2
NEMA CLASS 1 EFFICIENCY LEVELS FOR DRY-TYPE DISTRIBUTION TRANSFORMERS[1]

SINGLE PHASE EFFICIENCY			THREE PHASE EFFICIENCY		
kVa	**Low Voltage**	**Medium Voltage**	**kVa**	**Low Voltage**	**Medium Voltage**
15	97.7%	97.6%	15	97.0%	96.8%
25	98.0%	97.9%	30	97.5%	97.3%
37.5	98.2%	98.1%	45	97.7%	97.6%
50	98.3%	98.2%	75	98.0%	97.9%
75	98.5%	98.4%	112.5	98.2%	98.1%
100	98.6%	98.5%	150	98.3%	98.2%
167	98.7%	98.7%	225	98.5%	98.4%
250	98.8%	98.8%	300	98.6%	98.5%
333	98.9%	98.9%	500	98.7%	98.7%
500	—	99.0%	750	98.8%	98.8%
667	—	99.0%	1,000	98.9%	98.9%
833	—	99.1%	1,500	—	99.0%
			2,000	—	99.0%
			2,500	—	99.1%

1. Efficiency is calculated per conditions stated in NEMA Standard TP 1-1996.