CHAPTER 4 [CE]

COMMERCIAL ENERGY EFFICIENCY

SECTION C401
GENERAL

C401.1 Scope. The provisions in this chapter are applicable to *commercial buildings* and their *building sites.*

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

1. **Prescriptive Path.** The requirements of all of Chapter 4, other than Sections C401.3 and C407. ((~~Sections C402, C403, C404, C405, C406, C408, C409, and C410, C411 and C412.~~))
2. **Total Building Performance Path.** The requirements of Section C407 as well as ((~~Section~~)) Sections C402.5, C403.2, C404, C405.2, C405.3, ((~~C405.4~~)) C405.5, C405.6, ((~~and~~)) C405.7, C405.8, C405.9, C405.10, C405.13, C408, C409, C410, and C412. The building energy consumption shall be equal to or less than 87, 90 or 93 percent of the standard reference design building, depending on the option selected per Section C407.3.
3. **Target Performance Path.** The requirements of C401.3.

C401.2.1 Application to existing buildings. Work on existing buildings shall comply with Chapter 5, in addition to the applicable provisions of Chapter 4.

C401.3 Target Performance Path.

C401.3.1 Scope. Buildings of the following occupancy types are permitted to conform to the Target Performance Path and are not required to comply with Seattle Energy Code requirements other than the *mandatory* measures listed in Section C401.3.3.

1. Group B office
2. Group B medical office
3. Group R-2 multi-family over three stories
4. Group S-1 & S-2 warehouse (non-refrigerated)
5. Group E school
6. Group M retail
7. Group I-2 hospital
8. Other occupancy type, where specific permission is granted by the *code official*. Any such permission, if granted, shall be made either on the basis of an energy use target *approved* by the *code official* for that occupancy based on the best-performing local examples of that occupancy, or by provision of a metering system that segregates and separately reports the energy loads for the additional occupancy from those of the occupancies listed in 1 – 7 above.
9. Mixed use: A mixed use building is any building containing more than one of the occupancies listed in 1 – 8 above.

C401.3.2 Energy use targets. Buildings, including their initial tenant improvements, using the Target Performance Path shall be designed to use less energy than the weighted sum of the following energy use targets, as demonstrated by *approved* energy modeling. Energy use targets are expressed in terms of thousand BTU per square foot of *conditioned floor area* per year (kBTU/ft^2/yr).

1. Group B office: 40 kBTU/ ft^2/yr
2. Group B medical office: 50 kBTU/ ft^2/yr
3. Group R-2 multi-family: 35 kBTU/ ft^2/yr
4. Group S-1 & S-2 warehouse: 25 kBTU/ ft^2/yr
5. Group E school: 45 kBTU/ ft^2/yr
6. Group M retail: 60 kBTU/ ft^2/yr
7. Group I-2 hospital: 150 kBTU/ ft^2/yr
8. Parking garages, including unconditioned and *conditioned spaces*, within the above occupancies shall be calculated separately at: 10 kBTU/ ft^2/yr for enclosed garages and 6 kBTU/ ft^2/yr for open garages.

C401.3.2.1 Data Center Energy. Anticipated total data center energy use is permitted to be added to the overall building energy usage target in accordance with this section. The anticipated *IT energy* usage shall be multiplied by a factor of 1.45 to determine the anticipated total data center energy use. The *IT energy* usage shall be separately sub-metered in a secure manner *approved* by the *code official* and automatically exported to the *code official* showing daily, monthly and annual totals during the operational energy use demonstration period set forth in Section C401.3.6. Actual *IT energy* shall be adjusted in accordance with Section C401.3.7.

C401.3.3 *Mandatory* Measures. Buildings using the Target Performance Path shall:

1. Meet their assigned building energy use targets;
2. Have an area-weighted average U-value less than 0.40 for all *fenestration*; and
3. Comply with the following portions of the Seattle Energy Code. Each of the code chapters and sections listed below includes all of its sub-sections.
   - 3.1. Chapters 1, 2 and 3 (Scope and Administration, Definitions, and General Requirements) of the Seattle Energy Code, commercial section
   - 3.2. C402.5 Air Leakage
   - 3.3. C403.2.4 HVAC System Controls

3.4. C404.9 Domestic hot water meters

3.5. C408 System Commissioning

3.6. C409 Energy Metering and Energy Consumption Management

3.7. C410 Refrigeration System Requirements

3.8. C412 Solar Readiness

C401.3.4 Energy Modeling Methodology. Energy use shall be modeled according to the following procedures from Section C407, Total Building Performance:

1. C407.1 Scope
2. C407.4 Documentation (requirements for "Standard Reference Design" are not applicable)
3. C407.5.2 Thermal Blocks
4. C407.6 Calculation Software Tools

Schedules, internal loads and other assumptions related to the operation of the building are permitted to be developed at the discretion of the design team and the energy modeler. For occupancy types listed in Appendix B of this code, where any of the following operating loads or schedules of operating hours used in modeling calculations is less than 80 percent of that listed in Appendix B, or where the occupant density in square feet per occupant is more than 120 percent of that listed in Appendix B, such deviations shall be clearly documented in the final analysis report and are subject to approval by the *code official*.

1. Occupant density and schedule
2. Lighting operation schedule
3. Receptacle loads and schedule
4. Elevator and escalator schedule
5. Water heating quantity and schedule

In addition to documenting modeling assumptions, the compliance report required by Section C407.4.1 shall include the following:

1. Summary of principal building characteristics that are above or below prescriptive energy code requirements.
2. Sensitivity analysis of principal internal load and other building operational assumptions that demonstrate a range of expected energy performance in the context of typical meteorological year (TMY) conditions. The following sensitivity analyses shall be reported, in tabular format:
   - 2.1. Occupant density +/- 20 percent (except residential occupancies)
   - 2.2. Lighting Power Density +/- 20 percent
   - 2.3. Miscellaneous Load Power Density +/- 20 percent
   - 2.4. Infiltration Rates +/- 20 percent
   - 2.5. Temperature Setpoints +/- 2 degrees F

Table C401.3.4
Example of Sensitivity Analysis Report Format

Allowable EUI: 45 kBTU/ft^2		
Predicted EUI: 40 kBTU/ft^2		
Input	EUI (Low Range)	EUI (High Range)
Occupant Density	35	42
Lighting Power Density	38	41
Misc. Load Power Density	35	45
Infiltration	38	44
Temperature Setpoints	36	48

The annual modeled building site energy use, under nominal conditions, shall be lower than the building's assigned energy performance target.

C401.3.5 Energy Modeler Qualifications. Energy models shall be created only by persons qualified by education and training to perform such work and who have at least two years' experience modeling buildings of similar scale and complexity. The modeling documentation submitted shall be signed either by a licensed professional engineer who is qualified by training and experience to perform energy modeling or by an individual with an active certification from ASHRAE as a Building Energy Modeling Professional (BEMP).

C401.3.6 Demonstration of Operating Energy Use. Metered energy data shall be supplied directly via automated reporting from utilities to the *code official* using Portfolio Manager, and adjusted for the percentage of floor area occupied. While at least 75 percent occupied, the building shall operate at or below its assigned energy use target established in Section C401.3.2 or item 8 of Section C401.3.1 for any recording period of 12 consecutive months that is completed within three years of the date of the Certificate of Occupancy, as adjusted under this Section C401.3. The owner shall notify the *code official* when this 12-month period has been successfully completed.

C401.3.6.1 Extension of Demonstration Period. For good cause, including conditions where less than 75 percent of the building is occupied, the *code official* may extend the three-year period for one additional year, but in no case for more than three additional one-year periods. If the building is not at least 75 percent occupied after three additional one-year periods, the *code official* shall evaluate compliance with Section C401.3.6 based on the most recent one-year period and adjusted for the actual occupancy rate during that period.

C401.3.7 Adjustment for Data Center Energy Usage. Where data center *IT energy* usage during the demonstration period, multiplied by a factor of 1.45, is higher than the total data center energy use as calculated according to Section C401.3.2.1, that additional energy shall be added to the total allowable energy use. Where data center *IT energy* use, multiplied by a factor of 1.45, is lower than the total data center energy use as calculated according to Sec-

tion C401.3.2.1, that shortfall shall be subtracted from the total allowable energy use.

C401.3.8 Adjustment for Change in Occupancy. When the occupancy of the building or a portion of the building changes from that assumed in the permit submittal, the assigned energy performance target shall be adjusted to reflect the new occupancy. If the new occupancy is not listed in Section C401.3.2, either the *code official* shall assign it an energy use target based on the best-performing local examples of that occupancy type, or a metering system shall be provided that excludes the energy loads for the additional occupancy.

C401.3.9 Adjustment for Unusually Cold Years. If the heating degree days (HDD) recorded by the National Weather Service for the Seattle-Tacoma International Airport exceeds 4885 HDD for the 12-month demonstration period (4 percent above the average 4697 HDD at 65° F base), the assigned energy performance target is permitted to be increased by 1 percent for that period.

C401.3.10 Adjustment for Retail Operating Hours. If the annual number of hours that a retail occupancy is open to the public during the 12-month recording period exceeds the hours assumed in the energy model by more than 4 percent, the annual energy use target for the retail space use only is permitted to be increased by 1 percent for each 4 percent increase in such hours. This claim shall be documented by publicly-available published hours of operation.

C401.3.11 Financial Security. The applicant shall provide a financial security to be used as a penalty for failing to achieve an operating energy use lower than the building's energy use target according to Section C401.3.6. The penalty shall be administered as provided in Section C110, except that the amount of the penalty shall be determined using Table C401.3.12 and not Section C107. The financial security shall be submitted to and *approved* by the *code official* prior to issuance of the building's Certificate of Occupancy. The financial security requirement shall be fulfilled by one of the following methods:

1. An irrevocable letter of credit from a financial institution authorized to do business in Seattle, in an amount equal to $4.00 per square foot of gross floor area.
2. A bond secured by the applicant to ensure compliance with this section, in an amount equal to $4.00 per square foot of gross floor area.
3. A binding pledge that within 3 years of receipt of the Certificate of Occupancy, adjusted as allowed under Section C401.3.6.1, the applicant will comply with the requirements of this section.
   3.1 A binding pledge pursuant to item 3 of this subsection shall be recorded as a covenant in the land records of King County between the applicant and the City of Seattle in a form that is satisfactory to the Seattle City Attorney. The covenant shall bind the applicant and any successors in title to pay any fines levied pursuant to this section. A lien will be placed on the property in cases of non-payment.

If the owner provides evidence that the building has operated at or below its target energy performance level as provided in Section C401.3.6, the financial security provided by the applicant shall be returned to the applicant, or the pledge and covenant shall be released, and the applicant will have no further obligations under this section.

C401.3.12 Procedure for non-compliance. If the owner fails to provide evidence that the building has operated as required under Section C401.3.6, the *code official* shall, as applicable, either:

1. Draw down on a financial security provided in the form of an irrevocable letter of credit or a bond, in whole, or in part, or
2. Levy a fine against an applicant that provided a financial security in the form of a binding pledge as set forth in Section C401.3.11(3). The fine shall be issued as a civil penalty.

The amount of the fine levied or the amount drawn down from a financial security shall be determined according to Table C401.3.12.

C401.3.13 Reimbursements. Where a financial security has been drawn down pursuant to item 1 in Section C401.3.12, or a fine has been levied pursuant to item 2 in Section C401.3.12, the *code official* shall reimburse the owner for documented expenses incurred to lower the operating energy use of the building, including commissioning, repairs or improvements to the existing energy-consuming systems, or provision of additional energy efficiency measures, up to the maximum reimbursement amounts listed in Table C401.3.12. Such expenditures shall be *approved* in advance by the *code official*, and the work shall be fully completed within one year of the date when a financial security has been drawn down pursuant to item 1 in Section C401.3.12, or a fine has been levied pursuant to item 2 in Section C401.3.12.

Table C401.3.12
Financial Security and Energy Efficiency Reimbursements

Energy use exceeding target	Amount of fine or draw-down from financial security, per square foot	Maximum reimbursement per square foot for work *approved* under Section C401.3.12
Less than 10%	$1.00	$0.50
10% to less than 20%	$2.00	$1.00
20% to less than 30%	$3.00	$1.50
30% or greater	$4.00	$2.00

SECTION C402
BUILDING ENVELOPE REQUIREMENTS

C402.1 General (*Prescriptive*). *Building thermal envelope* assemblies for buildings that are intended to comply with the code on a prescriptive basis, in accordance with the compliance path described in Item 2 of Section C401.2, shall comply with the following:

1. The opaque portions of the *building thermal envelope* shall comply with the specific insulation requirements of Section C402.2 and the thermal requirements of either the *R*-value-based method of Section C402.1.3; the *U*-, *C*- and *F*-factor-based method of Section C402.1.4; or the component performance alternative of Section C402.1.5.
2. Fenestration in building envelope assemblies shall comply with Section C402.4.
3. Air leakage of building envelope assemblies shall comply with Section C402.5.

SDCI Informative Note: For the application of the building envelope requirements to elevator shafts and stair enclosures, see the definition of *conditioned space* in Chapter 2 and the exception to Section C402.1.3.

C402.1.1 Low-energy buildings. The following low-energy buildings, or portions thereof separated from the remainder of the building by *building thermal envelope* assemblies complying with this section, shall be exempt from the *building thermal envelope* provisions of Section C402.

1. Those with a peak design rate of energy usage less than 3.4 Btu/h · ft^2 (10.7 W/m^2) or 1.0 watt per square foot (10.7 W/m^2) of floor area for space conditioning purposes.
2. Those that do not contain *conditioned space*.
3. *Greenhouses* where cooling does not include a *condensing unit* and that are isolated from any other *conditioned space*.
4. Unstaffed equipment shelters or cabinets used solely for personal wireless service facilities.

C402.1.1.1 Semi-heated spaces. The building envelope of *semi-heated* buildings, or portions thereof, shall comply with the same requirements as that for *conditioned spaces* in Section C402, except as modified by this section. Building envelope assemblies separating *conditioned space* from *semi-heated space* shall comply with the exterior envelope insulation requirements. *Semi-heated spaces* heated by mechanical systems that do not include electric resistance heating equipment are not required to comply with the opaque wall insulation provisions of Section C402.2.3 for walls that separate *semi-heated spaces* from the exterior or low energy spaces. *Fenestration* shall comply with *building thermal envelope* requirements. *Semi-heated spaces* shall be calculated separately from other *conditioned spaces* for compliance purposes. Opaque walls in *semi-heated spaces* shall be calculated as fully code compliant opaque walls for both the target and proposed for the Target UA calculations for the component performance alternative in Section C402.1.5, and for the Standard Reference Design for Total Building Performance compliance per Section C407.

SDCI Informative Note: There is no separate "freeze protection" space conditioning category for unoccupied utility buildings. Spaces with no cooling and less than 3.4 BTU/h-ft^2 heating capacity are not required to be insulated. The opaque walls of spaces that meet the definition of "semi-heated" in Chapter 2 are not required to be insulated, but otherwise the thermal envelope of semiheated spaces must meet all requirements for *conditioned space*. Spaces with any mechanical cooling or with more than 8 BTU/h-ft^2 heating capacity must meet all the *building thermal envelope* requirements for *conditioned space*.

C402.1.2 Equipment buildings. Buildings that comply with the following shall be exempt from the *building thermal envelope* provisions of this code:

1. Are separate buildings with floor area no more than 500 square feet (50 m^2).
2. Are intended to house electronic equipment with installed equipment power totaling at least 7 watts per square foot (75 W/m^2) and not intended for human occupancy.
3. Have a heating system capacity not greater than 17,000 Btu/hr (5 kW) and a heating thermostat set point that is restricted to not more than 50°F (10°C).
4. Have an average wall and roof *U*-factor less than 0.200.

C402.1.3 Insulation component *R*-value method. *Building thermal envelope* opaque assemblies shall meet the requirements of Section C402.2 based on the climate zone specified in Chapter 3. For opaque portions of the *building thermal envelope* intended to comply on an insulation component *R-value* basis, the *R-values* for insulation in framing areas, where required, and for *continuous insulation*, where required, shall not be less than that specified in Table C402.1.3. *Commercial buildings* or portions of *commercial buildings* enclosing Group R occupancies shall use the *R*-values from the "Group R" column of Table C402.1.3. *Commercial buildings* or portions of *commercial buildings* enclosing occupancies other than Group R shall use the *R*-values from the "All other" column of Table C402.1.3. The thermal resistance or *R*-value of the insulating material installed in, or continuously on, below grade exterior walls of the building envelope required in accordance with Table C402.1.3 shall extend to the lowest floor of the *conditioned space* enclosed by the below grade wall. Doors having less than 50 percent opaque glass area shall be considered *opaque doors*. Opaque swinging doors shall comply with the Table C402.1.4 and opaque non-swinging doors shall comply with Table C402.1.3 or C402.1.4.

Exception. For stair and elevator shafts located within enclosed garages or other enclosed non-*conditioned spaces* and without conditioned supply air or cooling or heating appliances rated higher than 2 kW in any shaft, walls enclosing the shafts are permitted to be:

1. Concrete or masonry with minimum R-5 *continuous insulation*;
2. Metal studs with R-15 cavity insulation and without *continuous insulation*; or
3. Other assemblies with a maximum U-value of 0.120.

Additionally, slab floors, intermediate mass floor edges and elevator pits within shafts using this exception are excluded from envelope insulation requirements. Surfaces using this exception shall not be included in the gross exterior wall area for purposes of maximum *fenestration area* calculations in Section C402.4.1, component performance calculations in Section C402.1.5, or for total building performance calculation of Section C407.

TABLE C402.1.3
OPAQUE THERMAL ENVELOPE INSULATION COMPONENT MINIMUM REQUIREMENTS, R-VALUE METHOD[a, g]

CLIMATE ZONE	5 AND MARINE 4	
	All Other	Group R
Roofs		
Insulation entirely above deck	R-38ci	R-38ci
Metal buildings[b]	R-25 + R-((~~11~~)) 22 LS	R-25 + R-((~~11~~)) 22 LS
Attic and other	R-49	R-49
Walls, Above Grade		
Mass	((~~R-9.5 c.i.~~[e])) Exterior: R-16 c.i. Interior: R-13 + R-6 ci wood stud, or R-13 + R-10 ci metal stud	((~~R-13.3~~)) Exterior: R-16 c.i. Interior: R-13 + R-6 ci wood stud, or R-13 + R-10 ci metal stud
Metal building	R-19 ci, or R-13 + R-13ci	R-19 ci, or R-13 + R-13ci
Steel framed	R-13 + R-10ci	R-19 + R-8.5ci
Wood framed and other	((~~R-21 int~~)) R-13 + R-7.5 ci	R-21 int
Walls, Below Grade		
Below-grade wall[d]	((~~Same as above grade~~)) Exterior: R-10 ci Interior: R-19 wood stud, or R-13 + R-6 ci metal stud	((~~Same as above grade~~)) Exterior: R-10 ci Interior: R-19 wood stud, or R-13 + R-6 ci metal stud
Floors		
Mass	R-30ci	R-30ci
Joist/framing	((~~R-30~~[e])) Steel frame: R-38 +R-4 ci Wood frame: R-38	((~~R-30~~[e])) Steel frame: R-38 +R-4 ci Wood frame: R-38
Slab-on-Grade Floors		
Unheated slabs	R-10 for 24" below	R-10 for 24" below
Heated slabs[d]	R-10 perimeter & under entire slab	R-10 perimeter & under entire slab
Opaque Doors		
Swinging	U-0.37	U-0.37
Nonswinging	U-0.34	U-0.34

Keys for Table C402.1.3

For SI: 1 inch = 25.4 mm.

ci = *Continuous insulation*.

NR = No requirement.

LS = *Liner system*—A continuous membrane installed below the purlins and uninterrupted by framing members. Uncompressed, unfaced insulation rests on top of the membrane between the purlins.

Footnotes for Table C402.1.3

a. Assembly descriptions can be found in Chapter 2 and Appendix A.

b. Where using *R*-value compliance method, a thermal spacer block with a minimum R-value of 3.5 shall be provided, otherwise use the *U*-factor compliance method in Table C402.1.2.

c. (Reserved) ((~~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 *building thermal envelope* encloses one or more of the following uses: Warehouse (storage and retail), gymnasium, auditorium, church chapel, arena, kennel, manufacturing plant, indoor swimming pool, pump station, water and waste water treatment facility, storage facility, storage area, motor vehicle service facility. Where additional uses not listed (such as office, retail, etc.) are contained within the building, the exterior walls that enclose these areas may not utilize this exception and must comply with the appropriate mass wall R-value from Table C402.1.3/U-factor from Table C402.1.4.~~))

d. Where heated slabs are below grade, ((~~*below-grade walls*~~)) they shall comply with the ((~~exterior~~)) insulation requirements for heated slabs.

e. (Reserved) ((~~Steel floor joist systems shall be insulated to R-38 + R-10ci.~~))

f. "Mass floors" shall include floors weighing not less than:

1. 35 pounds per square foot of floor surface area; or
2. 25 pounds per square foot of floor surface area where the material weight is not more than 120 pounds per cubic foot.

g. For roof, wall or floor assemblies where the proposed assembly would not be *continuous insulation*, ((~~an~~)) alternate nominal *R*-value compliance ((~~option~~)) options for assemblies with isolated metal ((~~penetrations of~~)) fasteners that penetrate otherwise *continuous insulation* ((~~is~~)) are as shown in Columns B and C of Table C402.1.3(g):

Table C402.1.3(g)
Continuous Insulation Equivalents

Column A Assemblies with *continuous insulation* (see definition)	Column B Alternate option for assemblies with metal penetrations, greater than 0.04% but less than 0.08%	Column C Alternate option for assemblies with metal penetrations, greater than or equal to 0.08% but less than 0.12%
R-9.5ci	R-11.9ci	R-13ci
R-11.4ci	R-14.3ci	R-15.7ci
R-13.3ci	R-16.6ci	R-18.3ci
R-15.2ci	R-19.0ci	R-21ci
R-30ci	R-38ci	R-42ci
R-38ci	R-48ci	R-53ci
R-13 + R-7.5ci	R-13 + R-9.4ci	R-13 + R-10.3ci
R-13 + R-10ci	R-13 + R-12.5ci	R-13 + R-13.8ci
R-13 + R-12.5ci	R-13 + R-15.6ci	R-13 + R-17.2ci
R-13 + R-13ci	R-13 + R-16.3ci	R-13 + R-17.9ci
R-19 + R-8.5ci	R-19 + R-10.6ci	R-19 + R-11.7ci
R-19 + R-14ci	R-19 + R-17.5ci	R-19 + R-19.2ci
R-19 + R-16ci	R-19 + R-20ci	R-19 + R-22ci
R-20 + R-3.8ci	R-20 + R-4.8ci	R-20 + R-5.3ci
R-21 + R-5ci	R-21 + R-6.3ci	R-21 + R-6.9ci

Footnotes for Table C402.1.3(g)

((~~This~~)) These alternate nominal R-value compliance ((~~option is~~)) options are allowed for projects complying with all of the following:

1. The ratio of the cross-sectional area, as measured in the plane of the surface, of metal penetrations of otherwise *continuous insulation* to the opaque surface area of the assembly is greater than 0.0004 (0.04%), but less than 0.0008 (0.08%), for use of Column B equivalents, and greater than or equal to 0.0008 (0.08%), but less than 0.0012 (0.12%), for use of Column C equivalents.
2. The metal penetrations of otherwise *continuous insulation* are isolated or discontinuous (e.g., brick ties or other discontinuous metal attachments, offset brackets supporting shelf angles that allow insulation to go between the shelf angle and the primary portions of the wall structure). No continuous metal elements (e.g., metal studs, z-girts, z-channels, shelf angles) penetrate the otherwise continuous portion of the insulation.
3. Building permit drawings shall contain details showing the locations and dimensions of all the metal penetrations (e.g., brick ties or other discontinuous metal attachments, offset brackets, etc.) of otherwise *continuous insulation*. In addition, calculations shall be provided showing the ratio of the cross-sectional area of metal penetrations of otherwise *continuous insulation* to the overall opaque wall area.

For other cases where the proposed assembly is not *continuous insulation*, see Section C402.1.4 for determination of U-factors for assemblies that include metal other than screws and nails.

C402.1.4 Assembly *U*-factor, *C*-factor or *F*-factor based method. *Building thermal envelope* assemblies intended to comply on an assembly *U*-, *C*-, or *F*-factor basis shall have a *U*-, *C*-, or *F*-factor not greater than that specified in Table C402.1.4. *Commercial buildings* or portions of *commercial buildings* enclosing Group R occu-

pancies shall use the *U*-, *C*-, or *F*-factor from the "Group R" column of Table C402.1.4. *Commercial buildings* or portions of *commercial buildings* enclosing occupancies other than Group R shall use the *U*-, *C*-, or *F*-factor from the "All Other" column of Table C402.1.4. The ((C)) U-factor for the below-grade exterior walls of the building envelope, as required in accordance with Table C402.1.4, shall extend to the level of the lowest conditioned floor. Opaque swinging doors shall comply with Table C402.1.4 and opaque nonswinging doors shall comply with Table C402.1.3 or C402.1.4. The *U*-factors for typical construction assemblies are included in Appendix A. These values shall be used for all calculations. Where proposed construction assemblies are not represented in Appendix A, values shall be calculated in accordance with the ASHRAE *Handbook -- Fundamentals* using the framing factors listed in Appendix A where applicable and shall include the thermal bridging effects of framing materials.

C402.1.4.1 Thermal resistance of cold-formed steel stud walls. *U*-factors of walls with cold-formed steel studs shall be permitted to be determined either by using the values in Table C402.1.4.1, or in accordance with Equation 4-1:

$$U = 1/[R_s + (ER)] \quad \text{(Equation 4-1)}$$

where:

R_s = The cumulative *R*-value of the wall components along the path of heat transfer, excluding the cavity insulation and steel studs.

ER = The effective *R*-value of the cavity insulation with steel studs.

TABLE C402.1.4
OPAQUE THERMAL ENVELOPE ASSEMBLY MAXIMUM REQUIREMENTS, *U*-FACTOR METHOD[a, f]

	CLIMATE ZONE 5 AND MARINE 4	
	All Other	**Group R**
Roofs		
Insulation entirely above deck	U-0.027	U-0.027
Metal buildings	((U-0.031)) U-0.027	((U-0.031)) U-0.027
Attic and other	U-0.021	U-0.021
Joist or single rafter	U-0.027	U-0.027
Walls, Above Grade		
Mass	((U-0.104[d])) U-0.057	((U-0.078[d])) U-0.057
Mass transfer deck slab edge	U-0.20	U-0.20
Metal building	U-0.052	U-0.052
Steel framed	U-0.055	U-0.055
Wood framed and other	((U-0.55)) U-0.051	U-0.054
Walls, Below Grade		
Below-grade wall [b]	((Same as above-grade)) U-0.070	((Same as above-grade)) U-0.070
Floors		
Mass[e]	((U-0.031)) U-0.029	((U-0.031)) U-0.029
Joist/framing	((U-0.029)) U-0.029 steel joist U-0.025 wood joist	((U-0.029)) U-0.029 steel joist U-0.025 wood joist
Slab-on-Grade Floors		
Unheated slabs	F-0.54	F-0.54
Heated slabs[c]	F-0.55	F-0.55
Opaque Doors		
Swinging	U-0.37	U-0.37
Nonswinging	U-0.34	U-0.34

Footnotes for Table C402.1.4

a. Use of opaque assembly *U*-factors, *C-factors*, and *F*-factors from Appendix A is required unless otherwise allowed by Section C402.1.4.

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

c. Heated slab *F*-factors shall be determined specifically for heated slabs. Unheated slab factors shall not be used.

d. (Reserved) ((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 *building thermal envelope* encloses one or more of the following uses: Warehouse (storage and retail), gymnasium, auditorium, church chapel, arena, kennel, manufacturing plant, indoor swimming pool, pump station, water and waste water treatment facility, storage facility, storage area, motor vehicle service facility. Where additional uses not listed (such as office, retail, etc.) are contained within the building, the exterior walls that enclose these areas may not utilize this exception and must comply with the appropriate mass wall R-value from Table C402.1.3/U-factor from Table C402.1.4.))

e. "Mass floors" shall include floors weighing not less than:
   1. 35 pounds per square foot of floor surface area; or
   2. 25 pounds per square foot of floor surface area where the material weight is not more than 120 pounds per cubic foot.

f. Opaque assembly U-factors based on designs tested in accordance with ASTM C1363 shall be permitted. The R-value of *continuous insulation* shall be permitted to be added or subtracted from the original test design.

TABLE C402.1.4.1
EFFECTIVE R-VALUES FOR
STEEL STUD WALL ASSEMBLIES

NOMINAL STUD DEPTH (inches)	SPACING OF FRAMING (inches)	CAVITY R-VALUE (insulation)	CORRECTION FACTOR (Fc)	EFFECTIVE R-VALUE (ER) (Cavity R-Value ´ Fc)
3 1/2	16	13	0.46	5.98
		15	0.43	6.45
3 1/2	24	13	0.55	7.15
		15	0.52	7.80
6	16	19	0.37	7.03
		21	0.35	7.35
6	24	19	0.45	8.55
		21	0.43	9.03
8	16	25	0.31	7.75
	24	25	0.38	9.50

C402.1.5 Component performance alternative. Building envelope values and *fenestration areas* determined in accordance with Equation 4-2 shall be permitted in lieu of compliance with the *U*-, *F*- and *C-factors* in Tables C402.1.3 and C402.1.4 and the maximum allowable *fenestration areas* in Section ((~~C402.4~~)) C402.4.1.

A + B + C + D + E ≤ Zero (Equation 4-2)

where:

A = Sum of the (UA Dif) values for each distinct assembly type of the *building thermal envelope*, other than slabs on grade ((~~and *below-grade walls*~~)).
- UA Dif = UA Proposed - UA Table.
- UA Proposed = Proposed *U*-value x Area.
- UA Table = (*U*-factor from Tables C402.1.4 or C402.4 ((~~or Section C402.1.3~~)) x Area.

B = Sum of the (FL Dif) values for each distinct slab-on-grade perimeter condition of the *building thermal envelope*.
- FL Dif = FL Proposed - FL Table.
- FL Proposed = Proposed *F*-value x Perimeter length.
- FL Table = (*F*-factor specified in Table C402.1.4) x Perimeter length.

The maximum allowed prescriptive *vertical fenestration area*, identified as "*Vertical Fenestration Area* allowed" in factor CA below, as a percent of the gross above-grade wall area ratio is either:

1. 30%
2. 40% if the building complies with Section C402.4.1.1 or C402.4.1.4; or
3. 40% if the *U*-values used in calculating A for *vertical fenestration* are taken from Section C402.4.1.3 rather than Table C402.4

Where the proposed *vertical fenestration area* is less than or equal to the maximum allowed prescriptive *vertical fenestration area*, the value of C (Excess Vertical Glazing Value) shall be zero. Otherwise:

C = (CA x UV) – (CA x $U_{Wall)}$, but not less than zero

CA = (Proposed *Vertical Fenestration Area*) – (*Vertical Fenestration Area* allowed)

UA Wall = Sum of the (UA Proposed) values for each opaque assembly of the exterior wall

UAW = Sum of the (UA Proposed) values for each above-grade wall assembly

U_{Wall} = UAW/sum of wall area (excludes *vertical fenestration area*)

UAV = Sum of the (UA Proposed) values for each *vertical fenestration* assembly

UV = UAV/total *vertical fenestration area*

Where the proposed skylight area is less than or equal to the skylight area allowed by Section C402.4.1, the value of D (Excess Skylight Value) shall be zero. Otherwise:

D = (DA x US) – (DA x $_{URoof)}$, but not less than zero

DA = (Proposed Skylight Area) – (Allowable Skylight Area from Section C402.4.1)

UAR = Sum of the (UA Proposed) values for each roof assembly

U_{Roof} = UAR/sum of roof area (excludes skylight area)

UAS = Sum of the (UA Proposed) values for each skylight assembly

US = UAS/total skylight area

C402.1.5.1 Component *U*-factors and *F*-factors. The *U*-factors and *F*-factors for typical construction assemblies ((~~are~~)) included in Chapter 3 and Appendix A ((~~. These values~~)) shall be used for all calculations. Where proposed construction assemblies are not represented in Chapter 3 or Appendix A, values shall be calculated in accordance with the ASHRAE Handbook - Fundamentals, using the framing factors listed in Appendix A.

For envelope assemblies containing metal framing, the *U*-factor shall be determined by one of the following methods:

1. Results of laboratory measurements according to acceptable methods of test.

2. ASHRAE Handbook - Fundamentals where the metal framing is bonded on one or both sides to a metal skin or covering.
3. The zone method as provided in ASHRAE Handbook - Fundamentals.
4. Effective framing/cavity *R*-values as provided in Appendix A. When return air ceiling plenums are employed, the roof/ceiling assembly shall:
   a. For thermal transmittance purposes, not include the ceiling proper nor the plenum space as part of the assembly; and
   b. For gross area purposes, be based upon the interior face of the upper plenum surface.
5. Tables in ASHRAE 90.1, Normative Appendix A.

C402.1.5.2 SHGC rate calculations. Solar heat gain coefficient shall comply with Table C402.4. The target SHGCAt and the proposed SHGCAp shall be calculated using Equations 4-3 and 4-4 and the corresponding areas and SHGCs from Table C402.4.

EQUATION 4-3
TARGET $SHGCA_t$

$$SHGCA_t = SHGC_{ogt}(A_{ogt}) + SHGC_{vgt}(A_{vgt} + A_{vgmt} + A_{vgmot} + A_{vgdt})$$

Where:

$SHGCA_t$ = The target combined specific heat gain of the target *fenestration area*.

$SHGC_{ogt}$ = The solar heat gain coefficient for skylight fenestration found in Table C402.4.

A_{ogt} = The proposed skylight area.

$SHGC_{vgt}$ = The solar heat gain coefficient for fenestration found in Table C402.4 which corresponds to the proposed total *fenestration area* as a percent of gross exterior wall area.

A_{vgt} = The proposed *vertical fenestration area* with nonmetal framing

A_{vgmt} = The proposed *vertical fenestration area* with fixed metal framing

A_{vgmot} = The proposed *vertical fenestration area* with operable metal framing

A_{vgdt} = The proposed *entrance door* area

EQUATION 4-4
PROPOSED $SHGCA_P$

$$SHGCA_p = SHGC_{og}A_{og} + SHGC_{vg}A_{vg}$$

Where:

$SHGCA_p$ = The combined proposed specific heat gain of the proposed *fenestration area*.

$SHGC_{og}$ = The solar heat gain coefficient of the skylights.

A_{og} = The skylight area.

$SHGC_{vg}$ = The solar heat gain coefficient of the *vertical fenestration*.

A_{vg} = The *vertical fenestration area*.

((~~**NOTE:** The *vertical fenestration area* does not include *opaque doors* and opaque spandrel panels.~~))

C402.2 Specific building thermal envelope insulation requirements (*Prescriptive*). Insulation in *building thermal envelope* opaque assemblies shall comply with Sections C402.2.1 through ((~~C402.2.6~~)) C402.2.8 and Table C402.1.3. Where this section refers to installing insulation levels as specified in Table C402.1.3, assemblies complying with Section C402.1.4 and buildings complying with Section C402.1.5 are permitted to provide alternate levels of insulation provided that the U-factor of the insulated assembly is less than or equal to the U-factor required by the selected compliance path. *

C402.2.1 Multiple layers of continuous insulation. Where two or more layers of *continuous insulation* board are used in a construction assembly, the *continuous insulation* boards shall be installed in accordance with Section C303.2. Where the *continuous insulation* board manufacturer's instructions do not address installation of two or more layers, the edge joints between each layer of *continuous insulation* boards shall be staggered.

C402.2.2 Roof assembly. The minimum thermal resistance (*R*-value) of the insulating material installed either between the roof framing or continuously on the roof assembly shall be as specified in Table C402.1.3, based on construction materials used in the roof assembly. Skylight curbs shall be insulated to the level of roofs with insulation entirely above deck or R-5, whichever is less.

Exceptions:

1. Continuously insulated roof assemblies where the thickness of insulation varies 1 inch (25 mm) or less and where the area-weighted *U*-factor is equivalent to the same assembly with the *R*-value specified in Table C402.1.3.
2. (Reserved) ((~~Where tapered insulation is used with insulation entirely above deck, the *R*-value where the insulation thickness varies 1 inch (25 mm) or less from the minimum thickness of tapered insulation shall comply with the *R*-value specified in Table C402.1.3.~~))
3. Unit skylight curbs included as a component of a skylight listed and labeled in accordance with NFRC 100 shall not be required to be insulated.

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

C402.2.3 Thermal resistance of above-grade walls. The minimum thermal resistance (*R*-value) of materials installed in the wall cavity between framing members and continuously on the walls shall be as specified in Table C402.1.3, based on framing type and construction materials used in the wall assembly. The *R*-value of integral insulation installed in concrete masonry units shall not be used in determining compliance with Table C402.1.3.

"Mass walls" shall include walls:

1. Weighing not less than 35 psf (170 kg/m^2) of wall surface area.
2. Weighing not less than 25 psf (120 kg/m^2) of wall surface area where the material weight is not more than 120 pcf (1900 kg/m^3).
3. Having a heat capacity exceeding 7 Btu/ft^2 · °F (144 kJ/m^2 · K).
4. Having a heat capacity exceeding 5 Btu/ft^2 · °F (103 kJ/m^2 · K), where the material weight is not more than 120 pcf (1900 kg/m^3).

C402.2.4 Thermal resistance of below-grade walls. The minimum thermal resistance (*R*-value) of the insulating material installed in, or continuously on, the *below-grade walls* shall be as specified in Table C402.1.3.

C402.2.5 Floors. The thermal properties (component *R*-values or assembly *U*- or *F*-factors) of floor assemblies over outdoor air or unconditioned space shall be as specified in Table C402.1.3 or C402.1.4 based on the construction materials used in the floor assembly. Floor framing cavity insulation or structural slab insulation shall be installed to maintain permanent contact with the underside of the subfloor decking or structural slabs.

Exceptions:

1. The floor framing cavity insulation or structural slab insulation shall be permitted to be in contact with the top side of sheathing or *continuous insulation* installed on the bottom side of floor assemblies where combined with insulation that meets or exceeds the minimum *R*-value in Table C402.1.3 for "Metal framed" or "Wood framed and other" values for "Walls, Above Grade" and extends from the bottom of the top of all perimeter floor framing or floor assembly members.
2. Insulation applied to the underside of concrete floor slabs shall be permitted an air space of not more than 1 inch where it turns up and is in contact with the underside of the floor under walls associated with the *building thermal envelope.*

C402.2.6 Slabs-on-grade perimeter insulation. Where the slab-on-grade is in contact with the ground, the minimum thermal resistance (*R*-value) of the insulation around the perimeter of unheated or heated *slab-on-grade floors* designed in accordance with the *R*-value method of Section C402.1.3 shall be as specified in Table C402.1.3. The insulation shall be placed on the outside of the foundation or on the inside of the foundation wall. The insulation shall extend downward from the top of the slab for a minimum distance as shown in the table or to the top of the footing, whichever is less, or downward to at least the bottom of the slab and then horizontally to the interior or exterior for the total distance shown in the table. Insulation extending away from the building shall be protected by pavement or by a minimum of 10 inches (254 mm) of soil. Insulation complying with Table C402.1.3 shall be provided under the entire area of heated slabs-on-grade.

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

C402.2.7 Reserved.

C402.2.8 Insulation of radiant heating systems. *Radiant heating system* panels and their associated components that are installed in interior or exterior assemblies shall be insulated with a minimum of R-3.5 (0.62 m^2/K × W) on all surfaces not facing the space being heated. Radiant heating system panels that are installed in the *building thermal envelope* shall be separated from the exterior of the building or unconditioned or exempt spaces by not less than the R-value of the insulation installed in the opaque assembly in which they are installed or the assembly shall comply with Section C402.1.4.

Exception: Heated slabs-on-grade insulated in accordance with Section C402.2.6.

C402.3 Reserved.

((~~C403.4~~)) C402.4 Fenestration (*Prescriptive*). Fenestration shall comply with Sections C402.4 through C402.4.4. ((~~and Table C402.4~~)) *Daylight responsive controls* shall comply with this section and Section ((~~C405.2.4.1~~)) C405.2.4.

Fenestration shall comply with Table C402.4. U-values from Column A shall be used in buildings where the HVAC heating energy is provided by electric resistance or fossil fuel combustion appliances. Electric resistance HVAC heating appliances include but are not limited to electric baseboard, electric resistance fan coil and VAV electric resistance terminal reheat units, as well as heat pump systems that use electric resistance as the heating energy for the condenser water loop when the outside air temperature is above 32°F (0°C). Fossil fuel combustion HVAC heating appliances include but are not limited to appliances burning natural gas, heating oil, propane, or other fossil fuels, as well as heat pump systems that use fossil fuel as the heating energy for the condenser water loop when the outside air temperature is above 32°F (0°C).

Exceptions.

1. *U*-values from Column B are permitted to be used under any of the following conditions:
   1.1. Building permits for which a completed application has been accepted by SDCI prior to January 1, 2018.
   1.2. Buildings or areas of buildings that meet the interior temperature requirements of IBC Chapter 12 with a total installed HVAC heating capacity of 6 BTU/h per square foot or less. For purposes of this exception, overhead or wall-mounted radiant heating panels insulated in compliance with Section C402.2.8 and controlled by occupant sensing devices in compliance with Section C403.2.12 need not be included as part of the HVAC heating energy calculation.
   1.3. Group R-2 or R-3 occupancy areas of buildings

1.4. Buildings with less than 2,500 square feet of *conditioned floor area* that is not Group R-2 or R-3 occupancy area.

1.5. Buildings in which electric resistance or fossil fuel auxiliary heating is provided only when the outdoor temperature is below 32°F (0°C) or when a defrost cycle is required. Such systems shall be sized and configured to lock out electric resistance or fossil fuel heating from operation when the outdoor temperature is above 32 °F (0°C) unless the system is in defrost operation.

1.6. Buildings in which electric resistance or fossil fuel appliances, including decorative appliances, either provide less than 5 percent of the total building HVAC system heating capacity or serve less than 5 percent of the *conditioned floor area*. The calculation of these percentages shall exclude Group R-2 and R-3 areas of buildings and HVAC heating system capacity serving those areas.

1.7. Buildings or portions of buildings that require fossil fuel or electric resistance heating for research, health care, process or other specific needs that cannot practicably be provided by other heating systems.

1.8. Make-up air for commercial kitchen exhaust systems that is required to be tempered according to Section 508.1.1 of the International Mechanical Code is permitted to be heated with electric resistance or fossil fuel.

1.9. Steam or hot water supply systems that utilize fossil fuels as their primary source of heat energy, that serve multiple buildings, and that were already in existence prior to the effective date of this code, including more energy-efficient upgrades to such existing systems, are permitted to serve as the primary heating energy source.

1.10. Hot water supply systems that utilize waste heat, renewable energy or other energy sources other than electric resistance or fossil fuel as their source of heat energy when the outside air temperature is above 32°F (0°C).are permitted to utilize electric resistance or fossil fuel as their secondary source of heat energy.

2. Single-pane glazing is permitted for security purposes and for revolving doors, not to exceed 1 percent of the gross exterior wall area. Where Section C402.1.5, component performance alternative, is used, the single glazing shall be included in the percentage of the total glazing area, U-factor and SHGC requirements.

TABLE C402.4
BUILDING ENVELOPE FENESTRATION MAXIMUM U-FACTOR AND SHGC REQUIREMENTS

CLIMATE ZONE	5 AND MARINE 4			
Vertical Fenestration				
***U*-factor**				
	Column A Electric Resistance or Fossil Fuel Heating System, and does not comply with C402.4, Ex 1		Column B Other Heating System, or complies with C402.4, Exception 1	
Nonmetal framing (all)[a]	0.26		0.30	
Metal framing (fixed)[b]	0.31		0.38	
Metal framing (operable)[c]	0.38		0.40	
Metal framing (*entrance doors*)[d]	0.60		0.60	
SHGC				
Orientation	SEW	N	SEW	N
PF < 0.2	((~~0.40~~)) 0.35	0.53	((~~0.40~~)) 0.35	0.53
0.2 ≤ PF < 0.5	((~~0.48~~)) 0.45	0.58	((~~0.48~~)) 0.45	0.58
PF ≥ 0.5	((~~0.65~~)) 0.60	0.64	((~~0.65~~)) 0.60	0.64
Skylights				
***U*-factor**	((~~0.50~~)) 0.45			
SHGC	((~~0.35~~)) 0.32			
Keys for Table C402.4 NR = No requirement.				

Footnotes for Table C402.4

a. "Nonmetal framing" includes framing materials other than metal, with or without metal reinforcing or cladding.

b. "Metal framing" includes metal framing, with or without thermal break. "Fixed" includes curtain wall, storefront, picture windows, and other fixed windows.

c. "Metal framing" includes metal framing, with or without thermal break. "Operable" includes openable fenestration products other than "*entrance doors*."

d. "Metal framing" includes metal framing, with or without thermal break. "*Entrance door*" includes glazed swinging *entrance doors* and *automatic* glazed sliding *entrance doors*. Other doors which are not *entrance doors*, including sliding glass doors, are considered "operable."

C402.4.1 Maximum area. The *vertical fenestration area* (not including *opaque doors* and opaque spandrel panels) shall not be greater than 30 percent of the gross above-grade wall area. The skylight area shall not be greater than ((~~3~~)) 5 percent of the gross roof area.

EXCEPTION: For *vertical fenestration* at street level retail or for other occupancies where the Seattle Land Use Code requires street-level transparency, the *fenestration area* shall not exceed 75 percent of the area of the street-level wall that faces the street or that adjoins other pedestrian areas used for retail access. For the purposes of this exception, the street-level wall shall be measured from the street-level floor to the interior ceiling level or to 20 feet above floor level, whichever is lowest. When this exception is used, separate calculations shall be performed for these sections of the building envelope, and these values shall not be averaged with any others for compliance purposes. On the street level the 75 percent *fenestration area* is permitted to be exceeded, if the additional *fenestration area* is deducted from *fenestration* allowances from other areas of the building.

C402.4.1.1 Increased vertical fenestration area with daylight zone area ((~~responsive controls~~)). A maximum of 40 percent of the gross above-grade wall area shall be permitted to be *vertical fenestration* for the purpose of prescriptive compliance with Section C402.1.4 or for the component performance alternative in Section C402.1.5, provided all of the following requirements are met:

1. In buildings not greater than two stories above grade, no less than 50 percent of the *conditioned floor area* is within a *daylight zone*.
2. In buildings three or more stories above grade, not less than 25 percent of the *net floor area* is within a *daylight zone*.
3. *Daylight responsive controls* complying with Section ((~~C405.2.4.1~~)) C405.2.4 are installed in *daylight zones*.
4. Visible transmittance (VT) of *vertical fenestration* is greater than or equal to 1.1 times solar heat gain coefficient (SHGC).

   Exception: Fenestration that is outside the scope of NFRC 200 is not required to comply with Item 4.

SDCI Informative Note: NFRC 200 covers almost all commonly-used glazing products. *Fenestration* products not within NFRC 200's scope include glass block, translucent fiberglass, curved glass, corrugated or patterned glazing, double-pane glass with shading devices between the panes, and glazing with translucent or patterned films.

C402.4.1.2 Reserved.

C402.4.1.3 Increased *vertical fenestration area* with high-performance *fenestration*. For buildings that are permitted to use the Column B values in Table C402.4, the ((~~The~~)) *vertical fenestration area* (not including *opaque doors* and opaque spandrel panels) is permitted to exceed 30% but shall not exceed 40% of the gross above grade wall area, for the purpose of prescriptive compliance with Section ((~~C402.1.3~~)) C402.4.1 provided that each of the following conditions are met:

1. The *vertical fenestration* shall have the following maximum U-factors:
   a. Non-metal framing (all) = 0.28
   b. Metal framing (fixed) = 0.34
   c. Metal framing (operable) = 0.36
   d. Metal framing (*entrance doors*) = 0.60
2. The SHGC of the *vertical fenestration* shall be less than or equal to 0.35((~~, adjusted for projection factor in compliance with C402.4.3~~)).

   An area-weighted average shall be permitted to satisfy the U-factor requirement for each fenestration product category listed in Item 1 of this section. Individual fenestration products from different fenestration product categories shall not be combined in calculating the area-weighted average *U*-factor.

   The compliance path described in this section is not permitted to be used for the Total Building Performance compliance path in Section C407. The compliance path described in this section is permitted to be used for the component performance alternative in Section C402.1.5, provided that the requirements of Section C402.1.5 are met.

C402.4.1.4 Increased vertical fenestration area with high-performance mechanical systems. The *vertical fenestration area* (not including *opaque doors* and opaque spandrel panels) is permitted to exceed 30 percent but shall not exceed 40 percent of the gross above-grade wall area, for the purpose of prescriptive compliance with Section ((~~C402.1.4~~)) C402.4.1 or for the component performance alternative in Section C402.1.5, provided that the mechanical system complies with all requirements of Section C403.6, dedicated outdoor air systems (DOAS) without utilizing the exceptions to Section C403.6. This increased glazing fraction is not permitted to be used to establish the reference case for the Total Building Performance compliance path in Section C407.

C402.4.2 Minimum skylight fenestration area. For single story buildings only, in an *enclosed space* greater than 2,500 square feet (232 m^2) in floor area, directly under a roof with not less than 75 percent of the ceiling area with a ceiling heights greater than 15 feet (4572 mm), and used as an office, lobby, atrium, concourse, corridor, gymnasium/exercise center, convention center, automotive service, manufacturing, nonrefrigerated warehouse, retail store, distribution/sorting area, transportation, or workshop, skylights are required to provide a total toplight *day-*

light zone area not less than half the floor area and shall provide one of the following:

1. A minimum ratio of skylight area to toplight *daylight zone* area under skylights of not less than 3 percent where all skylights have a VT of at least 0.40 as determined in accordance with Section C303.1.3
2. A minimum skylight effective aperture of at least 1 percent determined in accordance with Equation 4-5.

Skylight Effective Aperture =

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

(Equation 4-5)

where:

Skylight area = Total *fenestration area* of skylights.

Skylight VT = Area weighted average visible transmittance of skylights.

WF = Area weighted average well factor, where well factor is 0.9 if light well depth is less than 2 feet (610 mm), or 0.7 if light well depth is 2 feet (610 mm) or greater.

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

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

1. Reserved.
2. Spaces where the designed *general lighting* power densities are less than 0.5 W/ft^2 (5.4 W/m^2).
3. Areas where it is documented that existing structures or natural objects block direct beam sunlight on at least half of the roof over the enclosed area for more than 1,500 daytime hours per year between 8 a.m. and 4 p.m.
4. Spaces where the *daylight zone* under *rooftop monitors* is greater than 50 percent of the *enclosed space* floor area.
5. Spaces where the total floor area minus the sidelight *daylight zone* area is less than 2,500 square feet (232 m^2), and where the lighting in the *daylight zone* is controlled in accordance with Section ((~~C405.2.3.1~~)) C405.2.4.

C402.4.2.1 Lighting controls in daylight zones under skylights. *Daylight responsive controls* complying with Section ((~~C405.2.4.1~~)) C405.2.4 shall be provided to control all electric lights within *daylight zones*.

C402.4.2.2 Haze factor. Skylights in office, storage, automotive service, manufacturing, nonrefrigerated warehouse, retail store and distribution/sorting area spaces shall have a glazing material or diffuser with a haze factor greater than 90 percent when tested in accordance with ASTM D 1003.

Exception: Skylights designed and installed to exclude direct sunlight entering the occupied space by the use of fixed or automated baffles or the geometry of skylight and light well.

C402.4.3 Maximum *U*-factor and SHGC. The maximum *U*-factor and solar heat gain coefficient (SHGC) for fenestration shall be as specified in Table C402.4.

The window projection factor shall be determined in accordance with Equation 4-6.

$$PF = A/B \qquad \textbf{(Equation 4-6)}$$

where:

PF = Projection factor (decimal).

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

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

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

C402.4.3.1 Reserved

C402.4.3.2 Reserved.

C402.4.3.3 Dynamic glazing. Where *dynamic glazing* is intended to satisfy the SHGC and VT requirements of Table C402.4, the ratio of the higher to lower labeled SHGC shall be greater than or equal to 2.4, and the *dynamic glazing* shall be automatically controlled to modulate the amount of solar gain into the space in multiple steps. *Dynamic glazing* shall be considered separately from other fenestration, and area-weighted averaging with other fenestration that is not *dynamic glazing* shall not be permitted.

Exception: *Dynamic glazing* is not required to comply with this section where both the lower and higher labeled SHGC already comply with the requirements of Table C402.4.

C402.4.3.4 Area-weighted *U*-factor. An area-weighted average shall be permitted to satisfy the *U*-factor requirements for each fenestration product category listed in Table C402.4. Individual fenestration products from different fenestration product categories listed in Table C402.4 shall not be combined in calculating area-weighted average *U*-factor.

C402.4.4 Doors. *Opaque doors* shall comply with the applicable requirements for doors as specified in Tables C402.1.3 and C402.1.4 and be considered part of the gross area of above grade walls that are part of the building *thermal envelope.* Other doors shall comply with the provisions of Section C402.4.3 for *vertical fenestration*, and the entire door area, including frame, shall be considered part of the *fenestration area* of the *building thermal envelope*.

C402.5 Air leakage – thermal envelope (*Mandatory*). The thermal envelope of buildings shall comply with Sections C402.5.1 through C402.5.8.

C402.5.1 Air barriers. A *continuous air barrier* shall be provided throughout the *building thermal envelope*. The air barriers shall be permitted to be located on the inside or outside of the building envelope, located within the assemblies composing the envelope, or any combination thereof. The air barrier shall comply with Sections C402.5.1.1 and C402.5.1.2.

C402.5.1.1 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. 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. Penetrations of the air barrier shall be caulked, gasketed or otherwise sealed in a manner compatible with the construction materials and location. Joints and seals associated with penetrations shall be sealed in the same manner or taped or covered with moisture vapor-permeable wrapping material. Sealing materials shall be appropriate to the construction materials being sealed and shall be securely installed around the penetrations so as not to dislodge, loosen or otherwise impair the penetrations' ability to resist positive and negative pressure from wind, stack effect, and mechanical ventilation. Sealing of concealed fire sprinklers, where required, shall be in a manner that is recommended by the manufacturer. Caulking or other adhesive sealants shall not be used to fill voids between fire sprinkler cover plates and walls or ceilings.
4. Recessed lighting fixtures shall comply with Section C402.5.8. Where similar objects are installed which penetrate the air barrier, provisions shall be made to maintain the integrity of the air barrier.
5. Construction documents shall contain a diagram showing the building's pressure boundary in plan(s) and section(s) and a calculation of the area of the pressure boundary to be considered in the test.

SDCI Informative Note: The *continuous air barrier* is intended to control the air leakage into and out of the *conditioned space*. The definition of *conditioned space* includes *semi-heated spaces*, so these spaces are included when detailing the *continuous air barrier* and when determining the pressure boundary for conducting the air leakage test. However, unheated spaces are not included when determining the pressure boundary.

C402.5.1.2 Building test. The completed building shall be tested and the air leakage rate of the *building envelope* shall not exceed ((~~0.40~~)) 0.30 cfm/ft^2 at a pressure differential of 0.3 inches water gauge ((~~(2.0 L/s x m^2 at 75 Pa)~~)) (1.5 L/s x m^2 at 75 Pa) at the upper 95 percent confidence interval in accordance with ASTM E 779 or an equivalent method *approved* by the code official. A report that includes the tested surface area, floor area, air by volume, stories above grade, and leakage rates shall be submitted to the building owner and the Code Official. If the tested rate exceeds that defined here, a visual inspection of the air barrier shall be conducted and any leaks noted shall be sealed to the extent practicable. An additional report identifying the corrective actions taken to seal air leaks shall be submitted to the building owner and the Code Official and any further requirement to meet the leakage air rate will be waived.

1. Test shall be accomplished using either (1) both pressurization and depressurization or (2) pressurization alone, but not depressurization alone. The test results shall be plotted against the correct P for pressurization in accordance with Section 9.4 of ASTM E779.
2. The test pressure range shall be from 25 Pa to 80 Pa per Section 8.10 of ASTM E779, but the upper limit shall not be less than 50 Pa, and the difference between the upper and lower limit shall not be less than 25 Pa.
3. If the pressure exponent *n* is less than 0.45 or greater than 0.85 per Section 9.6.4 of ASTM E779, the test shall be rerun with additional readings over a longer time interval.

C402.5.1.2.1 Building test for mixed-use buildings. Where a building is three or fewer stories above grade plane and contains both commercial and residential uses, the air barrier of the R-2 and R-3 occupancy areas of the building is permitted to be separately tested according to Section R402.4.1.2. Alternatively, it is permissible to test the air barrier of the entire building according to Section C402.5.1.2, provided that the tested air leakage rate does not exceed the rate specified in Section C402.5.1.2.

C402.5.2 Reserved.

C402.5.3 Rooms containing fuel-burning appliances. Where open combustion air ducts provide combustion air to open combustion space conditioning fuel-burning appliances, the appliances and combustion air openings shall be located outside of the *building thermal envelope* or enclosed in a room isolated from inside the thermal envelope. Such rooms shall be sealed and insulated in accordance with the envelope requirements of Table C402.1.3 or C402.1.4, where the walls, floors and ceilings shall meet the minimum of the *below-grade wall R*-value requirement. The door into the room shall be fully gas-

keted, and any water lines and ducts in the room insulated in accordance with Section C403. The combustion air duct shall be insulated, where it passes through *conditioned space*, to a minimum of R-8.

Exceptions:

1. Direct vent appliances with both intake and exhaust pipes installed continuous to the outside.
2. Fireplaces and stoves complying with Sections 901 through 905 of the International Mechanical Code, and Section 2111.13 of the International Building Code.

C402.5.4 Doors and access openings to shafts, chutes, stairways, and elevator lobbies. Doors and access openings from *conditioned space* to shafts, chutes, stairways and elevator lobbies shall be gasketed, weatherstripped or sealed.

Exceptions:

1. Door openings required to comply with Section ((~~715 or 715.4~~)) 716 of the *International Building Code.*
2. Doors and door openings required to comply with UL 1784 by the *International Building Code*.

C402.5.5 Air intakes, exhaust openings, stairways and shafts. Stairway enclosures, elevator shaft vents and other outdoor air intakes and exhaust openings integral to the building envelope shall be provided with dampers in accordance with Section C403.2.4.3.

C402.5.6 Loading dock weatherseals. Cargo doors and loading dock doors shall be equipped with weatherseals to restrict infiltration when vehicles are parked in the doorway.

C402.5.7 Vestibules. All *building entrances* shall be protected with an enclosed vestibule, with all doors opening into and out of the vestibule equipped with self-closing devices. Vestibules shall be designed so that in passing through the vestibule it is not necessary for the interior and exterior doors to open at the same time. The installation of one or more revolving doors in the *building entrance* shall not eliminate the requirement that a vestibule be provided on any doors adjacent to revolving doors. For the purposes of this section, "*building entrances*" shall include exit-only doors in buildings where separate doors for entering and exiting are provided.

Interior and exterior doors shall have a minimum distance between them of not less than 7 feet. The exterior envelope of conditioned vestibules shall comply with the requirements for a *conditioned space*. Either the interior or exterior envelope of unconditioned vestibules shall comply with the requirements for a *conditioned space*. The building lobby is not considered a vestibule.

Exception: Vestibules are not required for the following:

1. Doors not intended to be used as *building entrances*.
2. Unfinished ground-level space greater than 3,000 square feet (298 m^2) if a note is included on the permit documents at each exterior entrance to the space stating "Vestibule required at time of tenant build-out if entrance serves a space greater than 3,000 square feet in area."
3. Doors opening directly from a *sleeping unit* or dwelling unit.
4. Doors between a space smaller than 3,000 square feet (298 m^2) in area and the exterior of the building or the *building entrance* lobby, where those doors do not comprise one of the primary entrance paths to the remainder of the building.
5. Revolving doors.
6. Doors used primarily to facilitate vehicular movement or material handling and adjacent personnel doors.
7. In buildings less than three stories above grade or in spaces that do not directly connect with the building elevator lobby, doors that have an *air curtain* with a velocity of not less than 6.56 feet per second (2 m/s) at the floor that have been tested in accordance with ANSI/AMCA 220 and installed in accordance with the manufacturer's instructions. Manual or *automatic* controls shall be provided that will operate the *air curtain* with the opening and closing of the door. *Air curtains* and their controls shall comply with Section C408.2.3.
8. *Building entrances* in buildings that are less than four stories above grade and less than 10,000 square feet in area.
9. Elevator doors in parking garages provided that the elevators have an enclosed lobby at each level of the garage.
10. Entrances to *semi-heated spaces*.
11. Doors that are used only to access outdoor seating areas that are separated from adjacent walking areas with a fence or other barrier.

SDCI Informative Note: *Building entrance* is defined as the means ordinarily used to gain access to the building. Doors other than *building entrances*, such as those leading to service areas, mechanical rooms, electrical equipment rooms, outdoor seating areas or exits from fire stairways, are not covered by this requirement. There is less traffic through these doors, and the vestibule may limit access for large equipment. Note that enclosed lobbies in parking garages also serve to reduce the flow of vehicle exhaust into the building.

C402.5.8 Recessed lighting. Recessed luminaires installed in the *building thermal envelope* shall be all of the following:

1. IC Rated.

2. *Labeled* as having an air leakage rate of not more than 2.0 cfm (0.944 L/s) when tested in accordance with ASTM E 283 at a 1.57 psf (75 Pa) pressure differential.
3. Sealed with a gasket or caulk between the housing and interior wall or ceiling covering.

SECTION C403
BUILDING MECHANICAL SYSTEMS

C403.1 General. Mechanical systems and equipment serving heating, cooling, ventilating, and other needs shall comply with Section C403.2 and shall comply with Sections C403.3 and C403.4 based on the equipment and systems provided.

Exception: Energy using equipment used by a manufacturing, industrial or commercial process other than for conditioning spaces or maintaining comfort and amenities for the occupants and not otherwise regulated by C403.2.3, Tables C403.2.3 (1) through (10) inclusive, C403.2.4.5, C403.2.4.6, C403.2.7, C403.2.9, C403.5.4, C404.2, Table C404.2, C405.8, and C410. Data center HVAC equipment is not covered by this exception.

C403.2 Provisions applicable to all mechanical systems (*Mandatory*). Mechanical systems and equipment serving the building heating, cooling or ventilating needs shall comply with Sections C403.2.1 through ((~~C403.2.13~~)) C403.2.14.

C403.2.1 Calculation of heating and cooling loads. Design loads associated with heating, ventilating and air conditioning of the building shall be determined in accordance with ANSI/ASHRAE/ACCA Standard 183 or by an *approved* equivalent computational procedure using the design parameters specified in Chapter 3. Heating and cooling loads shall be adjusted to account for load reductions that are achieved where energy recovery systems are utilized in the HVAC system in accordance with the ASHRAE *HVAC Systems and Equipment Handbook* by an *approved* equivalent computational procedure.

C403.2.2 Equipment and system sizing. The output capacity of heating and cooling equipment shall be no greater than that of the smallest available equipment size that exceeds the loads calculated in accordance with Section C403.2.1. A single piece of equipment providing both heating and cooling shall satisfy this provision for one function with the capacity for the other function as small as possible, within available equipment options.

Exceptions:

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.

C403.2.3 HVAC equipment performance requirements. Equipment shall meet the minimum efficiency requirements of Tables C403.2.3(1), C403.2.3(2), C403.2.3(3), C403.2.3(4), C403.2.3(5), C403.2.3(6), C403.2.3(7), C403.2.3(8) and C403.2.3(9) when tested and rated in accordance with the applicable test procedure. Plate-type liquid-to-liquid heat exchangers shall meet the minimum requirements of Table C403.2.3(10). The efficiency shall be verified through certification under an *approved* certification program or, where a certification program does not exist, 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.

Gas-fired and oil-fired forced air furnaces with input ratings of 225,000 Btu/h (65 kW) or greater and all unit heaters shall also have an intermittent ignition or interrupted device (IID), and have either mechanical draft (including power venting) or a flue damper. A vent damper is an acceptable alternative to a flue damper for furnaces where combustion air is drawn from the *conditioned space*. All furnaces with input ratings of 225,000 Btu/h (65 kW) or greater, including electric furnaces, that are not located within the *conditioned space* shall have jacket losses not exceeding 0.75 percent of the input rating.

Chilled water plants and buildings with more than 500 tons total capacity shall not have more than 100 tons provided by air-cooled chillers.

Exceptions:

1. Where the designer demonstrates that the water quality at the building site fails to meet manufacturer's specifications for the use of water-cooled equipment.
2. Air-cooled chillers with minimum efficiencies at least 10 percent higher than those listed in Table C403.2.3(7).
3. Replacement of existing equipment.

C403.2.3.1 Water-cooled centrifugal chilling packages. Equipment not designed for operation at AHRI Standard 550/590 test conditions of 44°F (7°C) leaving chilled-water temperature and 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 4-7 and 4-8.

Exception: Centrifugal chillers designed to operate outside of these ranges are not covered by this section.

$FL_{adj} = FL/K_{adj}$ **(Equation 4-7)**

$PLV_{adj} = IPLV/K_{adj}$ **(Equation 4-8)**

where:

K_{adj} = A × B

FL = Full-load kW/ton values as specified in Table C403.2.3(7)

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

IPLV = Value as specified in Table C403.2.3(7).

PLV_{adj} = Maximum *NPLV* rating, adjusted for non-standard conditions.

A = $0.00000014592 \mathbf{x} (LIFT)^4 - 0.0000346496 \mathbf{x} (LIFT)^3 + 0.00314196 \mathbf{x} (LIFT)^2 - 0.147199 \mathbf{x} (LIFT) + 3.9302$

B = $0.0015 \mathbf{x} L_{vg}^{Evap}$ (°F) + 0.934

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

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

L_{vg}^{Evap} = 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. LIFT is not less than 20°F and not greater than 80°F.

C403.2.3.2 Positive displacement (air- and water-cooled) chilling packages. Equipment with a leaving fluid temperature higher than 32°F (0°C) and water-cooled positive displacement chilling packages with a condenser leaving fluid temperature below 115°F (46°C) shall meet the requirements of Table C403.2.3(7) when tested or certified with water at standard rating conditions, in accordance with the referenced test procedure.

C403.2.3.3 Packaged and split system electric heating and cooling equipment. Packaged and split system electric equipment providing both heating and cooling, and cooling only equipment with electric heat in the main supply duct before VAV boxes, in each case with a total cooling capacity greater than 6,000 Btu/h shall be a heat pump.

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

TABLE C403.2.3(1)A
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	13.0 SEER	14.0 SEERc	
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	

TABLE C403.2.3(1)A—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 EER 12.1 IEER	11.9 EER 12.1 IEER	
		All other	Split System and Single Package	11.7 EER 11.9 IEER	11.7 EER 11.9 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.7 EER 11.9 IEER	11.7 EER 11.9 IEER	
		All other	Split System and Single Package	11.5 EER 11.7 IEER	11.5 EER 11.7 IEER	
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.

c. Minimum efficiency as of January 1, 2015.

TABLE C403.2.3(1)B
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED VARIABLE REFRIGERANT FLOW AIR CONDITIONERS

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency		Test Procedure
				Before 1/1/2017	After 1/1/2017	
VRF Air Conditioners, Air Cooled	<65,000 Btu/h	All	VRF Multi-split System	13.0 SEER	13.0 SEER	AHRI 1230
	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	11.2 EER 13.1 IEER	11.2 EER 15.5 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	11.0 EER 12.9 IEER	11.0 EER 14.9 IEER	
	≥240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	10.0 EER 11.6 IEER	10.0 EER 13.9 EER	

TABLE C403.2.3(1)C
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED VARIABLE REFRIGERANT FLOW AIR-TO-AIR AND APPLIED HEAT PUMPS

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency		Test Procedure
				Before 1/1/2017	After 1/1/2017	
VRF Air Cooled, (cooling mode)	<65,000 Btu/h	All	VRF Multi-split System	13.0 SEER	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	11.0 EER 14.6 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	10.8 EER 14.4 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	10.6 EER 12.3 IEER	10.6 EER 13.9 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	10.4 EER 13.7 IEER	
	≥240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	9.5 EER 11.0 IEER	9.5 EER 12.7 IEER	
	≥240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System with Heat Recovery	9.3 EER 10.8 IEER	9.3 EER 12.5 IEER	
VRF Water source (cooling mode)	<65,000 Btu/h	All	VRF Multi-split systems 86ºF entering water	12.0 EER		AHRI 1230
	<65,000 Btu/h	All	VRF Multi-split systems with Heat Recovery 86ºF entering water	11.8 EER		
	≥65,000 Btu/h and <135,000 Btu/h	All	VRF Multi-split System 86ºF entering water	12.0 EER		
	≥65,000 Btu/h and <135,000 Btu/h	All	VRF Multi-split System with Heat Recovery 86ºF entering water	11.8 EER		
	≥135,000 Btu/h	All	VRF Multi-split System 86ºF entering water	10.0 EER		
	≥135,000 Btu/h	All	VRF Multi-split System with Heat Recovery 86ºF entering water	9.8 EER		
VRF Groundwater source (cooling mode)	<135,000 Btu/h	All	VRF Multi-split System 59ºF entering water	16.2 EER		AHRI 1230
	<135,000 Btu/h	All	VRF Multi-split System with Heat Recovery 59ºF entering water	16.0 EER		
	≥135,000 Btu/h	All	VRF Multi-split System 59ºF entering water	13.8 EER		
	≥135,000 Btu/h	All	VRF Multi-split System with Heat Recovery 59ºF entering water	13.6 EER		

TABLE C403.2.3(1)C—continued
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED VARIABLE REFRIGERANT FLOW AIR-TO-AIR AND APPLIED HEAT PUMPS

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency		Test Procedure
				Before 1/1/2017	After 1/1/2017	
VRF Ground source (cooling mode)	<135,000 Btu/h	All	VRF Multi-split System 77ºF entering water	13.4 EER		AHRI 1230
	<135,000 Btu/h	All	VRF Multi-split System with Heat Recovery 77ºF entering water	13.2 EER		
	≥135,000 Btu/h	All	VRF Multi-split System 77ºF entering water	11.0 EER		
	≥135,000 Btu/h	All	VRF Multi-split System with Heat Recovery 77ºF 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 47ºF db/43ºF wb outdoor air 17ºF db/15ºF wb outdoor air	3.3 COP 2.25 COP		
	≥135,000 Btu/h (cooling capacity)	- - -	VRF Multi-split System 47ºF db/43ºF wb outdoor air 17ºF db/15ºF wb outdoor air	3.2 COP 2.05 COP		
VRF Water source (heating mode)	<135,000 Btu/h (cooling capacity)	---	VRF Multi-split System 68ºF entering water	4.2 COP		AHRI 1230
	≥135,000 Btu/h (cooling capacity)	---	VRF Multi-split System 68ºF entering water	3.9 COP		
VRF Groundwater source (heating mode)	<135,000 Btu/h (cooling capacity)	---	VRF Multi-split System 50ºF entering water	3.6 COP		AHRI 1230
	≥135,000 Btu/h (cooling capacity)	---	VRF Multi-split System 50ºF entering water	3.3 COP		
VRF Ground source (heating mode)	<135,000 Btu/h (cooling capacity)	---	VRF Multi-split System 32ºF entering water	3.1 COP		AHRI 1230
	≥135,000 Btu/h (cooling capacity)	---	VRF Multi-split System 32ºF entering water	2.8 COP		

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

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY		TEST PROCEDURE[a]
				Before 1/1/2016	As of 1/1/2016	
Air cooled (cooling mode)	< 65,000 Btu/h[b]	All	Split System	13.0 SEERc	14.0 SEERc	AHRI 210/240
			Single Package	13.0 SEERc	14.0 SEERc	
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	
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	86°F entering water	12.2 EER	12.2 EER	ISO 13256-1
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	13.0 EER	13.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	13.0 EER	13.0 EER	
Water to Air: Ground Water (cooling mode)	< 135,000 Btu/h	All	59°F entering water	18.0 EER	18.0 EER	ISO 13256-1
Brine to Air: Ground Loop (cooling mode)	< 135,000 Btu/h	All	77°F entering water	14.1 EER	14.1 EER	ISO 13256-1
Water to Water: Water Loop (cooling mode)	< 135,000 Btu/h	All	86°F entering water	10.6 EER	10.6 EER	ISO 13256-2
Water to Water: Ground Water (cooling mode)	< 135,000 Btu/h	All	59°F entering water	16.3 EER	16.3 EER	
Brine to Water: Ground Loop (cooling mode)	< 135,000 Btu/h	All	77°F entering fluid	12.1 EER	12.1 EER	

(continued)

TABLE C403.2.3(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[b]	—	Split System	7.7 HSPFc	8.2 HSPFc	AHRI 210/240
		—	Single Package	7.7 HSPFc	8.0 HSPFc	
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	
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.

c. Minimum efficiency as of January 1, 2015.

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

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
PTAC (cooling mode) new construction	All Capacities	95°F db outdoor air	14.0 - (0.300 × Cap/1000) 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	—	3.7 - (0.052 × 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	10.0 EER	AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h	95°F db/ 75°F wb outdoor air	10.0 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95°F db/ 75°F wb outdoor air	10.0 EER	
SPVHP (cooling mode)	< 65,000 Btu/h	95°F db/ 75°F wb outdoor air	10.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	95°F db/ 75°F wb outdoor air	10.0 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95°F db/ 75°F wb outdoor air	10.0 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	3.0 COP	
Room air conditioners, with louvered sides	< 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, without louvered sides	< 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	

(continued)

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

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Room air conditioner casement only	All capacities	—	8.7 EER	ANSI/ AHAM RAC-1
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, wb = wet bulb, db = dry bulb.

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

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

b. Replacement unit shall be factory labeled as follows: "MANUFACTURED FOR NONSTANDARD SIZE APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW STANDARD PROJECTS" or "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY: NOT TO BE INSTALLED

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

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY[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 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

b. Minimum and maximum ratings as provided for and allowed by the unit's controls.

c. Combination units not covered by the National Appliance Energy Conservation Act of 1987 (NAECA) (3-phase power or cooling capacity greater than or equal to 65,000 Btu/h [19 kW]) shall comply with either rating.

d. E_t = Thermal efficiency. See test procedure for detailed discussion.

e. E_c = Combustion efficiency (100% less flue losses). See test procedure for detailed discussion.

f. E_c = Combustion efficiency. Units must also include an IID, have jackets not exceeding 0.75 percent of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the *conditioned space*.

g. E_t = Thermal efficiency. Units must also include an IID, have jacket losses not exceeding 0.75 percent of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the *conditioned space*.

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

EQUIPMENT TYPE[a]	SUBCATEGORY OR RATING CONDITION	SIZE CATEGORY (INPUT)	MINIMUM EFFICIENCY[d, e]	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[b]	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.

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).

d. E_c = Combustion efficiency (100 percent less flue losses).

e. E_t = Thermal efficiency. See referenced standard for detailed information.

TABLE C403.2.3(6)
RESERVED

TABLE C403.2.3(7)
MINIMUM EFFICIENCY REQUIREMENTS – WATER CHILLING PACKAGES[a]

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	AS OF 1/1/2015[b]				TEST PROCEDURE[c]
			PATH A		PATH B		
			FULL LOAD	*IPLV*	FULL LOAD	*IPLV*	
Air-cooled chillers	< 150 tons	EER	≥ 10.100	≥ 13.700	≥ 9.700	≥ 15.800	AHRI 550/590
	≥150 tons	EER	≥ 10.100	≥ 14.000	≥ 9.700	≥ 16.100	
Air cooled without condenser, electrical operated	All capacities	EER	Air-cooled chillers without condensers shall be rated with matching condensers and comply with the air-cooled chiller efficiency requirements				
Water cooled, electrically operated, reciprocating	All capacities	kW/ton	Reciprocating units shall comply with water cooled positive displacement efficiency requirements				
Water cooled, electrically operated, positive displacement	< 75 tons	kW/ton	≤ 0.750	≤ 0.600	≤ 0.780	≤ 0.500	
	≥75 tons and < 150 tons	kW/ton	≤ 0.720	≤ 0.560	≤ 0.750	≤ 0.490	
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.660	≤ 0.540	≤ 0.680	≤ 0.440	
	≥ 300 tons and < 600 tons	kW/ton	≤ 0.610	≤ 0.520	≤ 0.625	≤ 0.410	
	≥ 600 tons	kW/ton	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380	
Water cooled, electrically operated, centrifugal	< 150 tons	kW/ton	≤ 0.610	≤ 0.550	≤ 0.695	≤ 0.440	
	≥ 150 tons and < 300 tons	kW/ton					
	≥300 tons and < 600 tons	kW/ton	≤ 0.560	≤ 0.520	≤ 0.595	≤ 0.390	
	≥600 tons	kW/ton	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380	
Air cooled, absorption single effect	All capacities	COP	≥ 0.600	NR	NA	NA	AHRI 560
Water cooled, absorption single effect	All capacities	COP	≥ 0.700	NR	NA	NA	
Absorption double effect, indirect fired	All capacities	COP	≥1.000	≥ 1.050	NA	NA	
Absorption double effect, direct fired	All capacities	COP	≥ 1.000	≥ 1.000	NA	NA	

Keys for Table C403.2.3(7)
For SI: 1 ton = 3517 W, 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8.
NA = Not applicable, not to be used for compliance;
NR = No requirement.

Footnotes for Table C403.2.3(7)

a. ((~~The centrifugal chiller equipment requirements, after adjustment in accordance with Section C403.2.3.1 or Section C403.2.3.2, do not apply to chillers used in low-temperature applications where the design leaving fluid temperature is less than 36ºF. The requirements do not apply to positive displacement chillers with leaving fluid temperatures less than or equal to 32ºF. The requirements do not apply to absorption chillers with design leaving fluid temperatures less than 40ºF.~~)) The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the reference test procedure. The requirements for centrifugal chillers shall be adjusted for nonstandard rating conditions per Section C403.2.3.1 and are only applicable for the range of conditions listed there.

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

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

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

EQUIPMENT TYPE[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	≥ 38.2 gpm/hp	CTI ATC-105 and CTI STD-201
Centrifugal fan open circuit cooling towers	All	95°F entering water 85°F leaving water 75°F entering wb	≥ 20.0 gpm/hp	CTI ATC-105 and CTI STD-201
Propeller or axial fan closed-circuit cooling towers	All	102°F entering water 90°F leaving water 75°F entering wb	≥ 14.0 gpm/hp	CTI ATC-105S and CTI STD-201
Centrifugal fan 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	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
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	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
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
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	AHRI 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 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

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

g. 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 must meet the minimum efficiency requirements listed in this table with R-507A as the test fluid.

TABLE C403.2.3(9)
MINIMUM EFFICIENCY REQUIREMENTS:
AIR CONDITIONERS AND CONDENSING UNITS SERVING COMPUTER ROOMS

Equipment Type	Net Sensible Cooling Capacity[a]	Minimum Scop-127[b] Efficiency Downflow units/ Upflow units	Test Procedure
Air conditioners, air cooled	< 65,000 Btu/h (<19 kW)	2.20 / 2.09	ANSI/ASHRAE 127
	≥ 65,000 Btu/h and < 240,000 Btu/h (≥19 kW and < 70 kW)	2.10 / 1.99	
	≥ 240,000 Btu/h (≥ 70 kW)	1.90 / 1.79	
Air conditioners, water cooled	<65,000 Btu/h (<19 kW)	2.60 / 2.49	
	≥ 65,000 Btu/h and < 240,000 Btu/h (≥19 kW and < 70 kW)	2.50 / 2.39	
	≥ 240,000 Btu/h (≥ 70 kW)	2.40 /2.29	
Air conditioners, water cooled with fluid economizer	< 65,000 Btu/h (<19 kW)	2.55 /2.44	
	≥ 65,000 Btu/h and < 240,000 Btu/h (≥19 kW and < 70 kW)	2.45 / 2.34	
	≥ 240,000 Btu/h (≥ 70 kW)	2.35 / 2.24	
Air conditioners, glycol cooled (rated at 40% propylene glycol)	< 65,000 Btu/h (<19 kW)	2.50 / 2.39	
	≥ 65,000 Btu/h and < 240,000 Btu/h (≥19 kW and < 70 kW)	2.15 / 2.04	
	≥ 240,000 Btu/h (≥ 70 kW)	2.10 / 1.99	
Air conditioners, glycol cooled (rated at 40% propylene glycol) with fluid economizer	< 65,000 Btu/h (<19 kW)	2.45 / 2.34	
	≥ 65,000 Btu/h and < 240,000 Btu/h (≥19 kW and < 70 kW)	2.10 / 1.99	
	≥ 240,000 Btu/h (≥ 70 kW)	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 re-heaters 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 C403.2.3(10)
MINIMUM EFFICIENCY REQUIREMENTS: HEAT TRANSFER EQUIPMENT

EQUIPMENT TYPE	SUBCATEGORY	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Liquid-to-liquid heat exchangers	Plate type	NR	AHRI 400

NR = No Requirement

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

C403.2.3.4 Humidification. If an air economizer is required on a cooling system for which humidification equipment is to be provided to maintain minimum indoor humidity levels, then the humidifier shall be of the adiabatic type (direct evaporative media or fog atomization type).

Exceptions:

1. Health care facilities licensed by the state where Chapter 246-320 or 246-330 WAC requires steam injection humidifiers in duct work downstream of final filters.
2. Systems with water economizer.
3. 100% outside air systems with no provisions for air recirculation to the central supply fan.
4. Nonadiabatic humidifiers cumulatively serving no more than 10% of a building's air economizer capacity as measured in cfm. This refers to the system cfm serving rooms with stand-alone or duct mounted humidifiers.

C403.2.4 HVAC system controls. HVAC systems shall be provided with controls as defined in this section and shall be capable of and configured to implement all required control functions in this code.

C403.2.4.1 Thermostatic controls. The supply of heating and cooling energy to each *zone* shall be controlled by individual thermostatic controls capable of responding to temperature within the zone. Controls in the same zone or in neighboring zones connected by openings larger than 10 percent of the floor area of either zone shall not allow for simultaneous heating and cooling. At a minimum, each floor of a building shall be considered as a separate zone. Controls on systems required to have economizers and serving single zones shall have multiple cooling stage capability and activate the economizer when appropriate as the first stage of cooling. See Section C403.3.1 for further economizer requirements. Where humidification or dehumidification or both is provided, at least one humidity control device shall be provided for each humidity control system.

Exceptions:

1. 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:
   1.1. The perimeter system includes at least one thermostatic control *zone* for each building exposure having exterior walls facing only one orientation (within +/-45 degrees) (0.8 rad) for more than 50 contiguous feet (15,240 mm);
   1.2. The perimeter system heating and cooling supply is controlled by a thermostat located within the *zones* served by the system; and
   1.3. Controls are configured to prevent the perimeter system from operating in a different heating or cooling mode from the other equipment within the zones or from neighboring zones connected by openings larger than 10 percent of the floor area of either zone.
2. ((~~Any nonperimeter zones not separated from perimeter zones by an interior wall with openings no larger than 10 percent of the perimeter floor zone area shall have setpoints and deadbands coordinated so that cooling in adjacent zones shall not operate until the adjacent zone temperature is 5°F (2.8°C) higher than the perimeter zone temperature.~~)) Where an interior zone is open to a perimeter zone with permanent openings that are larger than 10 percent of the floor area of either zone, cooling in the interior zone is permitted to operate at times when the perimeter zone is in heating and the interior zone temperature is at least 5°F (2.8°C) higher than the perimeter zone temperature.

C403.2.4.1.1 Heat pump supplementary heat. Unitary air cooled heat pumps shall include microprocessor controls that minimize supplemental heat usage during start-up, set-up, and defrost conditions. These controls shall anticipate need for heat and use compression heating as the first stage of heat. Controls shall indicate when supplemental heating is being used through visual means (e.g., LED indicators). Heat pumps equipped with supplementary heaters shall be installed with controls that prevent supplemental heater operation above 40°F. At final inspection, the lock out control shall be set to 32° F (0°C) or less.

Exception: Packaged terminal heat pumps (PTHPs) of less than 2 tons (24,000 Btu/hr) cooling capacity provided with controls that prevent supplementary heater operation above 40°F.

C403.2.4.1.2 Deadband. Where used to control both heating and cooling, *zone* thermostatic controls shall be capable of providing 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.

Exceptions:

1. Thermostats requiring manual changeover between heating and cooling modes.
2. Occupancies or applications requiring precision in indoor temperature control as *approved* by the *code official*.

C403.2.4.1.3 Setpoint overlap restriction. Where a *zone* has a separate heating and a separate cooling thermostatic control located within the zone, a limit switch, mechanical stop or direct digital control system with software programming shall be configured

to prevent the heating set point from exceeding the cooling setpoint and to maintain a deadband in accordance with Section C403.2.4.1.2.

C403.2.4.2 Off-hour controls. For all occupancies other than Group R and for *conditioned spaces* other than dwelling units within Group R occupancies, each *zone* shall be provided with thermostatic setback controls that are controlled by either an *automatic* time clock or programmable control system.

Exceptions:

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

C403.2.4.2.1 Thermostatic setback capabilities. Thermostatic setback controls shall have the capability to set back or temporarily operate the system to maintain *zone* temperatures down to 55°F (13°C) or up to 85°F (29°C).

C403.2.4.2.2 Automatic setback and shutdown capabilities. *Automatic* time clock or programmable controls shall be capable of starting and stopping the system for seven different daily schedules per week and retaining their programming and time setting during a loss of power for at least 10 hours. Additionally, the controls shall have a manual override that allows temporary operation of the system for up to 2 hours; a manually operated timer capable of being adjusted to operate the system for up to 2 hours; or an occupancy sensor.

C403.2.4.2.3 Automatic start capabilities. *Automatic* start controls shall be provided for each HVAC system. The controls shall be capable of automatically adjusting the daily start time of the HVAC system in order to bring each space to the desired occupied temperature immediately prior to scheduled occupancy.

C403.2.4.3 Shutoff dampers. Outdoor air supply, exhaust openings and relief outlets and stairway and shaft vents shall be provided with Class I motorized dampers.

Return air openings used for airside economizer operation shall be equipped with Class I motorized dampers.

Class I dampers shall have a maximum leakage rate of 4 cfm/ft^2 (20.3 L/s x m^2) at 1.0 inch water gauge (w.g.) (249 Pa) when tested in accordance with AMCA 500D and shall be labeled by an *approved agency* for such purpose.

Exception: Motorized dampers on return air openings in unitary packaged equipment that have the minimum leakage rate available from the manufacturer shall be deemed to comply.

Outdoor air intake and exhaust dampers shall be installed with *automatic* controls configured to close when the systems or spaces served are not in use or during unoccupied period warm-up and setback operation, unless the systems served require outdoor or exhaust air in accordance with the *International Mechanical Code* or the dampers are opened to provide intentional economizer cooling.

Stairway and shaft vent dampers shall be installed with *automatic* controls configured to open upon the activation of any fire alarm initiating device of the building's fire alarm system or the interruption of power to the damper.

Exceptions:

1. Gravity (nonmotorized) dampers shall be permitted to be used as follows:
   1.1. Relief dampers serving systems less than ((~~5,000~~)) 300 cfm total supply shall be permitted ((~~in buildings less than three stories in height in height~~)).
   1.2. Gravity (nonmotorized) dampers in Group R occupancies where the design outdoor air intake or exhaust capacity does not exceed ((~~400~~)) 300 cfm (189 L/s).
2. Combustion air intakes.
3. Systems serving areas which require continuous operation.
4. Type I kitchen exhaust hoods.

Gravity (nonmotorized) dampers shall have an air leakage rate not greater than 20 cfm/ft^2 (101.6 L/s x m^2) where not less than 24 inches (610 mm) in either dimension and 40 cfm/ft^2 (203.2 L/s x m^2) where less than 24 inches in either dimension. The rate of air leakage shall be determined at 1.0 inch w.g. (249 Pa) when tested in accordance with AMCA 500D for such purpose. The dampers shall be labeled by an *approved agency*. Gravity dampers for ventilation air intakes shall be protected from direct exposure to wind.

C403.2.4.4 Zone isolation. HVAC systems serving ((~~zones~~)) areas that are over 25,000 square feet (2323 m^2) in floor area or that span more than one floor and are designed to operate or be occupied nonsimultaneously shall be divided into isolation areas. Each isolation area shall be equipped with isolation devices and controls configured to automatically shut off the supply of conditioned air and outdoor air to and exhaust air from the isolation area. Each isolation area shall be controlled independently by a device meeting the requirements of Section C403.2.4.2.2. Central systems and plants shall be provided with controls and devices that will allow system and equipment operation for any length of time while serving only the smallest isolation area served by the system or plant.

Exceptions:

1. Exhaust air and outdoor air connections to isolation areas where the fan system to which they connect is not greater than 5,000 cfm (2360 L/s).

2. Exhaust airflow from a single isolation area of less than 10 percent of the design airflow of the exhaust system to which it connects.
3. Isolation areas intended to operate continuously or intended to be inoperative only when all other isolation areas in a zone are inoperative.

C403.2.4.5 Snow- and ice-melt system controls. Snow- and ice-melting systems, supplied through energy service to the building, shall include *automatic* controls configured to shut 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 is configured to shut off when the outdoor temperature is above 40°F (4°C) so that the potential for snow or ice accumulation is negligible.

C403.2.4.6 Freeze protection system controls. Freeze protection systems, such as heat tracing of outdoor piping and heat exchangers, including self-regulating heat tracing, shall include *automatic* controls configured to shut off the systems when outdoor air temperatures are above 40°F (4°C) or when the conditions of the protected fluid will prevent freezing.

C403.2.4.7 Economizer fault detection and diagnostics (FDD). Air-cooled unitary direct-expansion units with a cooling capacity of 54,000 Btu/h or greater listed in Tables C403.2.3(1) through C403.2.3(3) that are equipped with an economizer in accordance with Section C403.3 shall include a fault detection and diagnostics (FDD) system complying with the following:

1. The following temperature sensors shall be permanently installed to monitor system operation:
   1.1. Outside air.
   1.2. Supply air.
   1.3. Return air.
2. Temperature sensors shall have an accuracy of ±2°F (1.1°C) over the range of 40°F to 80°F (4°C to 26.7°C).
3. Refrigerant pressure sensors, where used, shall have an accuracy of ±3 percent of full scale.
4. The unit controller shall be configured to provide system status by indicating the following:
   4.1. Free cooling available.
   4.2. Economizer enabled.
   4.3. Compressor enabled.
   4.4. Heating enabled.
   4.5. Mixed air low limit cycle active.
   4.6. The current value of each sensor.
5. The unit controller shall be capable of manually initiating each operating mode so that the operation of compressors, economizers, fans and the heating system can be independently tested and verified.
6. The unit shall be configured to report faults to a fault management application *accessible* by day-to-day operating or service personnel or annunciated locally on zone thermostats.
7. The FDD system shall be configured to detect the following faults:
   7.1. Air temperature sensor failure/fault.
   7.2. Not economizing when the unit should be economizing.
   7.3. Economizing when the unit should not be economizing.
   7.4. Damper not modulating.
   7.5. Excess outdoor air.

C403.2.4.8 Combustion heating equipment controls. Combustion heating equipment with a capacity over 225,000 Btu/h shall have modulating or staged combustion control.

Exceptions:

1. Boilers.
2. Radiant heaters.

C403.2.4.9 Group R-1 hotel/motel guest rooms. For hotel and motel guest rooms, a minimum of one of the following control technologies shall be required in hotels/motels with over 50 guest rooms such that the space temperature would automatically setback (winter) or set up (summer) by no less than 5°F (3°C) when the occupant is not in the room:

1. Controls that are activated by the room occupant via the primary room access method - Key, card, deadbolt, etc.
2. Occupancy sensor controls that are activated by the occupant's presence in the room.

C403.2.4.10 Group R-2 and R-3 dwelling units. The primary space conditioning system within each dwelling unit shall be provided with at least one programmable thermostat for the regulation of space temperature. The thermostat shall allow for, at a minimum, a 5-2 programmable schedule (weekdays/weekends) and be capable of providing at least two programmable setback periods per day.

Each additional system provided within the dwelling unit shall be provided with at least one adjustable thermostat for the regulation of temperature.

Exceptions:

1. Systems controlled by an occupant sensor that is configured to shut the system off when no occupant is sensed for a period of up to 30 minutes.
2. Systems controlled solely by a manually operated timer configured to operate the system for no more than two hours.
3. Ductless heat pumps.

Each thermostat shall be capable of being set by adjustment or selection of sensors as follows:

1. When used to control heating only: 55°F to 75°F.
2. When used to control cooling only: 70°F to 85°F.
3. All other: 55°F to 85°F with an adjustable deadband of not less than10°F.

C403.2.4.11 Group R-2 sleeping units. The primary space conditioning system within each *sleeping unit* shall be provided with at least one programmable thermostat for the regulation of space temperature. The thermostat shall allow for, at a minimum, a 5-2 programmable schedule (weekdays/weekends) and be capable of providing at least two programmable setback periods per day.

Each additional system provided within the *sleeping unit* shall be provided with at least one adjustable thermostat for the regulation of temperature.

Exceptions:

1. Systems controlled by an occupant sensor that is configured to shut the system off when no occupant is sensed for a period of up to 30 minutes.
2. Systems controlled solely by a manually operated timer configured to operate the system for no more than two hours.
3. *Zones* with a full HVAC load demand not exceeding 3,400 Btu/h (1 kW) and having a readily accessible manual shutoff switch.
4. Ductless heat pumps.

Each thermostat shall be capable of being set by adjustment or selection of sensors as follows:

1. When used to control heating only: 55°F to 75°F;
2. When used to control cooling only: 70°F to 85°F;
3. All other: 55°F to 85°F with an adjustable deadband of not less than 10°F.

C403.2.4.12 Direct digital control systems. Direct digital control (DDC) shall be required as specified in Sections C403.2.4.12.1 through C403.2.4.12.3.

C403.2.4.12.1 DDC applications. DDC shall be provided in the applications and qualifications listed in Table C403.2.4.12.1.

C403.2.4.12.2 DDC controls. Where DDC is required by Section C403.2.4.12.1, the DDC system shall be capable of all of the following, as required to provide the system and zone control logic required in Sections C403.2, C403.3 and C403.4:

1. Monitoring zone and system demand for fan pressure, pump pressure, heating and cooling.
2. Transferring zone and system demand information from zones to air distribution system controllers and from air distribution systems to heating and cooling plant controllers.

C403.2.4.12.3 DDC display. Where DDC is required by Section C403.2.4.12.1 for new buildings, the DDC system shall be capable of trending and graphically displaying input and output points.

TABLE C403.2.4.12.1
DDC APPLICATIONS AND QUALIFICATIONS

Building Status	Application	Qualifications
New Building	Air-handling system and all zones served by the system	All air-handling systems in buildings with building cooling capacity greater than 780,000 Btu/h
	Air-handling system and all zones served by the system	Individual systems supplying more than three zones and with fan system bhp of 10 hp and larger
	Chilled-water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design cooling capacity of 300,000 Btu/h and larger
	Hot-water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design heating capacity of 300,000 Btu/h and larger

TABLE C403.2.4.12.1—continued
DDC APPLICATIONS AND QUALIFICATIONS

Alteration or addition	Zone terminal units such as VAV box	Where existing zones served by the same air-handling, chilled-water, or hot-water system have DDC
	Air-handling system or fan coil	Where existing air-handling system(s) and fan coil(s) served by the same chilled- or hot-water plant have DDC
	New air-handling system and all new zones served by the system	Individual systems with fan system bhp 10 hp and larger and supplying more than three zones and more than 75% of zones are new
	New or upgraded chilled-water plant	Where all chillers are new and plant design cooling capacity is 300,000 Btu/h and larger
	New or upgraded hot-water plant	Where all boilers are new and plant design heating capacity is 300,000 Btu/h and larger

C403.2.4.13 Pressure Independent Control Valves. Where design flow rate of heating water and chilled water coils is 10 GPM or higher, modulating pressure independent control valves shall be provided.

C403.2.5 Hot water boiler outdoor temperature setback control. Hot water boilers that supply heat to the building through one- or two-pipe heating systems shall have an outdoor setback control that lowers the boiler water temperature based on the outdoor temperature.

C403.2.6 Ventilation. Ventilation, either natural or mechanical, shall be provided in accordance with Chapter 4 of the *International Mechanical Code*. Where mechanical ventilation is provided, the system shall be configured to provide no greater than 150 percent of the minimum outdoor air required by Chapter 4 of the *International Mechanical Code* or other applicable code or standard, whichever is greater.

Exceptions:

1. The mechanical system may supply outdoor air at rates higher than the limit above when it is used for particulate or VOC dilution, economizer, night flushing, dehumidification, pressurization, exhaust make-up, or other process air delivery. Outdoor air shall be reduced to the minimum ventilation rates when not required for the preceding uses.
2. Air systems supplying Group R-1, R-2 or I-2 occupancies.
3. Alterations that replace less than half of the total heating and cooling capacity of the system.
4. Systems with energy recovery complying with the requirements of Section C403.5.1.

C403.2.6.1 Reserved.

C403.2.6.2 Demand controlled ventilation. *Demand control ventilation (DCV)* shall be provided for spaces larger than 500 square feet (50 m^2) and with an occupant load greater than or equal to 25 people per 1000 square feet (93 m^2) of floor area (as established in Table 403.3.1.1 of the *International Mechanical Code*) and served by systems with one or more of the following:

1. An air-side economizer.
2. *Automatic* modulating control of the outdoor air damper.
3. A design outdoor airflow greater than 3,000 cfm (1416 L/s).

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

1. Systems with energy recovery complying with Section C403.5.1.
2. Multiple-*zone* systems without direct digital control of individual *zones* communicating with a central control panel.
3. System with a design outdoor airflow less than 750 cfm (354 L/s).
4. Spaces where the supply airflow rate minus any makeup or outgoing transfer air requirement is less than 1,200 cfm (566 L/s).
5. Ventilation provided for process loads only.
6. Spaces with one of the following occupancy categories (as defined by the *International Mechanical Code*): Correctional cells, daycare sickrooms, science labs, barbers, beauty and nail salons, and bowling alley seating.

C403.2.6.3 Occupancy sensors. Classrooms, gyms, auditoriums and conference rooms larger than 500 square feet of floor area shall have occupancy sensor control that will either close outside air dampers or turn off serving equipment when the space is unoccupied except where equipped with another means to automatically reduce outside air intake below design rates when spaces are partially occupied.

C403.2.6.4 Enclosed loading dock, motor vehicle repair garage and parking garage exhaust ventilation system control. Mechanical ventilation systems for enclosed loading docks, motor vehicle repair garages and parking garages shall be designed to exhaust the airflow rates (maximum and minimum)

determined in accordance with the *International Mechanical Code*.

Ventilation systems shall be equipped with a control device that operates the system automatically by means of carbon monoxide detectors applied in conjunction with nitrogen dioxide detectors. Controllers shall be configured to shut off fans or modulate fan speed to 50 percent or less of design capacity, or intermittently operate fans less than 20 percent of the occupied time or as required to maintain acceptable contaminant levels in accordance with the *International Mechanical Code* provisions.

Gas sensor controllers used to activate the exhaust ventilation system shall stage or modulate fan speed upon detection of specified gas levels. All equipment used in sensor controlled systems shall be designed for the specific use and installed in accordance with the manufacturer's recommendations. The system shall be arranged to operate automatically by means of carbon monoxide detectors applied in conjunction with nitrogen dioxide detectors. ((~~Garage~~)) Garages, repair garages and loading docks shall be equipped with a controller and a full array of carbon monoxide (CO) sensors set to maintain levels of carbon monoxide below 35 parts per million (ppm). Additionally, a full array of nitrogen dioxide detectors shall be connected to the controller set to maintain the nitrogen dioxide level below the OSHA standard for eight hour exposure. Spacing and location of the sensors shall be installed in accordance with manufacturer recommendations.

C403.2.6.4.1 System activation devices for enclosed loading docks. Ventilation systems for enclosed loading docks shall operate continuously during unoccupied hours at the minimum ventilation rate required by Section C404.2.2 of the International Mechanical Code and shall be activated to the full required ventilation rate by one of the following:

1. Gas sensors installed in accordance with the *International Mechanical Code*; or
2. Occupant detection sensors used to activate the system that detects entry into the loading area along both the vehicle and pedestrian pathways.

C403.2.6.4.2 System activation devices for enclosed parking garages. Ventilation systems for enclosed parking garages shall be activated by gas sensors.

Exception: A parking garage ventilation system having a total design capacity under 8,000 cfm may use occupant sensors to activate the full required ventilation rate.

C403.2.7 Exhaust systems.

C403.2.7.1 Kitchen hoods. Replacement air introduced directly into the exhaust hood cavity shall not be greater than 10 percent of the hood exhaust airflow rate. Conditioned supply air delivered to any space shall not exceed the greater of the following:

1. The ventilation rate required to meet the space heating or cooling load.
2. The hood exhaust flow minus the available transfer air from adjacent space where available transfer air is considered that portion of outdoor ventilation air not required to satisfy other exhaust needs, such as restrooms, and not required to maintain pressurization of adjacent spaces.

Where total kitchen hood exhaust airflow rate is greater than 2,000 cfm each hood shall be a factory built commercial exhaust hood listed by a nationally recognized testing laboratory in compliance with UL 710. Each hood shall have a maximum exhaust rate as specified in Table C403.2.7.1 and shall comply with one of the following:

1. Not less than 50 percent of all replacement air shall be transfer air that would otherwise be exhausted.
2. Demand ventilation systems on not less than 75 percent of the exhaust air that are configured to provide not less than a 50-percent reduction in exhaust and replacement air system airflow rates, including controls necessary to modulate airflow in response to appliance operation and to maintain full capture and containment of smoke, effluent and combustion products during cooking and idle.
3. Listed energy recovery devices with a sensible heat recovery effectiveness of not less than 40 percent on not less than 50 percent of the total exhaust airflow.

Where a single hood, or hood section, is installed over appliances with different duty ratings, the maximum allowable flow rate for the hood or hood section shall be based on the requirements for the highest appliance duty rating under the hood or hood section.

Exceptions:

1. Where not less than 75 percent of all the replacement air is transfer air that would otherwise be exhausted.
2. Certified grease extractor hoods that require a face velocity no greater than 60 fpm.

TABLE C403.2.7.1
MAXIMUM NET EXHAUST FLOW RATE,
CFM PER LINEAR FOOT OF HOOD LENGTH

TYPE OF HOOD	LIGHT-DUTY EQUIPMENT	MEDIUM-DUTY EQUIPMENT	HEAVY-DUTY EQUIPMENT	EXTRA-HEAVY-DUTY EQUIPMENT
Wall-mounted canopy	140	210	280	385
Single island	280	350	420	490
Double island (per side)	175	210	280	385
Eyebrow	175	175	NA	NA
Backshelf/Pass-over	210	210	280	NA

For SI: 1 cfm = 0.4719 L/s; 1 foot = 305 mm.
NA = Not Allowed

C403.2.7.2 Laboratory exhaust systems. Buildings with laboratory exhaust systems having a total exhaust rate greater than 5,000 cfm (2,360 L/s) shall include heat recovery systems to preconditioned makeup air from laboratory exhaust. The heat recovery system shall be capable of increasing the outside air supply temperature at design heating conditions by 25°F (13.9°C). A provision shall be made to bypass or control the heat recovery system to permit air economizer operation as required by Section C403.3.

Exceptions:

1. Variable air volume laboratory exhaust and room supply systems configured to reduce exhaust and make-up air volume to 50% or less of design values; or
2. Direct make-up (auxiliary) air supply equal to at least 75% of the exhaust rate, heated no warmer than 2°F (1.1°C) below room set point, cooled to no cooler than 3°F (1.7°C) above room set point, no humidification added, and no simultaneous heating and cooling used for dehumidification control; or
3. Combined energy reduction method: VAV exhaust and room supply system configured to reduce exhaust and makeup air volumes and a heat recovery system to precondition makeup air from laboratory exhaust that when combined will produce the same energy reduction as achieved by a heat recovery system with a 50% sensible recovery effectiveness as required above. For calculation purposes, the heat recovery component can be assumed to include the maximum design supply airflow rate at design conditions. The combined energy reduction (Q_{ER}) shall meet the following:

$$Q_{ER} \geq Q_{MIN}$$

$$Q_{MIN} = CFM_S \times (T_R - T_O) \times 1.1 \times 0.6$$

$$Q_{ER} = CFM_S \times (T_R - T_O) \times 1.1(A+B)/100$$

Where:

Q_{MIN} = Energy recovery at 60% sensible effectiveness (Btu/h)

Q_{ER} = Combined energy reduction (Btu/h)

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

T_R = Space return air dry bulb at winter design conditions

T_O = Outdoor air dry bulb at winter design conditions

A = Percentage that the exhaust and makeup air volumes can be reduced from design conditions

B = Percentage sensible heat recovery effectiveness

C403.2.8 Duct and plenum insulation and sealing.

C403.2.8.1 Ducts, shafts and plenums conveying outside air from the exterior of the building to the mechanical system shall meet all air leakage and building envelope insulation requirements of Section C402, plus building envelope vapor control requirements from the *International Building Code*, extending continuously from the building exterior to an *automatic* shutoff damper or heating or cooling equipment. For the purposes of building envelope insulation requirements, duct surfaces shall meet the requirements for metal framed walls per Table C402.1.4. Duct surfaces included as part of the building envelope shall not be used in the calculation of maximum glazing area as described in Section C402.4.1.

Exceptions:

1. Outside air ducts serving individual supply air units with less than 2,800 cfm of total supply air capacity, provided these are insulated to R-7.
2. Unheated equipment rooms with combustion air louvers, provided they are isolated from

conditioned space at sides, top and bottom of the room with R-11 nominal insulation.

C403.2.8.2 All other supply and return air ducts and plenums shall be insulated with a minimum of R-6 insulation where located in unconditioned spaces and where located outside the building with a minimum of R-8 insulation in Climate Zone 4 and R-12 insulation in Climate Zone 5. Where located within a building envelope assembly, the duct or plenum shall be separated from the building exterior or unconditioned or exempt spaces by minimum insulation value as required for exterior walls by Section C402.1.3.

Exceptions:

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

Where located within *conditioned space*, supply ducts which convey supply air at temperatures less than 55°F or greater than 105°F shall be insulated with a minimum of R-3.3 insulation.

Exception: Ductwork exposed to view within a *zone* that serves that zone is not required to be insulated.

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

C403.2.8.3 Duct construction. Ductwork shall be constructed and erected in accordance with the *International Mechanical Code*. For the purposes of this section, longitudinal seams are joints oriented in the direction of airflow. Transverse joints are connections of two duct sections oriented perpendicular to airflow. Duct wall penetrations are openings made by any screw, fastener, pipe, rod or wire. All other connections are considered transverse joints, including but not limited to spin-ins, taps and other branch connections, access door frames and jambs, and duct connections to equipment.

C403.2.8.3.1 Low-pressure duct systems. All longitudinal and transverse joints, seams and connections of supply and return ducts operating at a static pressure less than or equal to 2 inches water gauge (w.g.) (500 Pa) shall be securely fastened and sealed with welds, gaskets, mastics (adhesives), mastic-plus embedded-fabric systems or tapes installed in accordance with the manufacturer's installation instructions. Pressure classifications specific to the duct system shall be clearly indicated on the construction documents in accordance with the *International Mechanical Code*.

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

C403.2.8.3.2 Medium-pressure duct systems. All ducts and plenums designed to operate at a static pressure greater than 2 inches water gauge (w.g.) (500 Pa) but less than 3 inches w.g. (750 Pa) shall be insulated and sealed in accordance with Section C403.2.8. Pressure classifications specific to the duct system shall be clearly indicated on the construction documents in accordance with the *International Mechanical Code*.

C403.2.8.3.3 High-pressure and exterior duct systems. Ducts designed to operate at static pressures in excess of 3 inches water gauge (w.g.) (750 Pa) and all supply and return ductwork located outside the building envelope that serves a *conditioned space* shall be insulated and sealed in accordance with Section C403.2.8. In addition, ducts and plenums shall be leak-tested in accordance with the SMACNA *HVAC Air Duct Leakage Test Manual* and shown to have a rate of air leakage (*CL*) less than or equal to 4.0 as determined in accordance with Equation 4-9.

$$CL = F/P^{0.65} \qquad \textbf{(Equation 4-9)}$$

Where:

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

P = The static pressure of the test.

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

C403.2.9 Piping insulation. All piping serving as part of a heating or cooling system shall be thermally insulated in accordance with Table C403.2.9.

Exceptions:

1. Factory-installed piping within HVAC equipment tested and rated in accordance with a test procedure referenced by this code.
2. Factory-installed piping within room fan-coils and unit ventilators tested and rated according to AHRI 440 (except that the sampling and variation provisions of Section 6.5 shall not apply) and 840, respectively.
3. Piping that conveys fluids that have a design operating temperature range between 60°F (15°C) and 105°F (41°C).
4. Piping that conveys fluids that have not been heated or cooled through the use of fossil fuels or electric power.
5. Strainers, control valves, and balancing valves associated with piping 1 inch (25 mm) or less in diameter.
6. Direct buried piping that conveys fluids at or below 60°F (15°C).

TABLE C403.2.9
MINIMUM PIPE INSULATION THICKNESS (in inches)[a]

FLUID OPERATING TEMPERATURE RANGE AND USAGE (°F)	INSULATION CONDUCTIVITY		NOMINAL PIPE OR TUBE SIZE (inches)				
	Conductivity Btu · in./(h · ft^2 · °F)[b]	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

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

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

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

where:

T = minimum insulation thickness,
r = actual outside radius of pipe,
t = insulation thickness listed in the table for applicable fluid temperature and pipe size,
K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (Btu · in/h · ft^2 · °F) and
k = the upper value of the conductivity range listed in the table for the applicable fluid temperature.

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

C403.2.9.1 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~~)) Adhesive tape shall not be permitted.

C403.2.10 Mechanical systems commissioning and completion requirements. Mechanical systems shall be commissioned and completed in accordance with Section C408.

C403.2.11 Air system design and control. Each HVAC system having a total fan system motor nameplate horsepower (hp) exceeding 5 hp (3.7 kW) shall comply with the provisions of Sections C403.2.11.1 through C403.2.11.3. All motors less than 1 horsepower shall meet the provisions of Section C405.8.

The airflow requirements of Section C403.2.11.5 shall apply to all fan motors. Group R occupancy exhaust fans shall also comply with Section C403.2.11.4. In addition to the other requirements of this section, variable-air-volume systems shall comply with Sections C403.2.11.6 through C403.2.11.8.

C403.2.11.1 Allowable fan motor 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 C403.2.11.1(1). This includes supply fans, exhaust fans, return/relief fans, and fan-powered terminal units associated with systems providing heating or cooling capability. Single *zone* variable-air-volume systems shall comply with the constant volume fan power limitation.

Exceptions:

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

TABLE C403.2.11.1(1)
FAN POWER LIMITATION

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

For SI: 1 bhp = 735.5 W, 1 hp = 745.5 W, 1 cfm = 0.471 L/s.

where:

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

hp = The maximum combined motor nameplate horsepower.

Bhp = The maximum combined *fan brake horsepower*.

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

where:

PD = Each applicable pressure drop adjustment from Table C403.2.10.1(2) in. w.c.

CFM_D = The design airflow through each applicable device from Table C403.2.10.1(2) in cubic feet per minute.

TABLE C403.2.11.1(2)
FAN POWER LIMITATION PRESSURE DROP ADJUSTMENT

DEVICE	ADJUSTMENT
Credits	
Fully ducted return and/or exhaust air systems	0.5 inch w.c. (2.15 in w.c. for laboratory and vivarium systems)
Return and/or exhaust airflow control devices	0.5 inch w.c.
Exhaust filters, scrubbers or other exhaust treatment	The pressure drop of device calculated at fan system design condition
Particulate filtration credit: MERV 9 - 12	0.5 inch w.c.
Particulate filtration credit: MERV 13 - 15	0.9 inch. w.c.
Particulate filtration credit: MERV 16 and greater and electronically enhanced filters	Pressure drop calculated at 2x clean filter pressure drop at fan system design condition
Carbon and other gas-phase air cleaners	Clean filter pressure drop at fan system design condition
Biosafety cabinet	Pressure drop of device at fan system design condition
Energy recovery device, other than coil runaround loop	(2.2 × energy recovery effectiveness) – 0.5 inch w.c. for each airstream
Coil runaround loop	0.6 inch w.c. for each airstream.
Evaporative humidifier/cooler in series with another cooling coil	Pressure drop of device at fan system design conditions.
Sound attenuation section (fans serving spaces with design background noise goals below NC35)	0.15 inch w.c.
Exhaust system serving fume hoods	0.35 inch w.c.
Laboratory and vivarium exhaust systems in high-rise buildings	0.25 inch w.c./100 feet of vertical duct exceeding 75 feet.
Deductions	
Systems without central cooling device	- 0.6 in. w.c.
Systems without central heating device	- 0.3 in. w.c.
Systems with central electric resistance heat	- 0.2 in. w.c.

For SI: 1 inch w.c. = 249 Pa, 1 inch = 25.4 mm.
w.c. = water column, NC = Noise criterion.

TABLE ((~~C403.2. 4.11.5~~)) C403.2.11.4
MECHANICAL VENTILATION SYSTEM FAN EFFICACY

Fan location	Air Flow Rate Minimum (cfm)	Minimum Efficacy (cfm/watt)	Air Flow Rate Minimum (cfm)
Exhaust fan: Bathroom, utility room, whole house	10	1.4 cfm/watt	< 90
Exhaust fan: Bath	90	2.8 cfm/watt	Any

TABLE ((~~C403.2. 4.11.5~~)) C403.2.11.5
FAN CONTROL

Cooling System Type	Fan Motor Size	Mechanical Cooling Capacity
DX cooling	Any	≥65,000 Btu/h
Chilled water and evaporative cooling	((~~≥ 5 hp~~))	((~~Any~~))
	≥ ¼ hp	Any

C403.2.11.2 Motor nameplate horsepower. For each fan, the selected fan motor shall be no larger than the first available motor size greater than the brake horsepower (bhp). The fan bhp shall be indicated on the design documents to allow for compliance verification by the *code official*.

Exceptions:

1. For fans less than 6 bhp (4413 W), where the first available motor larger than the brake horsepower has a nameplate rating within 50

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

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

3. For fans used only in *approved* life safety applications such as smoke evacuation.

C403.2.11.3 Fan efficiency. Fans shall have a *fan efficiency grade (FEG)* of 67 or higher based on manufacturers' certified data, as defined by AMCA 205. The total efficiency of the fan at the design point of operation shall be within 15 percentage points of the maximum total efficiency of the fan.

Exception: The following fans are not required to have a *fan efficiency grade*:

1. Fans of 5 hp (3.7 kW) or less as follows:

   1.1. Single fan with a motor nameplate horsepower of 5 hp (3.7 kW) or less, unless Exception 1.2 applies.

   1.2. Multiple fans in series or parallel that have a combined motor nameplate horsepower of 5 hp (3.7 kW) or less and are operated as the functional equivalent of a single fan.

2. Fans that are part of equipment covered under Section C403.2.3.

3. Fans included in an equipment package certified by an *approved agency* for air or energy performance.

4. Powered wall/roof ventilators.

5. Fans outside the scope of AMCA 205.

6. Fans that are intended to operate only during emergency conditions.

C403.2.11.4 Group R occupancy exhaust fan efficacy. The Group R occupancies of the building shall be provided with ventilation that meets the requirements of the *International Mechanical Code*, as applicable, or with other *approved* means of ventilation. Mechanical ventilation system fans with 400 cfm or less in capacity shall meet the efficacy requirements of Table C403.2.11.4.

Exceptions:

1. Group R heat recovery ventilator and energy recovery ventilator fans that are less than 400 cfm.

2. Where whole house ventilation fans are integrated with forced-air systems that are tested and listed HVAC equipment, they shall be powered by an electronically commutated motor where required by Section C405.8

3. Domestic clothes dryer booster fans, domestic range rood exhaust fans, and domestic range booster fans that operate intermittently.

C403.2.11.5 Fan airflow control. Each cooling system listed in Table C403.2.11.5 shall be designed to vary the indoor fan airflow as a function of load and shall comply with the following requirements:

1. Direct expansion (DX) and chilled water cooling units that control the capacity of the mechanical cooling directly based on space temperature shall have not fewer than two stages of fan control. Low or minimum speed shall not be greater than 66 percent of full speed. At low or minimum speed, the fan system shall draw not more than 40 percent of the fan power at full fan speed. Low or minimum speed shall be used during periods of low cooling load and ventilation-only operation.

2. Other units including DX cooling units and chilled water units that control the space temperature by modulating the airflow to the space shall have modulating fan control. Minimum speed shall be not greater than 50 percent of full speed. At minimum speed, the fan system shall draw no more than 30 percent of the power at full fan speed. Low or minimum speed shall be used during periods of low cooling load and ventilation-only operation.

3. Units that include an airside economizer in accordance with Section C403.3 shall have not fewer than two speeds of fan control during economizer operation.

Exceptions:

1. Modulating fan control is not required for chilled water and evaporative cooling units with fan motors of less than 1 hp (0.746 kW) where the units are not used to provide ventilation air and the indoor fan cycles with the load.

2. Where the volume of outdoor air required to comply with the ventilation requirements of the *International Mechanical Code* at low speed exceeds the air that would be delivered at the minimum speed defined in this section, the minimum speed shall be selected to provide the required ventilation air.

C403.2.11.6 Single Zone Variable-Air-Volume Controls. HVAC systems shall have variable airflow controls as follows:

1. Supply fans for air handling and fan coil units with chilled-water cooling coils and supply fans with motors greater than or equal to 5 hp shall be controlled by variable-speed drives or electronically-commutated motors. 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:

   1.1. One half of the full fan speed; or

1.2. The volume of outdoor air required to meet the ventilation requirements of the *International Mechanical Code*.

2. Supply fans for air conditioning equipment and air handling units with direct expansion cooling and a cooling capacity greater than or equal to 110,000 Btu/h that serve single zones shall be controlled by variable-speed drives or electronically-commutated motors. Cooling capacity shall be determined at the rating conditions in the AHRI standard appropriate to the equipment, 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:

2.1. Two-thirds of the full fan speed; or

2.2. The volume of outdoor air required to meet the ventilation requirements of the *International Mechanical Code*.

C403.2.11.7 Multiple-zone Variable Air Volume (VAV) System Ventilation Optimization Control. Multiple-zone VAV systems with direct digital control (DDC) of individual zone boxes reporting to a central control panel shall include means to automatically reduce outdoor air intake flow below design rates in response to changes in system ventilation efficiency as set out in ASHRAE 62.1, Appendix A.

Exceptions. The following systems are exempt from this section:

1. VAV Systems with zonal transfer fans that recirculate air from other zones without directly mixing it with outdoor air.
2. Dual-duct dual-fan VAV systems.
3. VAV systems with fan-powered terminal units.
4. Systems where total design exhaust airflow is more than 70 percent of the total design outdoor air intake flow requirements.

C403.2.11.8 Multiple-zone VAV System Outdoor Airflow Control. Multiple-zone VAV systems with a minimum outside air requirement of 5,000 CFM or greater shall be equipped with a device capable of measuring outdoor airflow intake under all load conditions. The system shall be capable of increasing or reducing the outdoor airflow intake based on feedback from zonal systems as required by Sections C403.2.11.7 and C403.2.6.2.

Exceptions

1. Systems that meet all of the following are exempt from this section:

1.1 No spaces served by the system require *demand control ventilation* per Section C403.2.6.2.

1.2 The system meets the one of the exceptions to Section C403.2.11.7.

1.3 The system complies with Section 403.3.1.4 of the International Mechanical Code.

2. Systems where total design exhaust airflow is more than 70 percent of the total design outdoor air intake flow requirements are exempt from this section.

C403.2.12 Heating outside a building. Systems installed to provide heat outside a building shall be radiant systems.

Such heating systems shall be controlled by an occupancy sensing device or a timer switch, so that the system is automatically deenergized when no occupants are present in the area heated by each individual device for a period not to exceed one hour.

C403.2.13 Variable flow capacity. For fan and pump motors 7.5 hp and greater including motors in or serving custom and packaged air handlers serving variable air volume fan systems, constant volume fans, parking garage ventilation fans, heating and cooling hydronic pumping systems, pool and service water pumping systems, domestic water pressure boosting systems, cooling tower fan, and other pump or fan motors where variable flows are required, there shall be:

1. Variable speed drives; or
2. Other controls and devices that will result in fan and pump motor demand of no more than 30 percent of design wattage at 50 percent of design air volume for fans when static pressure set point equals 1/3 the total design static pressure, and 50 percent of design water flow for pumps, based on manufacturer's certified test data. Variable inlet vanes, throttling valves (dampers), scroll dampers or bypass circuits shall not be allowed.

Exception: Variable speed devices are not required for motors that serve:

1. Fans or pumps in packaged equipment where variable speed drives are not available as a factory option from the equipment manufacturer.
2. Fans or pumps that are required to operate only for emergency fire-life-safety events (e.g., stairwell pressurization fans, elevator pressurization fans, fire pumps, etc.).

C403.2.13.1 Heat rejection equipment. The requirements of this section apply to heat rejection equipment used in comfort cooling systems such as air-cooled condensers, open cooling towers, closed-circuit cooling towers, and evaporative condensers.

Exception: Heat rejection devices included as an integral part of equipment listed in Tables C403.2.3(1) through C403.2.3(3).

Heat rejection equipment shall have a minimum efficiency performance not less than values specified in Table C403.2.3(8). These requirements apply to all propeller, axial fan and centrifugal fan cooling towers. Table C403.2.3(8) specifies requirements for air-cooled

condensers that are within rating conditions specified within the table.

Cooling towers serving chilled water systems shall be selected to maintain a return condenser water temperature to the tower of 86° F (30° C) or less at peak design conditions.

EXCEPTION. In existing buildings where physical constraints preclude a change from the original design, replacement cooling towers of the same or smaller capacity are exempt from this requirement.

Single-pass water cooling systems that use domestic water only one time before dumping it to waste shall not be used for hydronic heat pump and other cooling and refrigeration equipment, including but not limited to icemakers and walk-in coolers.

EXCEPTIONS.

1. Replacement of existing icemakers is exempt from this requirement.
2. Use of single-pass cooling for medical and dental equipment during power outages and other emergencies is exempt from this requirement.

C403.2.13.1.1 Variable flow controls. Cooling tower fans 7.5 hp and greater shall have control devices that vary flow by controlling the leaving fluid temperature or condenser temperature/pressure of the heat rejection device.

C403.2.13.1.2 Limitation on centrifugal fan cooling towers. Open cooling towers with a combined rated capacity of 1,100 gpm and greater at 95°F condenser water return, 85°F condenser water supply and 75°F outdoor wet-bulb temperature shall meet the energy efficiency requirement for axial fan open circuit cooling towers.

EXCEPTION: Open circuit cooling towers that are ducted (inlet or discharge) ((~~or have external sound attenuation that requires~~)) and require external static pressure capability or open circuit cooling towers that have external sound attenuation.

C403.2.14 Electric motor efficiency. Electric motors, including fractional hp motors, shall comply with the provisions of Section C405.8.

C403.3 Economizers (*Prescriptive*). Air economizers shall be provided on all new systems including those serving computer server rooms, electronic equipment, radio equipment, and telephone switchgear. Economizers shall comply with Sections C403.3.1 through C403.3. 4.

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

1. Systems complying with Section C403.6 Dedicated outdoor air systems (DOAS) with year-round cooling loads from lights and equipment of less than 5 watts per square foot.
2. Unitary or packaged systems serving one zone with dehumidification ((~~that affect other systems so as to~~)) where an economizer would increase the overall building energy consumption. New humidification equipment shall comply with Section C403.2.3.4
3. Unitary or packaged systems serving one zone where the cooling efficiency meets or exceeds the efficiency requirements in Table C403.3(3).
4. Water-cooled refrigeration equipment serving chilled beams and chilled ceiling space cooling systems only which are provided with a water economizer meeting the requirements of Section C403.3.4.
5. Systems complying with all of the following criteria:
   - 5.1. Consist of multiple water source heat pumps connected to a common water loop.
   - 5.2. Have a minimum of 60 percent air economizer.
   - 5.3. Have water source heat pumps with an EER at least 15 percent higher for cooling and a COP of at least 15 percent higher for heating than that specified in Section C403.2.3.
   - 5.4. Where provided with a dedicated boiler or furnace for that building, have a central boiler or furnace efficiency of 90 percent minimum for units up to 199,000 Btu/h.
   - 5.5. Provide heat recovery with a minimum 50 percent heat recovery effectiveness as defined in Section C403.5 to preheat the outside air supply.
6. For Group R occupancies, cooling units installed outdoors or in a mechanical room adjacent to outdoors with a total cooling capacity less than 20,000 Btu/h and other cooling units with a total cooling capacity less than 54,000 Btu/h provided that these are high-efficiency cooling equipment with JEER, SEER, and EER values more than 15 percent higher than minimum efficiencies listed in Tables C403.2.3 (1) through (3), in the appropriate size category, using the same test procedures. PTAC and PTHP units with capacities no greater than 8,300 Btu/h are permitted for the purposes of this exception if they have EER values a minimum of 4 percent higher the minimum efficiencies listed in Table C403.2.3(3), in the appropriate size category, using the same test procedures. Equipment shall be listed in the appropriate certification program to qualify for this exception. For split systems, compliance is based on the cooling capacity of individual fan coil units.
7. Variable refrigerant flow (VRF) systems, multiple-zone split-system heat pumps, consisting of multiple, individually metered indoor units with multi-speed fan motors, served on a single com-

mon refrigeration circuit with an exterior reverse-cycle heat pump with variable speed compressor(s) and variable speed condenser fan(s). These systems shall also be capable of providing simultaneous heating and cooling operation, where in all rooms with VRF units recovered energy from the indoor units operating in one mode can be transferred to one or more perimeter zones (as determined by *conditioned floor area*) and the outdoor unit shall be at least 65,000 Btu/h in total capacity. Systems utilizing this exception shall have 50 percent heat recovery effectiveness as defined by Section C403.5 on the outside air. For the purposes of this exception, dedicated server rooms, electronic equipment rooms or telecom switch rooms are not considered perimeter zones and shall not exceed 20 percent of the floor area served by the VRF system.

8. Equipment used to cool *Controlled Plant Growth Environments* provided these are high-efficiency cooling equipment with SEER, EER and *IEER* values a minimum of 20 percent greater than the values listed in Tables C403.2.3(1), (3) and (7).
9. Equipment used to cool any spaces with year-round cooling loads from lights and equipment of greater than 5 watts per square foot, where it can be demonstrated through calculations, to the satisfaction of the code official, that the heat rejection load of the equipment will be recovered and used for on-site space heating or service water heating demands such that the energy use of the building is decreased in comparison to a baseline of the same equipment provided with an air economizer complying with Section C403.3.
10. Equipment used to cool any dedicated server room, electronic equipment room, elevator machine room or telecom switch room provided the system complies with Option a, b ((~~or~~)) c, d or e in ((~~the table~~)) Table C403.3(10) below. The total capacity of all systems qualifying under this exception without economizers shall not exceed 240,000 Btu/h per building or 10 percent of its air economizer capacity, whichever is greater. This exception shall not be used for Total Building Performance.
11. Medical and laboratory equipment that is directly water-cooled and is not dependent upon space air temperature.

Table C403.3(10)
Server room, electronic equipment room or telecom room cooling equipment

	Equipment Type	Higher Equipment Efficiency	Part-Load Control	Economizer
Option a	Tables C403.2.3(1) and C403.2.3(2)[a]	+15%[b]	Required over 85,000 Btu/h[c]	None Required
Option b	Tables C403.2.3(1) and C403.2.3(2)[a]	+5%[d]	Required over 85,000 Btu/h[c]	Waterside Economizer
Option c	ASHRAE Standard 127[f]	+10%[g]	Required over 85,000 Btu/h[c]	Waterside Economizer
Option d	Table C403.2.3(7)[h]	+ 25%[i]	Required for all chillers[j]	None Required
Option e	Table C403.2.3(7)[h]	+ 10/15%[k]	Required over 85,000 Btu/h[c]	Dedicated waterside economizer[e]

((~~Notes for Exception 10~~)) Footnotes for Table C403.3(10):

a. For a system where all of the cooling equipment is subject to the AHRI standards listed in Tables C403.2.3(1) and C403.2.3(2), the system shall comply with ((~~all of the following~~)) the higher equipment efficiency, part-load control and economizer requirements of the row in which this footnote is located, including the associated footnotes (note that if the system contains any cooling equipment that exceeds the capacity limits in Table C403.2.3(1) or C403.2.3(2), or if the system contains any cooling equipment that is not included in Table C403.2.3(1) or C403.2.3(2), then the system is not allowed to use this option).
b. The cooling equipment shall have an SEER/EER value and an *IEER*/*IPLV* value that each is a minimum of 15 percent greater than the value listed in Tables C403.2.3(1) and C403.2.3(2).
c. For units with a total cooling capacity over 85,000 Btu/h, the system shall utilize part-load capacity control schemes that are able to modulate to a part-load capacity of 50 percent of the load or less that results in the compressor operating at the same or higher EER at part loads than at full load (e.g., minimum of two-stages of compressor unloading such as cylinder unloading, two-stage scrolls, dual tandem scrolls, but hot gas bypass is not credited as a compressor unloading system).
d. The cooling equipment shall have an SEER/EER value and an *IEER*/*IPLV* value that each is a minimum of 5 percent greater than the value listed in Tables C403.2.3(1) and C403.2.3(2).
e. The system shall include a water economizer in lieu of air economizer. Water economizers shall meet the requirements of Sections C403.3.1 and C403.3.2 and be capable of providing the total concurrent cooling load served by the connected terminal equipment lacking airside economizer, at outside air temperatures of 50°F dry-bulb/45°F wet-bulb and below. For this calculation, all factors including solar and internal load shall be the same as those used for peak load calculations, except for the outside temperatures. The equipment shall be served by a dedicated condenser water system unless a nondedicated condenser water system exists that can provide appropriate water temperatures during hours when waterside economizer cooling is available.
f. For a system where all cooling equipment is subject to ASHRAE Standard 127, the system shall comply with the higher equipment efficiency, part-load control and economizer requirements of the row in which this footnote is located, including the associated footnotes.
g. The cooling equipment subject to ASHRAE Standard 127 shall have an SCOP ((~~EER value and an *IPLV*~~)) value that is ((~~equal or~~)) a minimum of 10 percent greater than the value listed in Tables C403.2.3(1) and C403.2.3(2) (1.10 x values in these tables) when determined in accordance with the rating conditions in ASHRAE Standard 127 (i.e., not the rating conditions in AHRI Standard 210/240 or 340/360). This information shall be provided by an independent third party.

h. For a system with chillers subject to the AHRI standards listed in Table C403.2.3(7) (e.g. a chilled water system with fan coil units), the system shall comply with the higher equipment efficiency, part-load control and economizer requirements of the row in which this footnote is located, including the associated footnotes.

i. The cooling equipment shall have an full-load EER value and an *IPLV* value that is a minimum of 25 percent greater than the value listed in Table C403.2.3(7) (1.25 x value in Table C403.2.3(7) or a full-load and *IPLV* kW/ton that is at least 25 percent lower than the value listed in Table C403.2.3(7) (0.75 x value in Table C403.2.3(7)).

j. For all chillers, the system shall utilize part-load capacity control schemes that are able to modulate to a part-load capacity of 50 percent of the load or less and that result in the compressor operating at the same or higher EER at part loads than at full load (e.g., minimum of two-stages of compressor unloading such as cylinder unloading, two-stage scrolls, or dual tandem scrolls, but hot gas bypass is not a qualifying compressor unloading system).

k. For air-cooled chillers, the cooling equipment shall have an *IPLV* EER value that is a minimum of 10 percent greater than the *IPLV* EER value listed in Table C403.2.3(7) (1.10 x values in Table C403.2.3(7). For water-cooled chillers, the cooling equipment shall have an *IPLV* kW/ton that is at least 15 percent lower than the IPLV kW/ton value listed in Table C403.2.3(7) (0.85 x values in Table C403.2.3(7)).

TABLE C403.3(3)
EQUIPMENT EFFICIENCY PERFORMANCE EXCEPTION FOR ECONOMIZERS

Climate Zone	Efficiency Improvement[a]
4C	64%
5B	59%

a. If a unit is rated with an *IPLV, IEER* or SEER then to eliminate the required air or water economizer, the minimum cooling efficiency of the HVAC unit must be increased by the percentage shown. If the HVAC unit is only rated with a full load metric like EER or COP cooling, then these must be increased by the percentage shown.

C403.3.1 Integrated economizer control. Economizer systems shall be integrated with the mechanical cooling system and be capable of providing partial cooling even where additional mechanical cooling is required to provide the remainder of the cooling load. Controls shall not be capable of creating a false load in the mechanical cooling systems by limiting or disabling the economizer or any other means, such as hot gas bypass, except at the lowest stage of mechanical cooling.

Units that include an air economizer shall comply with the following:

1. Unit controls shall have the mechanical cooling capacity control interlocked with the air economizer controls such that the outdoor air damper is at the 100 percent open position when mechanical cooling is on and the outdoor air damper does not begin to close to prevent coil freezing due to minimum compressor run time until the leaving air temperature is less than 45°F (7°C).
2. Direct expansion (DX) units with cooling capacity 65,000 Btu/H (19 kW) or greater of rated capacity shall comply with the following:
   2.1. DX units that control the capacity of the mechanical cooling directly based on occupied space temperature shall have not fewer than two stages of mechanical cooling capacity.
   2.2. Other DX units, including those that control space temperature by modulating the airflow to the space, shall be in accordance with Table C403.3.1.

C403.3.2 Economizer heating system impact. HVAC system design and economizer controls shall be such that economizer operation does not increase building heating energy use during normal operation.

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

C403.3.3 Air economizers. Air economizers shall comply with Sections C403.3.3.1 through C403.3.3.5.

C403.3.3.1 Design capacity. Air economizer systems shall be configured to modulate *outdoor air* and return air dampers to provide up to 100 percent of the design supply air quantity as *outdoor air* for cooling.

C403.3.3.2 Control signal. Economizer controls and dampers shall be configured to sequence the dampers with mechanical cooling equipment and shall not be controlled by only mixed air temperature. Air economizers on systems with cooling capacity greater than 65,000 Btu/h shall be configured to provide partial cooling even when additional mechanical cooling is required to meet the remainder of the cooling load.

Exception: The use of mixed air temperature limit control shall be permitted for systems that are both controlled from space temperature (such as single-*zone* systems) and having cooling capacity less than 65,000 Btu/h.

C403.3.3.3 High-limit shutoff. Air economizers shall be configured to automatically reduce *outdoor air* intake to the design minimum *outdoor air* quantity when *outdoor air* intake will no longer reduce cooling energy usage. High-limit shutoff control types for specific climates shall be chosen from Table C403.3.3.3. High-limit shutoff control settings for these control types shall be those specified in Table C403.3.3.3.

C403.3.3.4 Relief of excess outdoor air. Systems shall be capable of relieving excess *outdoor air* during air economizer operation to prevent over-pressurizing the building. The relief air outlet shall be located to avoid recirculation into the building.

C403.3.3.5 Economizer dampers. Return, exhaust/relief and outdoor air dampers used in economizers shall comply with Section C403.2.4.3.

TABLE C403.3.1
DX COOLING STAGE REQUIREMENTS FOR MODULATING AIRFLOW UNITS

Rating Capacity	Minimum Number of Mechanical Cooling Stages	Minimum Compressor Displacement[a]
≥ 65,000 Btu/h and < 240,000 Btu/h	3 stages	≤ 35% of full load
≥ 240,000 Btu/h	4 stages	≤ 25% of full load

a. For *mechanical cooling* stage control that does not use variable compressor displacement, the percent displacement shall be equivalent to the mechanical cooling capacity reduction evaluated at the full load rating conditions for the compressor.

TABLE C403.3.3.3
HIGH-LIMIT SHUTOFF CONTROL SETTING FOR AIR ECONOMIZERS[b]

DEVICE TYPE	CLIMATE ZONE	REQUIRED HIGH LIMIT (ECONOMIZER OFF WHEN):	
		EQUATION	DESCRIPTION
Fixed dry bulb	4C, 5B	T_{OA} > 75°F	Outdoor air temperature exceeds 75°F
Differential dry bulb	4C, 5B	$T_{OA} > T_{RA}$	Outdoor air temperature exceeds return air temperature
Fixed enthalpy with fixed dry-bulb temperatures	All	h_{OA} > 28 Btu/lb[a] or T_{OA} > 75°F	Outdoor air enthalpy exceeds 28 Btu/lb of dry air[a] or outdoor temperature exceeds 75°F
Differential enthalpy with fixed dry-bulb temperatures	All	$h_{OA} > H_{RA}$ or T_{OA} > 75°F	Outdoor air enthalpy exceeds return air enthalpy or outdoor temperature exceeds 75°F

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

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

b. Devices with selectable setpoint shall be capable of being set to within 2°F and 2 Btu/lb of the setpoint listed.

C403.3.4 Water-side economizers. Water-side economizers shall comply with Sections C403.3.4.1 and C403.3.4.2.

C403.3.4.1 Design capacity. Water economizer systems shall be capable of cooling supply air by indirect evaporation and providing up to 100 percent of the expected system cooling load at *outdoor air* temperatures of not greater than 50°F (10°C) dry bulb/45°F (7.2°C) wet-bulb.

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

C403.3.4.2 Maximum pressure drop. Precooling coils and water-to-water heat exchangers used as part of a water economizer system shall either have a water-side pressure drop of less than 15 feet (4572 mm) of water or a secondary loop shall be created so that the coil or heat exchanger pressure drop is not seen by the circulating pumps when the system is in the normal cooling (noneconomizer) mode.

C403.4 Hydronic and multiple-zone HVAC systems controls and equipment (*Prescriptive*). Hydronic and multiple-zone HVAC system controls and equipment shall comply with this section.

For buildings with a total equipment cooling capacity of 300 tons and above, the equipment shall comply with one of the following:

1. No one unit shall have a cooling capacity of more than 2/3 of the total installed cooling equipment capacity.
2. The equipment shall have a variable speed drive.
3. The equipment shall have multiple compressors.

C403.4.1 Multiple-zone system fan control. Controls shall be provided for fans in accordance with Sections C403.4.1.1 through C403.4.1.2.

C403.4.1.1 Static pressure sensor location. Static pressure sensors used to control VAV fans shall be located such that the controller setpoint is no greater than 1.2 inches w.g. (2099 Pa). Where this results in one or more sensors being located downstream of major duct splits, not less than one sensor shall be located on each major branch to ensure that static pressure can be maintained in each branch.

Exception: Systems complying with Section C403.4.1.2.

C403.4.1.2 Set points for direct digital control. For systems with direct digital control of individual *zones* reporting to the central control panel, the static pressure setpoint shall be reset based on the *zone* requiring the most pressure. In such cases, the set point is reset lower until one zone damper is nearly wide open. The direct digital controls shall be capable of monitoring zone damper positions or shall have an alternative method of

indicating the need for static pressure that is configured to provide all of the following:

1. Automatically detecting any zone that excessively drives the reset logic.
2. Generating an alarm to the system operational location.
3. Allowing an operator to readily remove one or more zones from the reset algorithm.

C403.4.2 Hydronic systems controls. The heating of fluids that have been previously mechanically cooled and the cooling of fluids that have been previously mechanically heated shall be limited in accordance with Sections C403.4.2.1 through C403.4.2.3. 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 configured to sequence operation of the boilers. Hydronic heating systems comprised of a single boiler and greater than 500,000 Btu/h (146,550 W) input design capacity shall include either a multi-staged or modulating burner.

C403.4.2.1 Three-pipe system. Hydronic systems that use a common return system for both hot water and chilled water are prohibited.

C403.4.2.2 Two-pipe changeover system. Systems that use a common distribution system to supply both heated and chilled water shall be designed to allow a dead band between changeover from one mode to the other of at least 15°F (8.3°C) outside air temperatures; be designed to and provided with controls that will allow operation in one mode for at least 4 hours before changing over to the other mode; and be provided with controls that allow heating and cooling supply temperatures at the changeover point to be no more than 30°F (16.7°C) apart.

C403.4.2.3 Hydronic (water loop) heat pump systems. Hydronic heat pump systems shall comply with Sections C403.4.2.3.1 through C403.4.2.3.3.

C403.4.2.3.1 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 configured to provide 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 real time conditions of demand and capacity, dead bands of less than 20°F (11°C) shall be permitted.

C403.4.2.3.2 Heat rejection. Heat rejection equipment shall comply with Sections C403.4.2.3.2.1 and C403.4.2.3.2.2.

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

C403.4.2.3.2.1 Climate Zone 4. For Climate Zone 4:

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

C403.4.2.3.2.2 Climate Zone 5. For Climate Zone 5, if an open- or closed-circuit cooling tower is used, then a separate heat exchanger shall be provided to isolate the cooling tower from the heat pump loop, and heat loss shall be controlled by shutting down the circulation pump on the cooling tower loop and providing an *automatic* valve to stop the flow of fluid.

C403.4.2.3.3 Isolation valve. Each hydronic heat pump on the hydronic system having a total pump system power exceeding 10 horsepower (hp) (7.5 kW) shall have a two-way (but not three-way) valve. For the purposes of this section, pump system power is the sum of the nominal power demand (i.e., nameplate horsepower at nominal motor efficiency) of motors of all pumps that are required to operate at design conditions to supply fluid from the heating or cooling source to all heat transfer devices (e.g., coils, heat exchanger) and return it to the source. This converts the system into a variable flow system and, as such, the primary circulation pumps shall comply with the variable flow requirements in Section ((~~C403.4.2.6~~)) C403.4.2.7.

C403.4.2.4 Part load controls. Hydronic systems greater than or equal to 300,000 Btu/h (88 kW) in design output capacity supplying heated or chilled water to comfort conditioning systems shall include controls that are configured to:

1. Automatically reset the supply-water temperatures in response to varying building heating and cooling demand using coil valve position, zone-return water temperature or outdoor air temperature. The temperature shall be reset by not less than 25

percent of the design supply-to-return water temperature difference.

Exception: Hydronic systems serving hydronic heat pumps.

2. Automatically vary fluid flow for hydronic systems with a combined motor capacity of 3 hp or larger with three or more control valves or other devices by reducing the system design flow rate by not less than 50 percent by designed valves that modulate or step open and close, or pumps that modulate or turn on and off as a function of load.
3. Automatically vary pump flow on chilled-water systems and heat rejection loops serving water-cooled unitary air conditioners with a combined motor capacity of 3 hp or larger by reducing pump design flow by not less than 50 percent utilizing adjustable speed drives on pumps, or multiple-staged pumps where not less than one-half of the total pump horsepower is capable of being automatically turned off. Pump flow shall be controlled to maintain one control valve nearly wide open or to satisfy the minimum differential pressure.

Exceptions:

1. Supply-water temperature reset for chilled-water systems supplied by off-site district chilled water or chilled water from ice storage systems.
2. Minimum flow rates other than 50 percent as required by the equipment manufacturer for proper operation of equipment where using flow bypass or end-of-line 3-way valves.
3. Variable pump flow on dedicated equipment circulation pumps where configured in primary/secondary design to provide the minimum flow requirements of the equipment manufacturer for proper operation of equipment.

C403.4.2.5 Boiler turndown. *Boiler systems* with design input of greater than 1,000,000 Btu/h (293 kW) shall comply with the turndown ratio specified in Table C403.4.2.5.

The system turndown requirement shall be met through the use of multiple single input boilers, one or more *modulating boilers* or a combination of single input and modulating boilers.

TABLE C403.4.2.5
BOILER TURNDOWN

Boiler System Design Input (Btu/h)	Minimum Turndown Ratio
≥1,000,000 and less than or equal to 5,000,000	3 to 1
> 5,000,000 and less than or equal to 10,000,000	4 to 1
>10,000,000	5 to 1

C403.4.2.6 Pump isolation. Chilled water plants including more than one chiller shall be capable of and configured to reduce flow automatically through the chiller plant when a chiller is shut down and automatically shut off flow to chillers that are shut down. Chillers piped in series for the purpose of increased temperature differential shall be considered as one chiller.

Exception: Chillers that are piped in series for the purpose of increased temperature differential.

Boiler plants including more than one boiler shall be capable of and configured to reduce flow automatically through the boiler plant when a boiler is shut down.

C403.4.2.7 Variable flow controls. Individual pumps required by this code to have variable speed control shall be controlled in one of the following manners:

1. For systems having a combined pump motor horsepower less than or equal to 20 hp (15 kW) and without direct digital control of individual coils, pump speed shall be a function of either:
   1.1. Required differential pressure; or
   1.2. Reset directly based on zone hydronic demand, or other zone load indicators; or
   1.3. Reset directly based on pump power and pump differential pressure.
2. For systems having a combined pump motor horsepower that exceeds 20 hp (15 kW) or smaller systems with direct digital control, pump speed shall be a function of either:
   2.1. The static pressure set point as reset based on the valve requiring the most pressure; or
   2.2. Directly controlled based on zone hydronic demand.

C403.4.3 Heat rejection equipment. Heat rejection equipment such as air-cooled condensers, dry coolers, open-circuit cooling towers, closed-circuit cooling towers and evaporative condensers used for comfort cooling applications shall comply with this section.

Exception: Heat rejection devices where energy use is included in the equipment efficiency ratings listed in Tables C403.2.3(1)A, C403.2.3(1)B, C403.2.3(1)C, C403.2.3(2), C403.2.3(3), C403.2.3(7) and C403.2.3(9).

C403.4.3.1 Fan speed control. The fan speed shall be controlled as provided in Sections C403.4.3.1.1 and C403.4.3.1.2.

C403.4.3.1.1 Fan motors not less than 7.5 hp. Each fan powered by a motor of 7.5 hp (5.6 kW) or larger shall have controls that automatically change the fan speed to control the leaving fluid temperature or condensing temperature/pressure of the heat rejection device.

C403.4.3.1.2 Multiple-cell heat rejection equipment. Multiple-cell heat rejection equipment with variable speed fan drives shall be controlled in both of the following manners:

1. To operate the maximum number of fans allowed that comply with the manufacturer's requirements for all system components.
2. So all fans can operate at the same fan speed required for the instantaneous cooling duty, as opposed to staged (on/off) operation. Minimum fan speed shall be the minimum allowable speed of the fan drive system in accordance with the manufacturer's recommendations.

C403.4.3.2 Limitation on centrifugal fan open-circuit cooling towers. Centrifugal fan open-circuit cooling towers with a combined rated capacity of 1,100 gpm (4164 L/m) or greater at 95°F (35°C) condenser water return, 85°F (29°C) condenser water supply, and 75°F (24°C) outdoor air wet-bulb temperature shall meet the energy efficiency requirement for axial fan open-circuit cooling towers listed in Table C403.2.3(8).

Exception: Centrifugal open-circuit cooling towers that are designed with inlet or discharge ducts or require external sound attenuation.

C403.4.3.3 Tower flow turndown. Open-circuit cooling towers used on water-cooled chiller systems that are configured with multiple- or variable-speed condenser water pumps shall be designed so that all open circuit cooling tower cells can be run in parallel with the larger of the flow that is produced by the smallest pump at its minimum expected flow rate or at 50 percent of the design flow for the cell.

C403.4.4 Requirements for mechanical systems serving multiple zones. Sections C403.4.4.1 through C403.4.4.4 shall apply to mechanical systems serving multiple zones. Supply air systems serving multiple zones shall be VAV systems which, during periods of occupancy, are designed and configured to reduce primary air supply to each *zone* to one of the following before reheating, recooling or mixing takes place:

1. Thirty percent of the maximum supply air to each *zone*.
2. Three hundred cfm (142 L/s) or less where the maximum flow rate is less than 10 percent of the total fan system supply airflow rate.
3. The minimum ventilation requirements of Chapter 4 of the *International Mechanical Code.*
4. Any higher rate that can be demonstrated to reduce overall system annual energy use by offsetting reheat/recool energy losses through a reduction in *outdoor* air intake for the system, as *approved* by the *code official.*
5. The airflow rate required to comply with applicable codes or accreditation standards, such as pressure relationships or minimum air change rates.

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

1. *Zones* or supply air systems where not less than 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.
2. *Zones* where special humidity levels are required to satisfy process needs.
3. *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.
4. *Zones* without DDC for which the volume of air that is reheated, recooled or remixed is less than the larger of the following:
   4.1. 30 percent of the zone design peak supply rate.
   4.2. The outdoor airflow rate required to meet the ventilation requirements of Chapter 4 of the *International Mechanical Code* for the zone.
   4.3. Any higher rate that can be demonstrated, to the satisfaction of the code official, to reduce overall system annual energy usage by offsetting reheat/recool energy losses through a reduction in outdoor air intake for the system.
   4.4. The airflow rate required to comply with applicable codes or accreditation standards, such as pressure relationships or minimum air change rates.
5. *Zones* with DDC that comply with all of the following:
   5.1. The airflow rate in dead band between heating and cooling does not exceed the larger of the following:
      5.1.1. 20 percent of the zone design peak supply rate.
      5.1.2. The outdoor airflow rate required to meet the ventilation requirements of Chapter 4 of the International Mechanical Code for the zone.
      5.1.3. Any higher rate that can be demonstrated, to the satisfaction

of the code official, to reduce overall system annual energy usage by offsetting reheat/recool energy losses through a reduction in outdoor air intake for the system.

5.1.4. The airflow rate required to comply with applicable codes or accreditation standards, such as pressure relationships or minimum air change rates.

5.2. The airflow rate that is reheated, recooled or mixed shall be less than 50 percent of the zone design peak supply rate.

5.3. The first stage of heating consists of modulating the zone supply air temperature setpoint up to a maximum setpoint while the airflow is maintained at the dead band flow rate.

5.4. The second stage of heating consists of modulating the airflow rate from the dead band flow rate up to the heating maximum flow rate.

6. *Zones* or supply air systems with thermostatic and humidistatic controls capable of operating in sequence the supply of heating and cooling energy to the *zones* and which are configured to 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.

C403.4.4.1 Single-duct VAV systems, terminal devices. Single-duct VAV systems shall use terminal devices capable of reducing the supply of primary supply air before reheating or recooling takes place.

C403.4.4.2 Dual-duct and mixing VAV systems, terminal devices. Systems that have one warm air duct and one cool air duct shall use terminal devices that are capable of reducing the flow from one duct to a minimum before mixing of air from the other duct takes place.

C403.4.4.3 Multiple-zone VAV system ventilation optimization controls. Multiple-zone VAV systems with direct digital control of individual zone boxes reporting to a central control panel shall have *automatic* controls configured to reduce outdoor air intake flow below design rates in response to changes in system ventilation efficiency (Ev) as defined by the *International Mechanical Code*.

Exceptions:

1. VAV systems with zonal transfer fans that recirculate air from other zones without directly mixing it with outdoor air, dual-duct dual-fan VAV systems, and VAV systems with fan-powered terminal units.
2. Systems having exhaust air energy recovery complying with Section C403.5.
3. Systems where total design exhaust airflow is more than 70 percent of total design outdoor air intake flow requirements.

C403.4.4.4 Supply-air temperature reset controls. Multiple *zone* HVAC systems shall include controls that automatically reset the supply-air temperature in response to representative building loads, or to outdoor air temperature. The controls shall be capable of resetting the supply air temperature at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.

Exceptions:

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

C403.4.5 Reserved. (See C403.5.4 for Heat recovery for service water heating.)

C403.4.6 Hot gas bypass limitation. Cooling systems shall not use hot gas bypass or other evaporator pressure control systems unless the system is designed with multiple steps of unloading or continuous capacity modulation. The capacity of the hot gas bypass shall be limited as indicated in Table C403.4.6, as limited by Section C403.3.1

TABLE C403.4.6
MAXIMUM HOT GAS BYPASS CAPACITY

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

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

C403.4.7 Hydronic System Design: All chilled water and condenser water piping shall be designed such that the design flow rate in each pipe segment shall not exceed the values listed in Table C403.4.7 for the appropriate total annual hours of operation. Pipe size selections for systems that operate under variable flow conditions (e.g. modulating 2-way control valves at coils) and that contain variable speed pump motors are allowed to be made from the "Variable Flow/ Variable Speed" columns. All others shall be made from the "Other" columns.

EXCEPTION: Design flow rates exceeding the values in Table C403.4.7 are allowed in specific sections of pipe if the pipe is not in the critical circuit at design conditions and is not predicted to be in the critical circuit during more than 30 percent of operating hours.

SDCI Informative Note: The flow rates listed here do not consider noise or erosion. Lower flow rates are often recommended for noise sensitive locations.

TABLE C403.4.7
PIPING SYSTEM DESIGN MAXIMUM FLOW RATE IN GPM[1]

Pipe Size (in)	<=2000 hours/yr		>2000 and <=4400 hours/year		> 4400 hours/year	
	Other	Variable Flow/Variable Speed	Other	Variable Flow/Variable Speed	Other	Variable Flow/Variable Speed
2 ½	120	180	85	130	68	110
3	180	270	140	210	110	170
4	350	530	260	400	210	320
5	410	620	310	470	250	370
6	740	1100	570	860	440	680
8	1200	1800	900	1400	700	1100
10	1800	2700	1300	2000	1000	1600
12	2500	3800	1900	2900	1500	2300

1 There are no requirements for pipe sizes smaller than the minimum shown in the table or larger than the maximum shown in the table.

** **C403.5 Energy recovery.**

C403.5.1 Energy recovery ventilation systems. Any system with minimum outside air requirements at design conditions greater than 5,000 cfm or any system where the system's supply airflow rate exceeds the value listed in Tables C403.5.1(1) and C403.5.1(2)m based on the climate zone and percentage of outdoor airflow rate at design conditions, shall include an energy recovery system. Table C403.5.1(1) shall be used for all ventilation systems that operate less than 8,000 hours per year, and Table C403.5.1(2) shall be used for all ventilation systems that operate 8,000 hours or more per year. The energy recovery system shall have the capability to provide a change in the enthalpy of the outdoor air supply of not less than 50 percent of the difference between the outdoor air and return air enthalpies, at design conditions. Where an air economizer is required, the energy recovery system shall include a bypass or controls which permit operation of the economizer as required by Section C403.3. Where a single room or space is supplied by multiple units, the aggregate ventilation (cfm) of those units shall be used in applying this requirement. The return/exhaust air stream temperature for heat recovery device selection shall be 70°F (21°C) at 30 percent relative humidity, or as calculated by the registered design professional.

SDCI Informative Note: In Seattle, the energy recovery effectiveness is determine typically by the winter heat recovery condition. See example below for how the minimum supply air enthalpy leaving the energy recovery media is calculated for the winter condition:

1. In Seattle, the winter outdoor design air temperature is 24°F as specified in Appendix C. The registered design professional shall determine the coincident winter wetbulb temperature or percent relative humidity at the anticipated design conditions. Based on these conditions the outdoor design air enthalpy is determined from a psychrometric chart.
2. Determine the return/exhaust air stream enthalpy from a psychrometric chart based on the 70°F (21°C) at 30 percent relative humidity.
3. Calculate the 50% difference between the outside air and return air enthalpies at design winter conditions.
4. See example below:
   a. OA Enthalpy at 24°F / 23°F (drybulb / wetbulb) = 8.2 BTU/LB
   b. RA/EA Enthalpy at 70°F and 30% RH = 21.9 BTU/LB
   c. SA Enthalpy Minimum Leaving Energy Recovery Media
      = (8.2 + (21.9 – 8.2)*50%)
      = 15.05 BTU/LB

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

1. Where energy recovery systems are restricted per Section 514 of the *International Mechanical Code* to sensible energy, recovery shall comply with one of the following:
   1.1. Kitchen exhaust systems where they comply with Section C403.2.7.1.
   1.2. Laboratory fume hood systems where they comply with Exception 2 of Section C403.5.1.
   1.3. Other sensible energy recovery systems with the capability to provide a change in dry bulb temperature of the outdoor air supply of not less than 50 percent of the difference between the outdoor air and the return air dry bulb temperatures, at design conditions.
2. Laboratory fume hood systems that include at least one of the following features and also comply with Section C403.2.7.2:

2.1. Variable-air-volume hood exhaust and room supply systems capable of reducing exhaust and makeup air volume to 50 percent or less of design values.

2.2. Direct makeup (auxiliary) air supply equal to at least 75 percent of the exhaust rate, heated no warmer than 2°F (1.1°C) above room setpoint, cooled to no cooler than 3°F (1.7°C) below room setpoint, no humidification added, and no simultaneous heating and cooling used for dehumidification control.

3. Systems serving spaces that are heated to less than 60°F (15.5°C) and are not cooled.

4. Where more than 60 percent of the outdoor heating energy is provided from site-recovered or site solar energy.

5. Systems exhausting toxic, flammable, paint or corrosive fumes or dust.

6. Cooling energy recovery in Climate Zones 3C, 4C, 5B, 5C, 6B, 7 and 8.

7. Systems requiring dehumidification that employ energy recovery in series with the cooling coil.

8. Multi-zone systems where the supply airflow rate is less than the values specified in Tables C403.5.1(1) and C403.5.1(2) for the corresponding percent of outdoor air. Where a value of NR is listed, energy recovery shall not be required.

TABLE C403.5.1(1)
ENERGY RECOVERY REQUIREMENT
(VENTILATION SYSTEMS OPERATING LESS THAN 8,000 HOURS PER YEAR)

CLIMATE ZONE	PERCENT (%) OUTDOOR AIR AT FULL DESIGN AIRFLOW RATE							
	≥ 10% and < 20%	≥ 20% and < 30%	≥ 30% and < 40%	≥ 40% and < 50%	≥ 50% and < 60%	≥ 60% and < 70%	≥70% and < 80%	≥ 80%
	DESIGN SUPPLY FAN AIRFLOW RATE (cfm)							
4C, 5B	NR	NR	NR	NR	NR	NR	≥5000	≥ 5000

NR = not required

TABLE C403.5.1(2)
ENERGY RECOVERY REQUIREMENT
(VENTILATION SYSTEMS OPERATING NOT LESS 8,000 HOURS PER YEAR)

CLIMATE ZONE	PERCENT (%) OUTDOOR AIR AT FULL DESIGN AIRFLOW RATE							
	≥ 10% and < 20%	≥ 20% and < 30%	≥ 30% and < 40%	≥ 40% and < 50%	≥ 50% and < 60%	≥ 60% and < 70%	≥70% and < 80%	80%
	DESIGN SUPPLY FAN AIRFLOW RATE (cfm)							
4C	NR	≥ 19500	≥ 9000	≥ 5000	≥ 4000	≥ 3000	≥ 1500	≥ 0
5B	≥ 2500	≥ 2000	≥ 1000	≥ 500	≥ 0	≥ 0	≥ 0	≥ 0

NR = not required

9. Systems serving Group R dwelling or *sleeping units* where the largest source of air exhausted at a single location at the building exterior is less than 25 percent of the design outdoor air flow rate.

C403.5.2 Condensate systems. On-site steam heating systems shall have condensate water ((~~heat~~)) recovery. On-site includes a system that is located within or adjacent to one or more buildings within the boundary of a contiguous area or campus under one ownership and which serves one or more of those buildings.

Buildings using steam generated off-site with steam heating systems which do not have condensate water recovery shall have condensate water heat recovery.

C403.5.3 Condenser heat recovery. Facilities having food service, meat or deli departments and having 500,000 Btu/h or greater of remote refrigeration condensers shall have condenser waste heat recovery from freezers and coolers and shall use the waste heat for service water heating, space heating or for dehumidification reheat. Facilities having a gross *conditioned floor area* of 40,000 ft^2 or greater and 1,000,000 Btu/h or greater of remote refrigeration shall have condenser waste heat recovery from freezers and coolers and shall use the waste heat for service water heating, and either for space heating or for dehumidification reheat for maintaining low space humidity. The required heat recovery system shall have the capacity to provide the smaller of:

1. 60 percent of the peak heat rejection load at design conditions; or

2. 50 percent of the sum of the service water heating load plus space heating load.

C403.5.4 Heat recovery for service water heating. Condenser heat recovery shall be installed for heating or reheating of service hot water provided the facility operates 24 hours a day, the total installed heat capacity of water cooled systems exceeds 1,500,000 Btu/hr of heat rejection, and the design service water heating load exceeds 250,000 Btu/hr.

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

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

Exceptions:

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

* **C403.6 Dedicated outdoor air systems (DOAS). (This section is Optional through 6/30/2017; it becomes *Prescriptive* as of 7/1/2017).** For office, retail, education, libraries and fire stations, outdoor air shall be provided to each occupied space by a dedicated outdoor air system (DOAS) which delivers 100 percent outdoor air without requiring operation of the heating and cooling system fans for ventilation air delivery.

Exceptions:

1. Occupied spaces that are not ventilated by a mechanical ventilation system and are only ventilated by a natural ventilation system per Section 402 of the *International Mechanical Code*.
2. High efficiency variable air volume (VAV) systems complying with Section C403.7. This exception shall not be used as a substitution for a DOAS per Section C406.6 or as a modification to the requirements for the Standard Reference Design per Section C407.
3. Spaces that are within building types not covered by Section C403.6 and that qualify as accessory occupancies according to Section 508.2 of the *International Building Code* are not required to comply with this section.

C403.6.1 Energy recovery ventilation with DOAS. The DOAS shall include either *energy recovery ventilation* that complies with the minimum energy recovery efficiency and energy recovery bypass requirements, where applicable, of Section C403.5.1.

Exceptions:

1. Occupied spaces under the threshold of Section C403.5 with an average occupant load greater than 25 people per 1000 square feet (93 m^2) of floor area (as established in Table 403.3.1.1 of the *International Mechanical Code*) that include *demand control ventilation* configured to reduce outdoor air by at least 50% below design minimum ventilation rates when the actual occupancy of the space served by the system is less than the design occupancy.
2. Systems installed for the sole purpose of providing makeup air for systems exhausting toxic, flammable, paint, or corrosive fumes or dust, dryer exhaust, or commercial kitchen hoods used for collecting and removing grease vapors and smoke.

C403.6.2 Heating/cooling system fan controls. Heating and cooling equipment fans, heating and cooling circulation pumps, and terminal unit fans shall cycle off and terminal unit primary cooling air shall be shut off when there is no call for heating or cooling in the zone.

Exception: Fans used for heating and cooling using less than 0.12 watts per cfm may operate when space temperatures are within the setpoint deadband (Section C403.2.4.1.2) to provide destratification and air mixing in the space.

C403.6.3 Impracticality. Where the *code official* determines full compliance with all of the requirements of Section C403.6.1 and C403.6.2 would be impractical, it is permissible to provide an *approved* alternate means of compliance that achieves a comparable level of energy efficiency. For the purposes of this section, impractical means that an HVAC system complying with Section C403.6 cannot effectively be utilized due to an unusual use or configuration of the building.

C403.7 High efficiency variable air volume (VAV) systems. For HVAC systems subject to the requirements of Section C403.6 but utilizing Exception 2 of that section, a high efficiency VAV system may be provided without a separate parallel DOAS when the system is designed, installed, and configured to comply with all of the following criteria in addition to the applicable requirements of Sections C403.2.11.6 through C403.2.11.8 (this exception shall not be used as a substitution for a DOAS per Section C406.6 or as a modification to the requirements for the Standard Reference Design per Section C407):

1. The VAV systems are provided with airside economizer per Section 403.3 without exceptions.
2. A direct-digital control (DDC) system is provided to control the VAV air handling units and associated terminal units per Section C403.2.4.12 regardless of sizing thresholds of Table C403.2.4.12.1.
3. Multiple-zone VAV systems with a minimum outdoor air requirement of 2,500 cfm (1180 L/s) or greater shall be equipped with a device capable of measuring outdoor airflow intake under all load conditions. The system shall be capable of increasing or reducing the outdoor airflow intake based on feedback from the VAV terminal units as required by Section C403.4.4.3, without exceptions, and Section C403.2.6.2 demand controlled ventilation.
4. Multiple-zone VAV systems with a minimum outdoor air requirement of 2,500 cfm (1180 L/s) or greater shall be equipped with a device capable of measuring supply airflow to the VAV terminal units under all load conditions.

5. In addition to meeting the zone isolation requirements of C403.2.4.4 a single VAV air handling unit shall not serve more than 50,000 square feet (2323 m^2) unless a single floor is greater than 50,000 square feet (2323 m^2) in which case the air handler is permitted to serve the entire floor.
6. The primary maximum cooling air for the VAV terminal units serving interior cooling load driven zones shall be sized for a supply air temperature that is a minimum of 5°F greater than the supply air temperature for the exterior zones in cooling.
7. Air terminal units with a minimum primary airflow setpoint of 50% or greater of the maximum primary airflow setpoint shall be sized with an inlet velocity of no greater than 900 feet per minute.
8. DDC systems be designed and configured per the guidelines set by *High Performance Sequences of Operation for HVAC Systems* (ASHRAE GPC 36, RP-1455).
9. Allowable fan motor horsepower shall not exceed 90% of the allowable HVAC *fan system bhp* (Option 2) as defined by Section C403.2.11.1.
10. All fan powered VAV terminal units (series or parallel) shall be provided with electronically commutated motors. The DDC system shall be configured to vary the speed of the motor as a function of the heating and cooling load in the space. Minimum speed shall not be greater than 66 percent of design airflow required for the greater of heating or cooling operation. Minimum speed shall be used during periods of low heating and cooling operation and ventilation-only operation.

    Exception: For series fan powered terminal units where the volume of primary air required to deliver the ventilation requirements at minimum speed exceeds the air that would be delivered at the speed defined above, the minimum speed setpoint shall be configured to exceed the value required to provide the required ventilation air.
11. Fan-powered VAV terminal units shall only be permitted at perimeter zones with an envelope heating load requirement. All other VAV terminal units shall be single duct terminal units.
12. When in occupied heating or in occupied deadband between heating and cooling all fan powered VAV terminal units shall be configured to reset the primary air supply setpoint, based on the VAV air handling unit outdoor air vent fraction, to the minimum ventilation airflow required per *International Mechanical Code* without utilizing exceptions 2, 3, or 4 of Section C403.4.4.
13. Spaces that are larger than 150 square feet (14 m^2) and with an occupant load greater than or equal to 25 people per 1000 square feet (93 m^2) of floor area (as established in Table 403.3.1.1 of the *International Mechanical Code*) shall be provided with all of the following features:
    13.1. A dedicated VAV terminal unit capable of controlling the space temperature and minimum ventilation shall be provided.
    13.2. *Demand control ventilation (DCV)* shall be provided that utilizes a carbon dioxide sensor to reset the ventilation setpoint of the VAV terminal unit from the design minimum to design maximum ventilation rate as required by Chapter 4 of the *International Mechanical Code*.
    13.3. Occupancy sensors shall be provided that are configured to reduce the minimum ventilation rate to zero and setback room temperature setpoints by a minimum of 5°F, for both cooling and heating, when the space is unoccupied.
14. Dedicated server rooms, electronic equipment rooms, telecom rooms, or other similar spaces with cooling loads greater than 5 watts/ft^2 shall be provided with separate, independent HVAC systems to allow the VAV air handlers to turn off during unoccupied hours in the office space and to allow the supply air temperature reset to occur.

    Exception: The VAV air handling unit and VAV terminal units may be used for secondary backup cooling when there is a failure of the primary HVAC system.

    Additionally, server rooms, electronic equipment rooms, telecom rooms, or other similar spaces shall be provided with airside economizer per Section 403.3 without using the exceptions to Section C403.3.

    Exception: Heat recovery per exception 9 of Section 403.3 may be in lieu of airside economizer for the separate, independent HVAC system.
15. HVAC system central heating or cooling plant will include a minimum of one of the following options:
    15.1. VAV terminal units with hydronic heating coils connected to systems with hot water generation equipment limited to the following types of equipment: gas-fired hydronic boilers with a thermal efficiency, Et, of not less than 90 percent, air-to-water heat pumps or heat recovery chillers.
    15.2. Chilled water VAV air handing units connected to systems with chilled water generation equipment with *IPLV* values more than 25 percent higher than the minimum part load efficiencies listed in Table C403.2.3(7), in the appropriate size category, using the same test procedures. Equipment shall be listed in the appropriate certification program to qualify. The smallest chiller or compressor in the central plant shall not exceed 20% of the total central plant cooling capacity or the chilled water system shall include thermal storage sized for a minimum of 20% of the total central cooling plant capacity.

16. The DDC system shall include a fault detection and diagnostics (FDD) system complying with the following:
    16.1. The following temperature sensors shall be permanently installed to monitor system operation:
        16.1.1. Outside air.
        16.1.2. Supply air.
        16.1.3. Return air.
    16.2. Temperature sensors shall have an accuracy of ±2°F (1.1°C) over the range of 40°F to 80°F (4°C to 26.7°C).
    16.3. The VAV air handling unit controller shall be configured to provide system status by indicating the following:
        16.3.1. Free cooling available.
        16.3.2. Economizer enabled.
        16.3.3. Compressor enabled.
        16.3.4. Heating enabled.
        16.3.5. Mixed air low limit cycle active.
        16.3.6. The current value of each sensor.
    16.4. The VAV air handling unit controller shall be capable of manually initiating each operating mode so that the operation of compressors, economizers, fans and the heating system can be independently tested and verified.
    16.5. The VAV air handling unit shall be configured to report faults to a fault management application *accessible* by day-to-day operating or service personnel or annunciated locally on zone thermostats.
    16.6. The VAV terminal unit shall be configured to report if the VAV inlet valve has failed by performing the following diagnostic check at a maximum interval of once a month:
        16.6.1. Command VAV terminal unit primary air inlet valve closed and verify that primary airflow goes to zero or other *approved* means to verify that the VAV terminal unit damper actuator and flow ring are operating properly.
        16.6.2. Command VAV thermal unit primary air inlet valve to design airflow and verify that unit is controlling to with 10% of design airflow.
    16.7. The VAV terminal unit shall be configured to report and trend when the zone is driving the following VAV air handling unit reset sequences. The building operator shall have the capability to exclude zones used in the reset sequences from the DDC control system graphical user interface:
        16.7.1. Supply air temperature setpoint reset to lowest supply air temperature setpoint for cooling operation.
        16.7.2. Supply air duct static pressure setpoint reset for the highest duct static pressure setpoint allowable.
    16.8. The FDD system shall be configured to detect the following faults:
        16.8.1. Air temperature sensor failure/ fault.
        16.8.2. Not economizing when the unit should be economizing.
        16.8.3. Economizing when the unit should not be economizing.
        16.8.4. Outdoor air or return air damper not modulating.
        16.8.5. Excess outdoor air.
        16.8.6. VAV terminal unit primary air valve failure.

C403.8 Compressed air and vacuum air. Compressed air and vacuum air systems shall comply with all of the following:

EXCEPTION: Compressed air and vacuum air systems used for medical purposes are exempt from this section.

1. Air Compressors (50-150 PSI), General**:** Air compressors operating at 50-150 PSI shall comply with the following:
    a. All water drains shall be "no loss" drains.
    b. Timed unheated desiccant air driers shall not be allowed.
2. Rotary Screw Air Compressors over 10 hp (50-150 PSI)**:** Rotary screw air compressors over 10 hp operating at 50-150 PSI shall not rely on modulation control and shall have one of the following:
    a. Receiver capacity greater than three gallons per cfm to allow efficient load/unload control;
    b. Variable speed drive controlled air compressor; or
    c. Multiple air compressors using a smaller trim-air compressor to trim. The trim compressor shall use variable speed drive control, or shall use load/unload control with greater than three gallon receiver capacity per cfm for the trim air compressor.

C403.9 Commercial food service. The following types of equipment within the scope of the applicable Energy Star program shall comply with the energy-efficiency and water-efficiency criteria required to achieve the Energy Star label:

a. Commercial fryers: Energy Star Program Requirements for Commercial Fryers.
b. Commercial hot food holding cabinets: Energy Star Program Requirements for Hot Food Holding Cabinets.

c. Commercial steam cookers: Energy Star Program Requirements for Commercial Steam Cookers.

d. Commercial dishwashers: Energy Star Program Requirements for Commercial Dishwashers.

SECTION C404
SERVICE WATER HEATING (*MANDATORY*)

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

C404.2 Service water-heating equipment performance efficiency. Water-heating equipment and hot water storage tanks shall meet the requirements of Table C404.2. The efficiency shall be verified through certification and *listed* under an *approved* certification program, or if no certification program exists, the equipment efficiency ratings shall be supported by data furnished by the manufacturer. Water-heating equipment also intended to be used to provide space heating shall meet the applicable provisions of Table C404.2.

C404.2.1 High input-rated service water-heating systems. Gas-fired water-heating equipment installed in new buildings shall be in compliance with this section. Where a singular piece of water-heating equipment serves the entire building and the input rating of the equipment is 1,000,000 Btu/h (293 kW) or greater, such equipment shall have a thermal efficiency, E_t, of not less than 90 percent. Where multiple pieces of water-heating equipment serve the building and the combined input rating of the water-heating equipment is 1,000,000 Btu/h (293 kW) or greater, the combined input-capacity-weighted-average thermal efficiency, E_t, shall be not less than 90 percent.

Exceptions:

1. Where 25 percent of the annual service water-heating requirement is provided by site-solar or site-recovered energy, the minimum thermal efficiency requirements of this section shall not apply.
2. The input rating of water heaters installed in individual dwelling units shall not be required to be included in the total input rating of *service water-heating* equipment for a building.
3. The input rating of water heaters with an input rating of not greater than 100,000 Btu/h (29 kW) shall not be required to be included in the total input rating of service water-heating equipment for a building.

TABLE C404.2
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 - 0.00 132*V*, EF	DOE 10 CFR Part 430
	> 12 kW	Resistance	$(0.3 + 27/V_m)$, %/h	Section G.2 of ANSI Z21.10.3
	≤ 24 amps and ≤ 250 volts	Heat pump	0.93 - 0.00132*V*, EF	DOE 10 CFR Part 430
Instantaneous water heaters, electric	All	Resistance	0.97 - 0.00132*V*, EF	DOE 10 CFR Part 430
Storage water heaters, gas	≤ 75,000 Btu/h	≥ 20 gal	0.67 - 0.0019*V*, EF	DOE 10 CFR Part 430
	> 75,000 Btu/h and ≤ 155,000 Btu/h	< 4,000 Btu/h/gal	80% E_t $(Q/800 + 110\sqrt{V})SL$, Btu/h	Section G.1 and G.2 of ANSI Z21.10.3
Instantaneous water heaters, gas	> 50,000 Btu/h and < 200,000 Btu/h[c]	≥ 4,000 (Btu/h)/gal and < 2 gal	0.62 - 0.00 19*V*, EF	DOE 10 CFR Part 430
	≥ 200,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	80% E_t	Section G.1 and G.2 of ANSI Z21.10.3
	≥ 200,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal	80% E_t $(Q/800 + 110\sqrt{V})SL$, Btu/h	
Storage water heaters, oil	≤ 105,000 Btu/h	≥ 20 gal	0.59 - 0.0019*V*, EF	DOE 10 CFR Part 430
	≥ 105,000 Btu/h	< 4,000 Btu/h/gal	80% E_t $(Q/800 + 110\sqrt{V})SL$, Btu/h	Section G.1 and G.2 of ANSI Z21.10.3

TABLE C404.2—continued
MINIMUM PERFORMANCE OF WATER-HEATING EQUIPMENT

EQUIPMENT TYPE	SIZE CATEGORY (input)	SUBCATEGORY OR RATING CONDITION	PERFORMANCE REQUIRED[a, b]	TEST PROCEDURE
Instantaneous water heaters, oil	≤ 210,000 Btu/h	≥ 4,000 Btu/h/gal and < 2 gal	0.59 - 0.0019V, EF	DOE 10 CFR Part 430
	> 210,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	80% E_t	Section G.1 and G.2 of ANSI Z21.10.3
	> 210,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal	78% E_t (Q/800 + 110$\sqrt{V}$)SL, Btu/h	
Hot water supply boilers, gas and oil	≥ 300,000 Btu/h and < 12,500,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	80% E_t	Section G.1 and G.2 of ANSI Z21.10.3
Hot water supply boilers, gas	≥ 300,000 Btu/h and < 12,500,000 Btu/h	≥ 4,000 Btu/h/gal and ≥ 10 gal	80% E_t (Q/800 + 110$\sqrt{V}$)SL, Btu/h	
Hot water supply boilers, oil	≥ 300,000 Btu/h and < 12,500,000 Btu/h	≥ 4,000 Btu/h/gal and > 10 gal	78% E_t (Q/800 + 110$\sqrt{V}$)SL, Btu/h	
Pool heaters, gas and oil	All	—	78% E_t	ASHRAE 146
Heat pump pool heaters	All	—	4.0 COP	AHRI 1160
Unfired storage tanks	All	—	Minimum insulation requirement R-12.5 (h x ft^2 x °F)/Btu	(none)

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

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

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

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

d. Electric water heaters with an input rating of 12 kW (40,950 Btu/hr) 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 12 kW.

C404.3 Efficient heated water supply piping. Heated water supply piping shall be in accordance with Section C404.3.1 or C404.3.2. The flow rate through 1/4-inch (6.4 mm) piping shall be not greater than 0.5 gpm (1.9 L/m). The flow rate through 5/16-inch (7.9 mm) piping shall be not greater than 1 gpm (3.8 L/m). The flow rate through 3/8-inch (9.5 mm) piping shall be not greater than 1.5 gpm (5.7 L/m). Water heaters, circulating water systems and heat trace temperature maintenance systems shall be considered sources of heated water.

C404.3.1 Maximum allowable pipe length method. The maximum allowable piping length from the nearest source of heater water to the termination of the fixture supply pipe shall be in accordance with the following. Where the piping contains more than one size of pipe, the largest size of pipe within the piping shall be used for determining the maximum allowable length of the piping in Table C404.3.1.

1. For a public lavatory faucet, use the "Public lavatory faucets" column in Table C404.3.1.
2. For all other plumbing fixtures and plumbing appliances, use the "Other fixtures and appliances" column in Table C404.3.1.

TABLE C404.3.1
PIPING VOLUME AND MAXIMUM PIPING LENGTHS

NOMINAL PIPE SIZE (inches)	VOLUME (liquid ounces per foot length)	MAXIMUM PIPING LENGTH (feet)	
		Public lavatory faucets	Other fixtures and appliances
1/4	0.33	6	50
5/16	0.5	4	50
3/8	0.75	3	50
1/2	1.5	2	43
5/8	2	1	32
3/4	3	0.5	21
7/8	4	0.5	16
1	5	0.5	13

TABLE C404.3.1—continued
PIPING VOLUME AND MAXIMUM PIPING LENGTHS

NOMINAL PIPE SIZE (inches)	VOLUME (liquid ounces per foot length)	MAXIMUM PIPING LENGTH (feet)	
		Public lavatory faucets	Other fixtures and appliances
$1^1/_4$	8	0.5	8
$1^1/_2$	11	0.5	6
2 or larger	18	0.5	4

C404.3.2 Maximum allowable pipe volume method. The water volume in the piping shall be calculated in accordance with Section C404.3.2.1. Water heaters, circulating water systems and heat trace temperature maintenance systems shall be considered sources of heated water. The volume from the nearest source of heated water to the termination of the fixture supply pipe shall be as follows:

1. For a public lavatory faucet: not more than 2 ounces (0.06 L).
2. For other plumbing fixtures or plumbing appliances; not more than 0.5 gallon (1.89 L).

C404.3.2.1 Water volume determination. The volume shall be the sum of the internal volumes of pipe, fittings, valves, meters and manifolds between the nearest source of heated water and the termination of the fixture supply pipe. The volume in the piping shall be determined from the "Volume" column in Table C404.3.1. The volume contained within fixture shutoff valves, within flexible water supply connectors to a fixture fitting and within a fixture fitting shall not be included in the water volume determination. Where heated water is supplied by a recirculating system or heat-traced piping, the volume shall include the portion of the fitting on the branch pipe that supplies water to the fixture.

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

C404.5 Water heater installation. Electric water heaters in unconditioned spaces or on concrete floors shall be placed on an incompressible, insulated surface with a minimum thermal resistance of R-10.

C404.6 Insulation of piping. Piping from a water heater to the termination of the heated water fixture supply pipe shall be insulated in accordance with Table C403.2.9. On both the inlet and outlet piping of a storage water heater or heated water storage tank, the piping to a heat trap or the first 8 feet (2438 mm) of piping, whichever is less, shall be insulated. Piping that is heat traced shall be insulated in accordance with Table C403.2.9 or the heat trace manufacturer's instructions. Tubular pipe insulation shall be installed in accordance with the insulation manufacturer's instructions. Pipe insulation shall be continuous except where the piping passes through a framing member. The minimum insulation thickness requirements of this section shall not supersede any greater insulation thickness requirements necessary for the protection of piping from freezing temperatures or the protection of personnel against external surface temperatures on the insulation.

Exception: Tubular pipe insulation shall not be required on the following:

1. The tubing from the connection at the termination of the fixture supply piping to a plumbing fixture or plumbing appliance.
2. Valves, pumps, strainers and threaded unions in piping that is 1 inch (25 mm) or less in nominal diameter.
3. Piping from user-controlled shower and bath mixing valves to the water outlets.
4. Cold-water piping of a *demand recirculation water system*.
5. Tubing from a hot drinking-water heating unit to the water outlet.
6. Piping at locations where a vertical support of the piping is installed.
7. Piping surrounded by building insulation with a thermal resistance (R-value) of not less than R-3.

C404.7 Heated-water circulating and temperature maintenance systems. Heated-water circulation systems shall be in accordance with Section C404.7.1. Heat trace temperature maintenance systems shall be in accordance with Section C404.7.2. Controls for hot water storage shall be in accordance with Section C404.7.3. *Automatic* controls, temperature sensors and pumps shall be *accessible*. Manual controls shall be readily accessible.

C404.7.1 Circulation systems. Heated-water circulation systems shall be provided with a circulation pump. The system return pipe shall be a dedicated return pipe or a cold water supply pipe. Gravity and thermo-syphon circulation systems shall be prohibited. Controls for *circulating hot water system* pumps shall start the pump based on the identification of a demand for hot water within the occupancy. The controls shall automatically turn off the pump when the water in the circulation loop is at the desired temperature and when there is no demand for hot water.

C404.7.2 Heat trace systems. Electric heat trace systems shall comply with IEEE 515.1. Controls for such systems shall be able to automatically adjust the energy input to the heat tracing to maintain the desired water temperature in the piping in accordance with the times when heated water is used in the occupancy. Heat trace shall be arranged to be turned off automatically when there is no hot water demand.

C404.7.3 Controls for hot water storage. The controls on pumps that circulate water between a water heater and a heated-water storage tank shall limit operation of the pump from heating cycle startup to not greater than 5 minutes after the end of the cycle.

C404.8 Demand recirculation controls. A water distribution system having one or more recirculation pumps that pump water from a heated-water supply pipe back to the heated-water source through a cold-water supply pipe are not permitted. ((~~shall be a *demand recirculation water system*.~~

~~Pumps shall have controls that comply with both of the following:~~

~~1. The control shall start the pump upon receiving a signal from the action of a user of a fixture or appliance, sensing the presence of a user of a fixture or sending the flow of hot or tempered water to a fixture fitting or appliance.~~

~~2. The control shall limit the temperature of the water entering the cold water piping to 104°F (40°C).~~))

C404.9 Domestic hot water meters. Each individual dwelling unit in a Group R-2 multi-family residential occupancy with central service shall be provided with a domestic hot water meter to allow for domestic hot water billing based on actual domestic hot water usage.

C404.10 Drain water heat recovery units. Drain water heat recovery units shall comply with CSA B55.2. Potable water-side pressure loss shall be less than 10 psi (69 kPa) at maximum design flow. For Group R occupancies, the efficiency of drain water heat recovery unit efficiency shall be in accordance with CSA B55.1.

C404.11 Energy consumption of pools and permanent spas (*Mandatory*). The energy consumption of pools and permanent spas shall be controlled by the requirements in Sections C404.11.1 through C404.11.4.

C404.11.1 Heaters. Pool water heaters using electric resistance heating as the primary source of heat are prohibited for pools over 2,000 gallons. Heat pump pool heaters shall have a minimum COP of 4.0 at 50°F db, 44.2°F wb outdoor air and 80°F entering water, determined in accordance with ((~~ASHRAE Standard 146, Method of Testing for Rating Pool Heaters~~)) AHRI Standard 1160, Performance Rating of Heat Pump Pool Heaters. Other pool heating equipment shall comply with the applicable efficiencies in Section C404.2.

The electric power to all heaters shall be controlled by a readily accessible on-off switch that is an integral part of the heater, mounted on the exterior of the heater, or external to and within 3 feet of the heater. Operation of such switch shall be in addition to a circuit breaker for the power to the heater. Gas fired heaters shall not be equipped with constant burning pilot lights.

C404.11.2 Time switches. Time switches or other control methods that can automatically turn off and on heaters and pump motors according to a preset schedule shall be installed for heaters and pump motors. Heaters and pump motors that have built in time switches shall be in compliance with this section.

Exceptions:

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

C404.11.3 Covers. Heated pools and in-ground permanent spas shall be provided with a vapor-retardant cover on or at the water surface. Pools heated to more than 90°F shall have a pool cover with a minimum insulation value of R-12, and the sides and bottom of the pool shall also have a minimum insulation value of R-12.

C404.11.4 Heat recovery. Heated indoor swimming pools, spas or hot tubs with water surface area greater than 200 square feet shall provide for energy conservation by an exhaust air heat recovery system that heats ventilation air, pool water or domestic hot water. The heat recovery system shall be configured to decrease the exhaust air temperature at design heating conditions (80°F indoor) by 36°F (10°C).

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. Renewable energy;
2. Dehumidification heat recovery;
3. Waste heat recovery; or
4. A combination of these system sources capable of and configured to provide at least 70 percent of the heating energy required over an operating season.

C404.12 Energy consumption of portable spas (*Mandatory*). The energy consumption of electric-powered portable spas shall be controlled by the requirements of APSP 14.

C404.13 Service water-heating system commissioning and completion requirements. Service water-heating systems, swimming pool water-heating systems, spa water-heating systems and the controls for those systems shall be commissioned and completed in accordance with Section C408.

C404.14 Conservation of water pumping energy. Pumps for domestic water systems shall comply with Section C403.2.13. Water pressure booster systems shall comply with the following:

1. One or more pressure sensors shall be used to vary pump speed or to start and stop pumps, or for both purposes. Either the sensor(s) shall be located near the critical fixtures(s) that determine the pressure required, or logic shall be employed that adjusts the setpoint to simulate operation of remote sensors(s).
2. No device shall be installed for the purpose of reducing the pressure of all of the water supplied by any booster system pump or booster system, except for safety devices.
3. No booster system pumps shall operate when there is no service water flow.

SECTION C405
ELECTRICAL POWER AND LIGHTING SYSTEMS

C405.1 General (*mandatory*). This section covers lighting system controls, the maximum lighting power for interior and exterior applications, electrical energy consumption, vertical and horizontal transportation systems, and minimum efficiencies for motors and transformers. Receptacles shall be controlled according to Section C405.10. *Controlled receptacles* and lighting systems shall be commissioned according to Section

C405.13. Solar readiness shall be provided according to Section C412.

Exception: Dwelling units within *commercial buildings* shall not be required to comply with Sections C405.2 through C405.5, provided that they comply with Section R404.1.

➡ **C405.2 Lighting controls (*Mandatory*).** Lighting systems shall be provided with controls as specified in Sections C405.2.1 through C405.2.8.

Exception: Except for specific application controls required by Section C405.2.5:

1. Areas designated as security or emergency areas that are required to be continuously lighted.
2. Interior exit stairways, interior exit ramps and exit passageways.
3. Emergency egress lighting that is normally off.
4. Industrial or manufacturing process areas, as may be required for production and safety.
5. *Luminaire-level lighting controls* (LLLC) that control interior lighting. The LLLC luminaire shall be independently configured to:
   - 5.1. Monitor occupant activity to brighten or dim its lighting when occupied or unoccupied, respectively.
   - 5.2. Monitor ambient light (both electric light and daylight) and brighten or dim electric light to maintain desired light level.
   - 5.3. Configuration and reconfiguration of performance parameters, including bright and dim setpoints, time-outs, dimming, fade rates, sensor sensitivity adjustments, and wireless zoning configurations, for each control strategy.
   - 5.4. Meet the operational and commissioning requirements of Sections C405.2.1, C405.2.2, C405.2.3, C405.2.4, and C408.
6. Stairwells and parking garages are not permitted to use wall-mounted manual switches.

** **C405.2.1 Occupancy sensor controls.** Occupancy sensors shall be installed to control lights in the following space types:

1. Classrooms/lecture/training rooms.
2. Conference/ meeting/multipurpose rooms.
3. Copy/print rooms.
4. Lounges.
5. Employee lunch and break rooms.
6. Private offices.
7. Restrooms.
8. Storage rooms.
9. Janitorial closets.
10. Locker rooms.
11. Other spaces 300 square feet (28 m^2) or less that are enclosed by floor-to- ceiling height partitions.
12. Warehouses.

C405.2.1.1 Occupant sensor control function. Occupant sensor controls shall comply with the following:

1. Automatically turn off lights within 30 minutes of all occupants leaving the space. At initial installation, occupancy sensor controls shall be set to turn lights off after 15 minutes unless other thresholds required for safety, security or operational considerations are specifically set out in the *approved* construction documents.
2. Be manual on or shall be controlled to automatically turn the lighting on to not more than 50 percent power.

   Exception: Full automatic-on controls shall be permitted to control lighting in public corridors, stairways, restrooms, primary *building entrance* areas and lobbies, parking garages, and areas where manual-on operation would endanger the safety or security of the room or building occupants.
3. Shall incorporate a manual control to allow occupants to turn lights off.

C405.2.1.2 Occupant sensor control function in warehouses. In warehouses, the lighting in aisleways and open areas shall be controlled with occupant sensors that automatically reduce lighting power by not less than 50 percent when the areas are unoccupied. The occupancy sensor shall control lighting in each aisleway independently, and shall not control lighting beyond the aisleway being controlled by the sensor.

C405.2.2 Time switch controls. Each area of the building that is not provided with occupant sensor controls complying with Section C405.2.1.1 or digital timer switch controls complying with Section C405.2.6 shall be provided with time switch controls complying with Section C405.2.2.1. **

Exception: Where a manual control provides light reduction in accordance with Section C405.2.2.2, *automatic* controls shall not be required for the following:

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

C405.2.2.1 Time switch control function. Each space provided with time switch controls shall also be provided with a manual control for light reduction in accordance with Section C405.2.2.2. Time switch controls shall comply with the following:

1. Have a minimum 7 day clock.

2. Be capable of being set for 7 different day types per week.
3. Incorporate an *automatic* holiday "shut-off" feature, which turns off all loads for at least 24 hours and then resumes normally scheduled operations.
4. Have program back-up capabilities, which prevent the loss of program and time settings for at least 10 hours, if power is interrupted.
5. Include an override switching device that complies with the following:
   5.1. The override switch shall be a manual control.
   5.2. The override switch, when initiated, shall permit the controlled lighting to remain on for not more than 2 hours.
   5.3. Any individual override switch shall control the lighting for an area not larger than ((~~5,000~~)) 2,500 square feet (((~~465~~)) 232 m^2).

Exceptions:

1. Within malls, arcades, auditoriums, single tenant retail spaces, industrial facilities, pools, gymnasiums, skating rinks and arenas:
   1.1. The time limit shall be permitted to be greater than 2 hours provided the override switch is a captive key device.
   1.2. The area controlled by the override switch is permitted to be greater than 5,000 square feet (465 m^2), but shall not be greater than 20,000 square feet (1860 m^2).
2. Where provided with manual control, the following areas are not required to have light reduction control:
   2.1. Spaces that have only one luminaire with a rated power of less than 100 watts.
   2.2. Spaces that use less than 0.6 watts per square foot (6.5 W/m^2).
   2.3. Corridors, equipment rooms, public lobbies, electrical or mechanical rooms.

C405.2.2.2 Light reduction controls. Spaces required to have light reduction controls shall have a manual control that allows 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 *approved* methods:

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

Exception: Light reduction controls are not required in *daylight zones* with *daylight responsive controls* complying with Section C405.2.4.

C405.2.3 Manual controls. Manual controls for lights shall comply with the following:

1. Shall be readily accessible to occupants.
2. Shall be located where the controlled lights are visible, or shall identify the area served by the lights and indicate their status.
3. Where manual controls are required, at least one separate manual control shall be provided for each area enclosed by walls or floor-to-ceiling partitions.

C405.2.4 Daylight responsive controls. *Daylight responsive controls* complying with Section C405.2.4.1 shall be provided to control the lighting with *daylight zones* in the following spaces:

1. Sidelight *daylight zones* as defined in Section C405.2.4.2 with more than two general lighting fixtures within the primary and secondary sidelight *daylight zones*.
2. Toplight *daylight zones* as defined in Section C405.2.4.3 with more than two general lighting fixtures within the *daylight zone*.

Exception: *Daylight responsive controls* are not required for the following:

1. Spaces in health care facilities where patient care is directly provided.
2. Dwelling units and *sleeping units*.
3. Lighting that is required to have specific application control in accordance with Section ((~~C405.2.4~~)) C405.2.5.
4. Sidelight *daylight zones* on the first floor above grade in Group A-2 and Group M occupancies where the *fenestration* adjoins a sidewalk or other outdoor pedestrian area, provided that the light fixtures are controlled separately from the general area lighting.
5. *Daylight zones* where the total proposed lighting power density is less than 35 percent of the lighting power allowance per Section C405.4.2.

C405.2.4.1 Daylight responsive controls function. Where required, *daylight responsive controls* shall be provided within each space for control of lights in that space and shall comply with all of the following:

1. Lights in primary sidelight *daylight zones* shall be controlled independently of lights in secondary sidelight *daylight zones* in accordance with Section C405.2.4.2.

   Exception: Spaces enclosed by walls or ceiling height partitions no more than three gen-

eral lighting fixtures may have combined *daylight zone* control of primary and secondary *daylight zones* provided *uniform illumination* can be achieved.

2. Lights in toplight *daylight zones* in accordance with Section C405.2.4.3 shall be controlled independently of lights in sidelight *daylight zones* in accordance with Section C405.2.4.2.
3. *Daylight responsive controls* within each space shall be configured so that they can be calibrated from within that space by authorized personnel.
4. Calibration mechanisms shall be readily accessible.
5. *Daylight responsive controls* shall be configured to completely shut off all controlled lights in that zone.
6. Lights in sidelight *daylight zones* in accordance with Section C405.2.4.2 facing different cardinal orientations (i.e., within 45 degrees of due north, east, south, west) shall be controlled independently of each other.

   Exception: Up to two light fixtures in each space are permitted to be controlled together with lighting in a *daylight zone* facing a different cardinal orientation.
7. Incorporate time-delay circuits to prevent cycling of light level changes of less than three minutes.
8. The maximum area a single *daylight responsive control* device serves shall not exceed 2,500 square feet (232 m^2) and no more than 60 lineal feet (18.3 m) of façade.
9. Occupant override capability of daylight dimming controls is not permitted, other than a reduction of light output from the level established by the daylighting controls.
10. Be set initially at 30 footcandles (323 lux) or not more than 110 percent of the illuminance level specified on the construction documents.

C405.2.4.1.1 Dimming. *Daylight responsive controls* shall be configured to automatically reduce the power of *general lighting* in the *daylight zone* in response to available daylight, while maintaining *uniform illumination* in the space through one of the following methods:

1. Continuous dimming using dimming ballasts/ dimming drivers and daylight-sensing *automatic* controls. The system shall reduce lighting power continuously to less than 15 percent of rated power at maximum light output.
2. Stepped dimming using multi-level switching and daylight-sensing controls. The system shall provide a minimum of two steps of *uniform illumination* between 0 and 100 percent of rated power at maximum light output. Each step shall be in equal increments of power, plus or minus 10 percent.

General lighting within *daylight zones* in offices, classrooms, laboratories and library reading rooms shall use the continuous dimming method. Stepped dimming is not allowed as a method of *daylight zone* control in these spaces.

C405.2.4.2 Sidelight daylight zone. The sidelight *daylight zone* is the floor area adjacent to *vertical fenestration* which complies with the following:

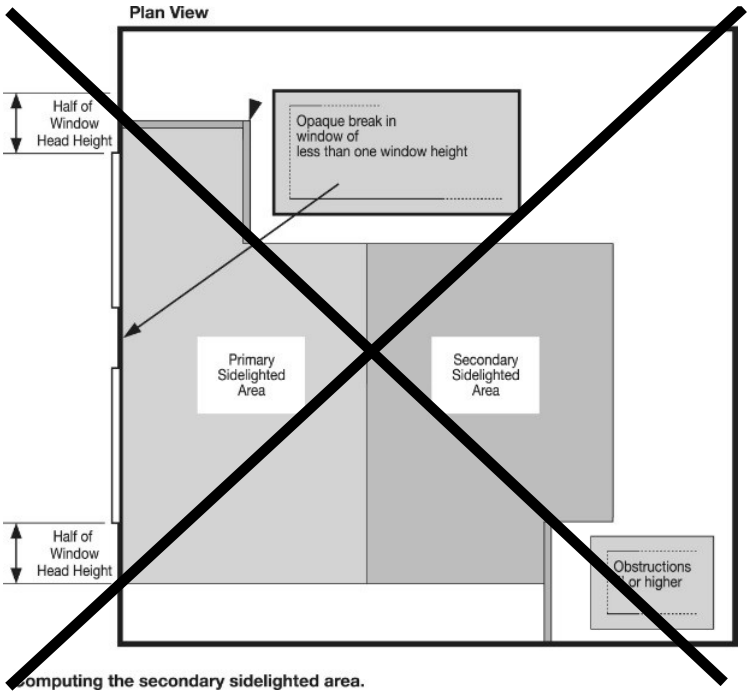
1. Where the *fenestration* is located in a wall, the sidelight *daylight zone* includes the primary and secondary *daylight zones*. The primary *daylight zone* shall extend laterally to the nearest full height wall, or up to 1.0 times the height from the floor to the top of the fenestration, and longitudinally from the edge of the fenestration to the nearest full height wall, or up to 2 feet (610 mm), whichever is less, as indicated in Figure C405.2.4.2(1). The secondary *daylight zone* begins at the edge of the primary *daylight zone* and extends laterally to the nearest full height wall, or up to 2.0 times the height from the floor to the top of the fenestration, whichever is less, as indicated in Figure C405.2.4.2(1).
2. Where the fenestration is located in a *rooftop monitor*, the sidelight *daylight zone* shall extend laterally to the nearest obstruction that is taller than 0.7 times the ceiling height, or up to 1.0 times the height from the floor to the bottom of the fenestration, whichever is less, and longitudinally from the edge of the fenestration to the nearest obstruction that is taller than 0.7 times the ceiling height, or up to 0.25 times the height from the floor to the bottom of the *fenestration*, whichever is less, as indicated in Figures C405.2.4.2(2) and C405.2.4.2(3).
3. Where *clerestory fenestration* is located in a wall, the sidelight *daylight zone* includes a lateral area twice the depth of the *clerestory fenestration* height, projected upon the floor at a 45 degree angle from the center of the *clerestory fenestration*. The longitudinal width of the *daylight zone* is calculated the same as for fenestration located in a wall. Where the 45 degree angle is interrupted by an obstruction greater than 0.7 times the ceiling height, the *daylight zone* shall remain the same lateral area but be located between the clerestory and the obstruction, as indicated in Figure C405.2.4.2(4).
4. If the rough opening area of a *vertical fenestration* assembly is less than 10 percent of the calculated primary *daylight zone* area for this fenestration, it does not qualify as a *daylight zone*.

5. Where located in existing buildings, the visible transmittance of the fenestration is no less than 0.20.
6. In parking garages with floor area adjacent to perimeter wall openings, the *daylight zone* shall include the area within 20 feet of any portion of a perimeter wall that has a net opening to wall ratio of at least 40 percent.

C405.2.4.3 Toplight daylight zone. The toplight *daylight zone* is the floor area underneath a roof fenestration assembly which complies with the following:

1. The toplight *daylight zone* shall extend laterally and longitudinally beyond the edge of the roof fenestration assembly to the nearest obstruction that is taller than 0.7 times the ceiling height, or up to 0.7 times the ceiling height, whichever is less, as indicated in Figure C405.2.4.3(1).
2. Where toplight *daylight zones* overlap with sidelight *daylight zones*, lights within the overlapping area shall be assigned to the toplight *daylight zone*.
3. Where located in existing buildings, the product of the *visible transmittance* of the roof fenestration assembly and the area of the rough opening of the roof fenestration assembly, divided by the area of the *daylight zone* is no less than 0.008.
4. Where located under atrium fenestration, the *daylight zone* shall include the bottom floor area directly beneath the atrium fenestration, and the top floor directly under the atrium fenestration, as indicated in Figure C405.2.4.3(2). The *daylight zone* area at the top floor is calculated the same as for a toplight *daylight zone*. Intermediate levels below the top floor that are not directly beneath the atrium are not included.

FIGURE C405.2.4.2(1)
DAYLIGHT ZONE ADJACENT TO FENESTRATION IN A WALL



Computing the secondary sidelighted area.

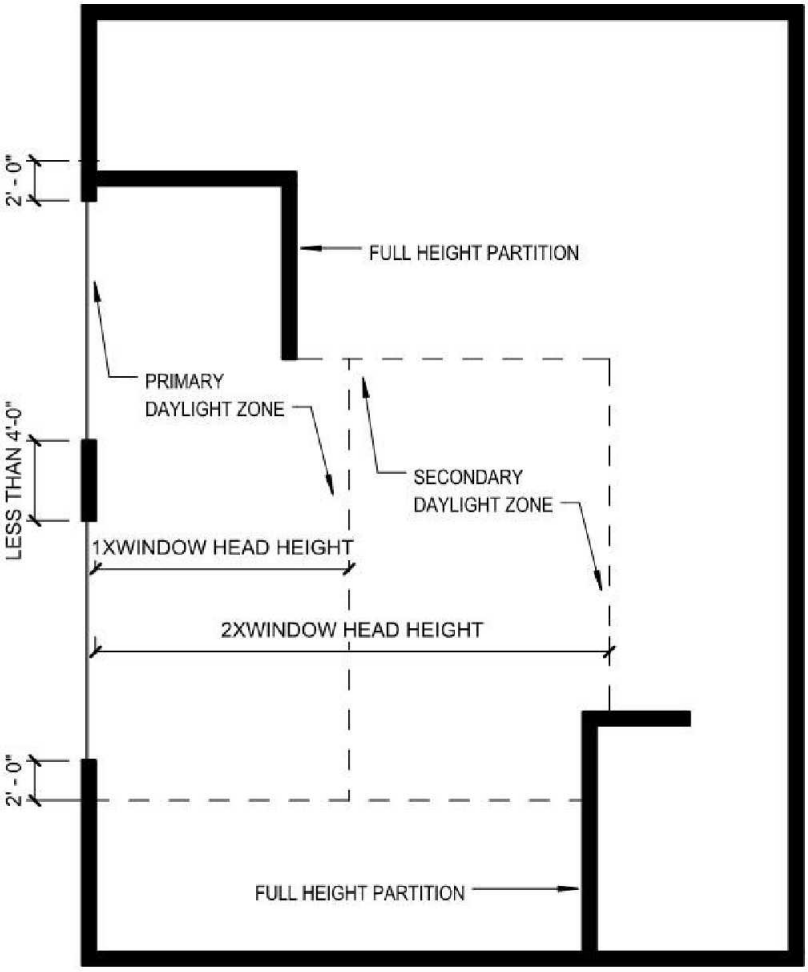
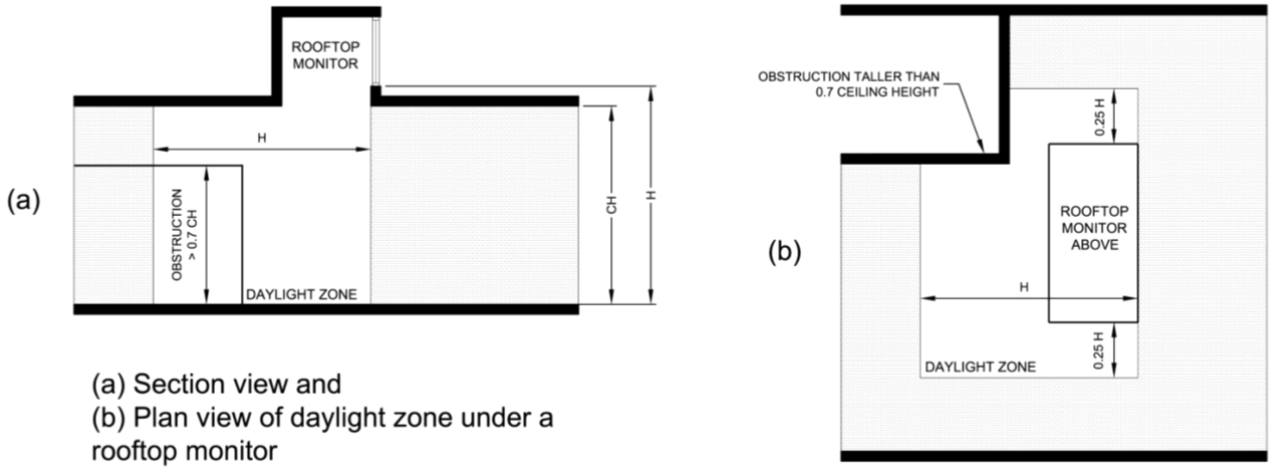
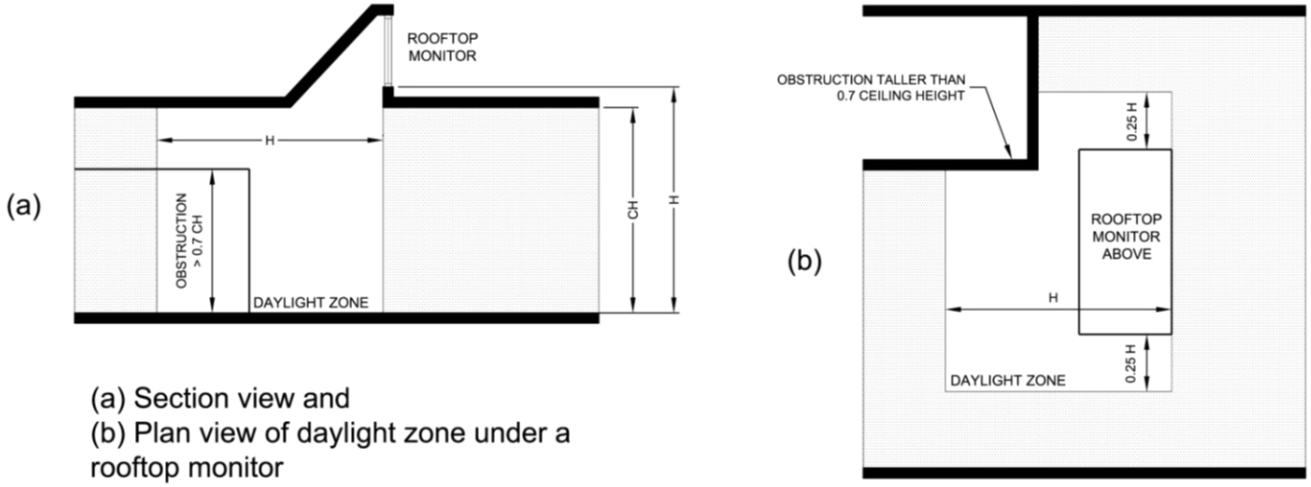


FIGURE C405.2.4.2(2)
DAYLIGHT ZONE UNDER A ROOFTOP MONITOR



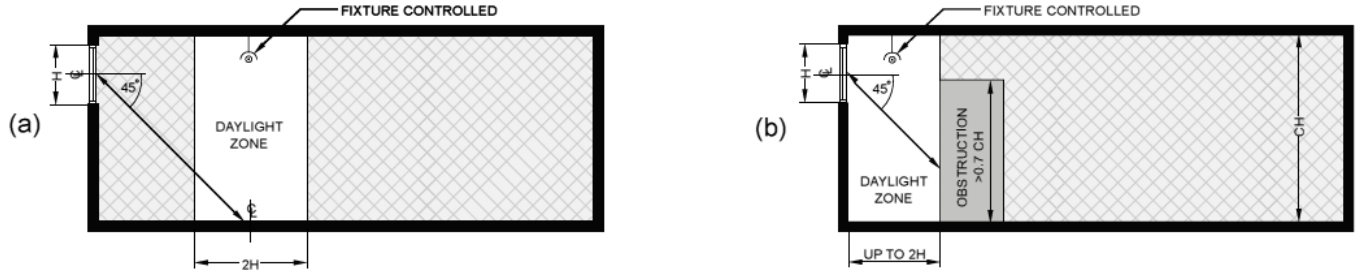
(a) Section view and
(b) Plan view of daylight zone under a rooftop monitor

FIGURE C405.2.4.2(3)
DAYLIGHT ZONE UNDER A SLOPED ROOFTOP MONITOR



(a) Section view and
(b) Plan view of daylight zone under a rooftop monitor

FIGURE C405.2.4.2(4)
DAYLIGHT ZONE ADJACENT TO CLERESTORY FENESTRATION IN A WALL



(a) Section view
(b) Section view with obstruction

FIGURE C405.2.4.3(1)
DAYLIGHT ZONE UNDER A ROOFTOP FENESTRATION ASSEMBLY

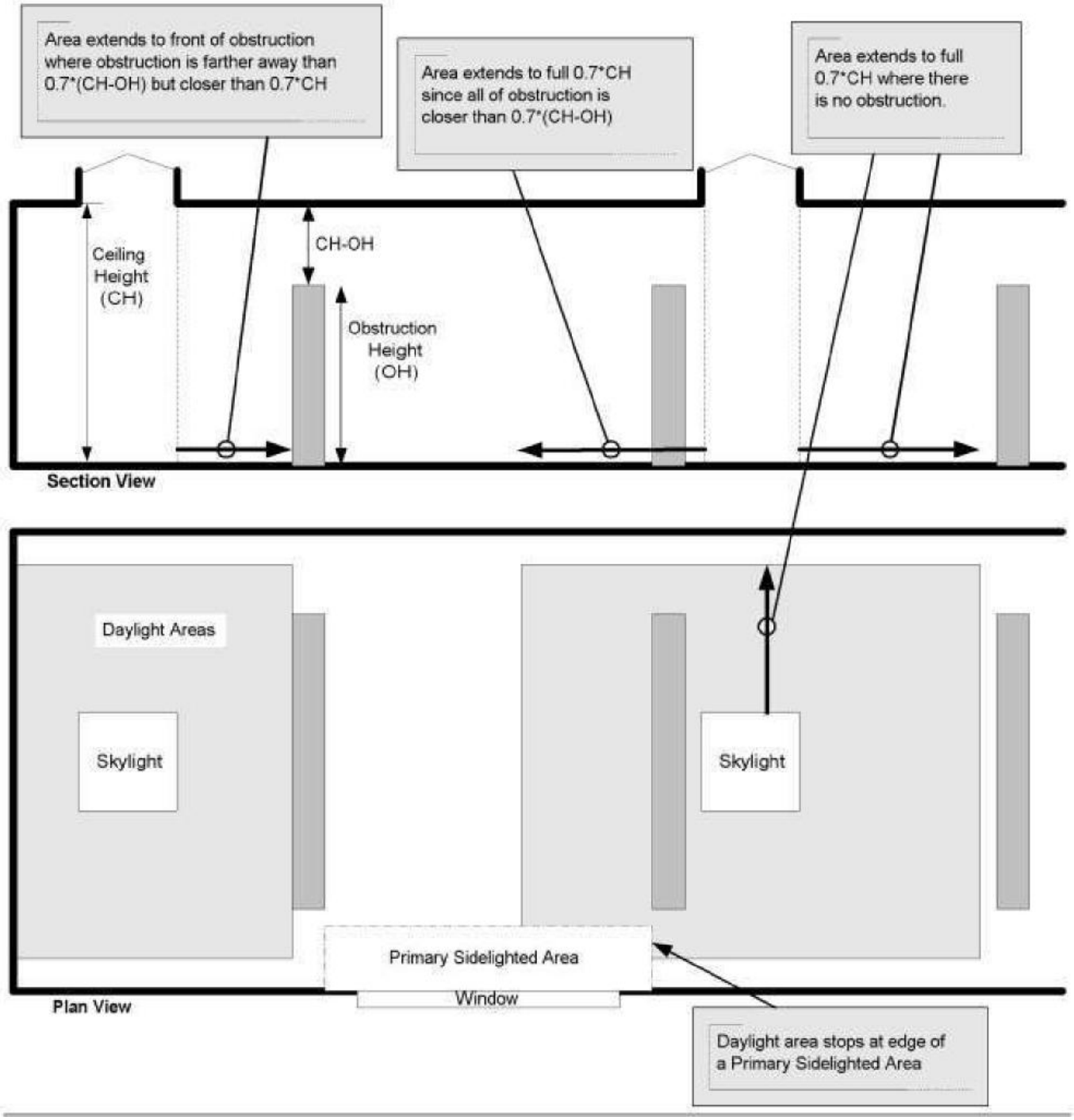
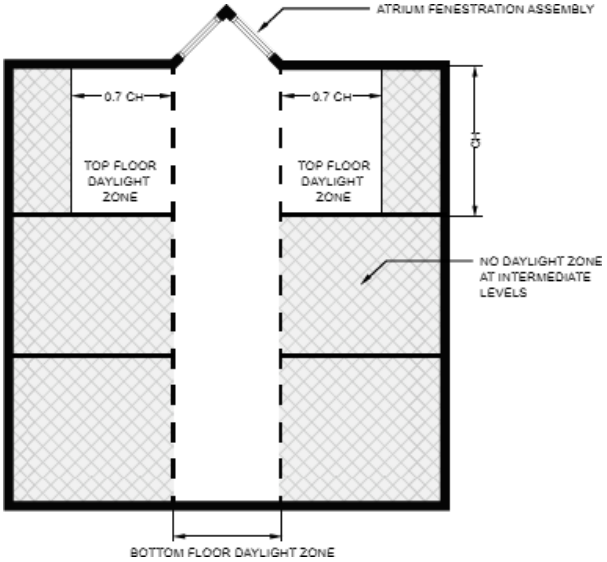


FIGURE C405.2.4.3(2)
DAYLIGHT ZONE UNDER ATRIUM FENESTRATION



C405.2.5 Additional lighting controls. Specific application lighting shall be provided with controls, in addition to controls required by other sections, for the following:

1. Display and accent light shall be controlled by a dedicated control that is independent of the controls for other lighting within the room or space.
2. Lighting in cases used for display case purposes shall be controlled by a dedicated control that is independent of the controls for other lighting within the room or space.
3. Hotel and motel *sleeping units* and guest suites shall have control devices configured to automatically switch off all installed luminaires and switched receptacles within 20 minutes after all occupants leave the room.

   Exception: Lighting and switched receptacles controlled by captive key systems.
4. Supplemental task lighting, including permanently installed under-shelf or under-cabinet lighting, shall be automatically shut off whenever that space is unoccupied and shall have a control device integral to the luminaires or be controlled by a wall-mounted control device provided that the control device is readily accessible.
5. Lighting for nonvisual applications, such as plant growth and food warming, shall be controlled by a dedicated control that is independent of the controls for other lighting within the room or space. ((~~Each control zone shall be no greater than the area served by a single luminaire or 4,000 square feet, whichever is larger.~~))
6. Lighting equipment that is for sale or for demonstrations in lighting education shall be controlled by a dedicated control that is independent of the controls for other lighting within the room or space.
7. Luminaires serving the exit access and providing means of egress illumination required by Section 1006.1 of the *International Building Code*, including luminaires that function as both normal and emergency means of egress illumination shall be controlled by a combination of listed emergency relay and occupancy sensors, or signal from another building control system, that automatically shuts off the lighting when the areas served by that illumination are unoccupied.

   Exception: Means of egress illumination serving the exit access that does not exceed 0.02 watts per square foot of building area is exempt from this requirement.
8. Each stairway shall have one or more control devices to automatically reduce lighting power by not less than 50 percent when no occupants have been detected in the stairway for a period not exceeding 15 minutes, and restore lighting to full power when occupants enter the stairway. All portions of stairways shall remain illuminated to meet the requirements of Seattle Building Code Section 1009 or Code Alternate CA1009.2 when the lighting power is reduced.
9. Lighting in parking garages shall have one or more control devices to automatically reduce lighting power in any one controlled zone by not less than 50 percent when no occupants have been detected in that zone for a period not exceeding 30 minutes, and restore lighting to full power when occupants enter or approach the zone. Each lighting zone controlled by occupancy sensors shall be no larger than 7,200 square feet. Pedestrian occupancy sensors controlling any lighting zone are permitted to be configured to detect pedestrians no more than 30 feet outside of that zone. Vehicle occupancy sensors controlling any lighting zone are permitted to be configured to detect vehicles no more than 60 feet outside of that zone.

C405.2.6 Digital timer switch. For each of the following space types, when under 300 square feet, digital timer switch controls may be provided in lieu of occupancy sensor controls:

1. Copy/print rooms.
2. Storage rooms.
3. Janitorial closets

C405.2.6.1 Digital timer switch function. Digital timer switches shall comply with the following:

1. Turn lights on or off with operation of a button, switch or other manual means.
2. Automatically turn lights off within 15 minutes of the lights being turned on. The means for setting the time delay shall not be visible on the front of the switch.
3. The switch shall provide both audible and visual indication of impending time-out of the switch. Audible and visual indication shall be given at least once within five minutes of time-out of the switch. Visual indication shall consist of turning the lights momentarily off, and then back on.

C405.2.7 Exterior lighting controls. Lighting for exterior applications other than emergency lighting that is intended to be automatically off during building operation, lighting specifically required to meet health and life safety requirements, or decorative gas lighting systems shall:

1. Be provided with a control that automatically turns off the lighting as a function of available daylight.
2. Where lighting the building façade or landscape, the lighting shall have controls that automatically shut off the lighting ((~~as a function of dawn/dusk and a set opening and closing time.~~)) between midnight or business/facility closing, whichever is later, and 6 a.m. or business/facility opening, whichever is earlier.
3. Where not covered in Item 2, the lighting shall have controls configured to automatically reduce the connected lighting power by at least 30 percent from no later than 12 midnight to 6 a.m. or from one hour after business closing to one hour before business opening or during any period when no activity has been detected for a time of no longer than 15 minutes.

Time switches shall be capable of retain programming and the time setting during loss of power for a period of at least 10 hours.

Exception: Lighting for covered vehicle entrances or exits from buildings or parking structures where required for safety, security or eye ((~~adaption~~)) adaptation.

((~~C405.2.5~~)) C405.2.8 Area controls. The maximum lighting power that may be controlled from a single switch or *automatic* control shall not exceed that which is provided by a 20 ampere circuit loaded to not more than 80 percent. A master control may be installed provided the individual switches retain their capability to function independently. Circuit breakers may not be used as the sole means of switching.

Exception: Areas less than 5 percent of the building footprint for footprints over 100,000 ft^2.

C405.3 Exit signs (*Mandatory*). Internally illuminated exit signs shall not be more than 5 watts per side.

C405.4 Interior lighting power requirements (*Prescriptive*). A building complies with this section where its total connected lighting power calculated under Section C405.4.1 is not greater than the interior lighting power calculated under Section C405.4.2.

C405.4.1 Total connected interior lighting power. The total connected interior lighting power shall be determined in accordance with Equation 4-10.

As an option, in areas of the building where all interior lighting equipment is fed from dedicated lighting branch circuits, the total connected interior lighting power is permitted to be calculated as the sum of the capacities of the lighting branch circuits serving those areas. For the purposes of this section, the connected interior lighting power of a 20-ampere circuit is considered to be 16 amperes, and that of a 15-ampere circuit is 12 amperes. Use of this alternative and the boundaries of the applicable areas shall be clearly documented on the electrical construction documents.

$$TCLP = [SL + LV + LTPB + \text{Other}] \quad \textbf{(Equation 4-10)}$$

where:

TCLP = Total connected lighting power (watts).

SL = Labeled wattage of luminaires for screw-in lamps.

LV = Wattage of the transformer supplying *low-voltage lighting*.

LTPB = Wattage of line-voltage lighting tracks and plug-in busways as the specified wattage of the luminaires, but at least 50 W/lin. ft., or the wattage limit of the system's circuit breaker, or the wattage limit of other permanent current-limiting devices on the system.

Other = The wattage of all other luminaires and lighting sources not covered previously and associated with interior lighting verified by data supplied by the manufacturer or other *approved* sources.

Exceptions:

1. The connected power associated with the following lighting equipment is not included in calculating total connected lighting power.
   - 1.1. Professional sports arena playing field lighting.
   - 1.2. Emergency lighting automatically off during normal building operation.
   - 1.3. Lighting in spaces specifically designed for use by occupants

with special lighting needs, including those with visual impairment and other medical and age-related issues.

1.4. Casino gaming areas.

1.5. General area lighting power in industrial and manufacturing occupancies dedicated to the inspection or quality control of goods and products.

1.6 Lighting in *sleeping units*, provided that the lighting complies with Section R404.1.

1.7. Mirror lighting in dressing rooms.

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 installed by the manufacturer.

6. ((~~Task lighting~~)) Lighting for plant growth or maintenance where the lamp ((~~efficacy is not less than 90 lumens per watt~~)) has a tested photosynthetic photon flux (PPF) per watt of not less than 1.20 micromoles per joule.

7. Advertising signage or directional signage.

8. In restaurant buildings and areas, lighting for food warming or integral to food preparation equipment.

9. Lighting equipment that is for sale.

10. Lighting demonstration equipment in lighting education facilities.

11. Lighting *approved* because of safety or emergency considerations, inclusive of exit lights.

12. Lighting integral to both open and glass-enclosed refrigerator and freezer cases.

13. Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions.

14. Furniture mounted supplemental task lighting that is controlled by *automatic* shutoff.

15. Lighting used for aircraft painting.

C405.4.2 Interior lighting power. The total interior lighting power allowance (watts) is determined according to Table C405.4.2(1) using the Building Area Method, or Table C405.4.2(2) using the Space-by-Space Method, for all areas of the building covered in this permit. Dates indicated in the column headers refer to the date that a completed building permit application has been accepted by SDCI.

C405.4.2.1 Building Area Method. For the Building Area Method, the interior lighting power allowance is the floor area for each building area type listed in Table C405.4.2(1) times the value from Table C405.4.2(1) for that area. For the purposes of this method, an "area" shall be defined as all contiguous spaces that accommodate or are associated with a single building area type, as listed in Table C405.4.2(1). Where this method is used to calculate the total interior lighting power for an entire building, each building area type shall be treated as a separate area.

C405.4.2.2 Space-by-Space Method. For the Space-by-Space Method, the interior lighting power allowance is determined by multiplying the floor area of each space times the value for the space type in Table C405.4.2(2) that most closely represents the proposed use of the space, and then summing the lighting power allowances for all spaces. Trade-offs among spaces other than covered parking areas are permitted.

Each area enclosed by partitions that are 80 percent of the ceiling height or taller shall be considered a separate space and assigned the appropriate space type from Table C405.4.2(2). If a space has multiple functions where more than one space type is applicable, that space shall be broken up into smaller subspaces, each using their own space type. Any of these subspaces that are smaller in floor area than 20 percent of the *enclosed space* and less than 1,000 square feet need not be broken out separately.

C405.4.2.2.1 Additional interior lighting power. Where using the Space-by-Space Method, an increase in the interior lighting power allowance is permitted for specific lighting functions. Additional power shall be permitted only where the specified lighting is installed and automatically controlled separately from the general lighting, to be turned off during nonbusiness hours. This additional power shall be used only for the specified luminaires and shall not be used for any other purpose. An increase in the interior lighting power allowance is permitted for lighting equipment to be installed in sales areas specifically to highlight merchandise. The additional lighting power shall be determined in accordance with Equation 4-11:

Additional interior lighting power allowance = 500 watts + (Retail Area 1 x 0.6 W/ft^2) + (Retail Area 2 x 0.6 W/ft^2) + (Retail Area 3 x 1.4 W/ft^2) + (Retail Area 4 x 2.5 W/ft^2)

(Equation 4-11)

Where:

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

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

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

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

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

C405.5 Exterior lighting (*Mandatory*). Where the power for exterior lighting is supplied through the energy service to the building, all exterior lighting shall comply with Section C405.5((.1)).

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

C405.5.1 Exterior building grounds lighting. All exterior building grounds luminaires that operate at greater than 100 watts shall have a minimum efficacy of 80 lumens per watt unless the luminaire is controlled by a motion sensor or qualifies for one of the exceptions under Section C405.5.2.

C405.5.2 Exterior building lighting power. The total exterior lighting power allowance for all exterior building applications is the sum of the base site allowance plus the individual allowances for areas that are to be illuminated and are permitted in Table C405.5.2(2) for the applicable lighting zone. Tradeoffs are allowed only among exterior lighting applications listed in Table C405.5.2(2), Tradable Surfaces section. Parking garage lighting cannot be traded with exterior lighting or with other interior lighting. The lighting zone for the building exterior is determined from Table C405.5.2(1) unless otherwise specified by the local jurisdiction.

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

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

TABLE C405.4.2(1)
INTERIOR LIGHTING POWER ALLOWANCES: BUILDING AREA METHOD

Building Area Type	LPD (w/ft^2) Before Jan 1 2018	LPD (w/ft^2) After Jan 1 2018
Automotive facility	0.64	0.58
Convention center	0.81	0.73
Court house	0.81	0.73
Dining: Bar lounge/ leisure	0.79	0.71
Dining: Cafeteria/fast food	0.72	0.65
Dining: Family	0.71	0.64
Dormitory	0.46	0.41
Exercise center	0.67	0.60
Fire station	0.54	0.49
Gymnasium	0.75	0.68
Health care clinic	0.70	0.70
Hospital	0.84	0.84
Hotel	0.70	0.63
Library	0.94	0.85
Manufacturing facility	0.89	0.80
Motion picture theater	0.61	0.55
Multifamily	0.41	0.37
Museum	0.80	0.72
Office	0.66	0.59
Parking garage	0.16	0.14
Penitentiary	0.65	0.59
Performing arts theater	1.00	0.90
Police station	0.70	0.63
Post office	0.70	0.63
Religious building	0.80	0.72
Retail	1.01	0.91
School/university	0.70	0.63
Sports arena	0.62	0.56
Town hall	0.71	0.64
Transportation	0.56	0.50
Warehouse	0.40	0.36

TABLE C405.4.2(1)—continued
INTERIOR LIGHTING POWER ALLOWANCES: BUILDING AREA METHOD

Building Area Type	LPD (w/ft^2) Before Jan 1 2018	LPD (w/ft^2) After Jan 1 2018
Workshop	0.95	0.90

TABLE C405.4.2(2)
INTERIOR LIGHTING POWER ALLOWANCES: SPACE-BY-SPACE METHOD

COMMON SPACE-BY-SPACE TYPES[a]	LPD (w/ft^2)[d] Before Jan 1 2018	LPD (w/ft^2)[d] After Jan 1 2018
Atrium - First 40 feet in height[e]	((~~0.02~~)) 0.024 per ft. ht.	0.024 per ft. ht.
Atrium - Above 40 feet in height[e]	((~~0.03 + 0.02~~)) 0.32 + 0.016 per total ft. ht.	0.32 + 0.016 per total ft. ht.
Audience/seating area - Permanent		
In an auditorium	0.50	0.45
In a convention center	0.66	0.59
In a gymnasium	0.34	0.31
In an motion picture theater	0.91	0.82
In a penitentiary	((~~0.22~~)) 0.34	0.31
In an performing arts theater	1.94	1.75
In a religious building	1.22	1.10
In a sports arena	0.34	0.31
Otherwise	0.34	0.31
Banking activity area	0.81	0.73
Breakroom (see Lounge/ breakroom)		
Classroom/lecture/training		
In a penitentiary	1.07	0.96
Otherwise	1.00	0.90
Conference/meeting/ multipurpose	0.98	0.88
Copy/print room	0.58	0.52
Corridor		
In a facility for the visually impaired (and not used primarily by the staff)[b]	0.74	0.74
In a hospital	0.63	0.63
In a manufacturing facility	0.33	0.30
Otherwise	0.53	0.48
Courtroom	1.38	1.24

TABLE C405.4.2(2)
INTERIOR LIGHTING POWER ALLOWANCES: SPACE-BY-SPACE METHOD

COMMON SPACE-BY-SPACE TYPES[a]	LPD (w/ft^2)[d] Before Jan 1 2018	LPD (w/ft^2)[d] After Jan 1 2018
Computer room	1.37	1.23
Dining area		
In a penitentiary	0.77	0.69
In a facility for the visually impaired (and not used primarily by the staff)[b]	1.52	1.52
In a bar/lounge or leisure dining	0.86	0.77
In a family dining area	0.71	0.64
Otherwise	0.52	0.47
Electrical/mechanical	0.76	0.68
Emergency vehicle garage	0.45	0.41
Food preparation	0.79	0.71
Guest room	0.38	
Laboratory		
In or as a classrooms	1.02	0.92
Otherwise	1.45	1.31
Laundry/washing area	0.48	0.43
Loading dock, interior	0.38	0.34
Lobby[c]		
In a facility for the visually impaired (and not used primarily by the staff)[b]	1.44	1.44
For an elevator	0.51	0.46
In a hotel	0.85	0.77
In a motion picture theater	0.42	0.38
In a performing arts theater	1.60	1.44
Otherwise	0.72	0.65
Locker room	0.60	0.54
Lounge /breakroom		
In a health care facility	0.74	0.67
Otherwise	0.58	0.52
Office[f]		
Enclosed	0.89	0.80
Open plan	0.78	0.70
Parking area, interior	0.15	0.14
Pharmacy area	0.91	0.82

TABLE C405.4.2(2)
INTERIOR LIGHTING POWER ALLOWANCES: SPACE-BY-SPACE METHOD

COMMON SPACE-BY-SPACE TYPES[a]	LPD (w/ft^2)[d] Before Jan 1 2018	LPD (w/ft^2)[d] After Jan 1 2018
Restroom		
In a facility for the visually impaired (and not used primarily by the staff)[b]	0.97	0.97
Otherwise	0.78	0.70
Sales area	1.27	1.14
Seating area, general	0.43	0.39
((~~Stairway (See space containing stairway)~~))		
Stairwell	0.55	0.50
Storage room	0.50	0.45
Vehicular maintenance	0.54	0.49
Workshop	1.27	1.14

BUILDING SPECIFIC SPACE-BY-SPACE TYPES

BUILDING SPECIFIC SPACE-BY-SPACE TYPES[a]	LPD (w/ft^2)[d] Before Jan 1 2018	LPD (w/ft^2)[d] After Jan 1 2018
Automotive (see Vehicular maintenance, above)		
Convention center - Exhibit space	1.16	1.04
Dormitory living quarters	0.30	0.27
Facility for the visually impaired[b]		
In a chapel (and not used primarily by the staff)[b]	1.77	1.59
In a recreation room (and not used primarily by the staff)[b]	1.93	1.74
Fire stations		
Engine rooms	0.45	0.45
Sleeping quarters	0.18	0.18
Gymnasium/fitness center		
In an exercise area	0.58	0.52
In a playing area	0.96	0.86
Health care facility		
In an exam/treatment room	1.33	1.33
In an imaging room	1.06	1.06
In a medical supply room	0.59	0.59

BUILDING SPECIFIC SPACE-BY-SPACE TYPES—continued

BUILDING SPECIFIC SPACE-BY-SPACE TYPES[a]	LPD (w/ft^2)[d] Before Jan 1 2018	LPD (w/ft^2)[d] After Jan 1 2018
In a nursery	0.70	0.70
In a nurse's station	0.57	0.57
In an operating room	1.51	1.51
In a patient room	0.50	0.50
In a physical therapy room	0.73	0.73
In a recovery room	0.92	0.92
Library[f]		
In a reading area	0.74	0.67
In the stacks	1.37	1.23
Manufacturing facility		
In a detailed manufacturing area	1.03	0.93
In an equipment room	0.59	0.53
In an extra high bay area (> 50-foot floor-ceiling height)	0.84	0.76
In a high bay area (25 - 50-foot floor-ceiling height)	0.98	0.88
In a low bay area (< 25-foot floor-ceiling height)	0.95	0.86
Museum		
In a general exhibition area	0.84	0.76
In a restoration room	0.82	0.74
Performing arts theater dressing/fitting room	0.32	0.29
Post office—Sorting area	0.75	0.68
Religious building		
In a fellowship hall	0.51	0.46
In a worship pulpit/choir area	1.22	1.10
Retail		
In a dressing/fitting room	0.57	0.51
In a mall concourse	0.88	0.79
Sports arena—Playing area		
For a Class 1 facility	2.41	2.17
For a Class 2 facility	1.54	1.39
For a Class 3 facility	0.96	0.86
For a Class 4 facility	0.58	0.52

BUILDING SPECIFIC
SPACE-BY-SPACE TYPES—continued

BUILDING SPECIFIC SPACE-BY-SPACE TYPES[a]	LPD (w/ft^2)[d] Before Jan 1 2018	LPD (w/ft^2)[d] After Jan 1 2018
Transportation		
In a baggage/carousel area	0.42	0.38
In an airport concourse	0.29	0.26
At a terminal ticket counter	0.64	0.58
Warehouse—Storage area		
For medium to bulky palletized items	0.46	0.41
For smaller, hand-carried items	0.76	0.68

Keys to Table C405.4.2(2)
For SI: 1 foot = 304.8 mm
1 watt per square foot = 11 W/m^2.
Footnotes to Table C405.4.2(2)

a. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply.
b. A "Facility for the visually impaired" is a facility that is licensed or will be licensed by local or state authorities for senior long-term care, adult daycare, senior support or people with special visual needs.
c. For spaces in which lighting is specified to be installed in addition to, and controlled separately from, the general lighting for the purposed of highlighting art or exhibits, provided that the additional lighting power shall not exceed 0.5 W/ft2 of such spaces.
d. The watts per square foot may be increased by 2 percent per foot of ceiling height above 20 feet, unless specifically directed otherwise by subsequent footnotes.
e. Footnote d may not be used for these occupancy types.
f. The watts per square foot may be increased by 2 percent per foot of ceiling height above 9 feet. Footnote d may not be used for these occupancy types.

TABLE C405.5.2(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~~)) not used	((~~High-activity commercial districts in major metropolitan areas as designated by the local land use planning authority~~))

TABLE C405.5.2(2)
INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS

		LIGHTING ZONES			
		Zone 1	**Zone 2**	**Zone 3**	**Zone 4**
Base Site Allowance (Base allowance is usable in tradable or nontradable surfaces.)		500 W	600 W	750 W	1300 W
Tradable Surfaces (Lighting power densities for uncovered parking areas, building grounds, *building entrances* and exits, canopies and overhangs and outdoor sales areas are tradable.)	**Uncovered Parking Areas**				
	Parking areas and drives	0.04 W/ft^2	0.06 W/ft^2	0.08 W/ft^2	0.10 W/ft^2
	Building Grounds				
	Walkways less than 10 feet wide	0.7 W/linear foot	0.7 W/linear foot	0.8 W/linear foot	1.0 W/linear foot
	Walkways 10 feet wide or greater, plaza areas special feature areas	0.14 W/ft^2	0.14 W/ft^2	0.16 W/ft^2	0.2 W/ft^2
	Stairways	0.75 W/ft^2	1.0 W/ft^2	1.0 W/ft^2	1.0 W/ft^2
	Pedestrian tunnels	0.15 W/ft^2	0.15 W/ft^2	0.2 W/ft^2	0.3 W/ft^2
	Building Entrances and Exits				
	Main entries	20 W/linear foot of door width	20 W/linear foot of door width	30 W/linear foot of door width	30 W/linear foot of door width
	Other doors	20 W/linear foot of door width	20 W/linear foot of door width	20 W/linear foot of door width	20 W/linear foot of door width
	Entry canopies	0.25 W/ft^2	0.25 W/ft^2	0.4 W/ft^2	0.4 W/ft^2
	Sales Canopies				
	Free-standing and attached	0.6 W/ft^2	0.6 W/ft^2	0.8 W/ft^2	1.0 W/ft^2
	Outdoor Sales				
	Open areas (including vehicle sales lots)	0.25 W/ ft^2	0.25 W/ ft^2	0.5 W/ ft^2	0.7 W/ ft^2
	Street frontage for vehicle sales lots in addition to “open area” allowance	No allowance	10 W/linear foot	10 W/linear foot	30 W/linear foot
Nontradable Surfaces (Lighting power density calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the “Tradable Surfaces” section of this table.)	Building facades	No allowance	0.075 W/ft^2 of gross above-grade wall area	0.113 W/ft^2 of gross above-grade wall area	0.150 W/ft^2 of gross above-grade wall area
	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.

C405.5.3 Full cutoff luminaires. For open parking and outdoor areas and roadways, luminaires mounted more than 15 feet above the ground shall have a luminaire light distribution in which zero candela intensity occurs at an angle of 90 degrees above nadir, and all greater angles from nadir.

C405.6 Electrical transformers (*Mandatory*). Electric transformers shall meet the minimum efficiency requirements of Table C405.6 as tested and rated in accordance with the test procedure listed in DOE 10 CFR 431. The efficiency shall be verified through certification under an *approved* certification program or, where no certification program exists, the equipment efficiency ratings shall be supported by data furnished by the transformer manufacturer.

Exception: The following transformers are exempt:

1. Transformers that meet the Energy Policy Act of 2005 exclusions based on the DOE 10 CFR 431 definition of special purpose applications.
2. Transformers that meet the Energy Policy Act of 2005 exclusions that are not to be used in general purpose applications based on information provided in DOE 10 CFR 431.
3. Transformers that meet the Energy Policy Act of 2005 exclusions with multiple voltage taps where the highest tap is at least 20 percent more than the lowest tap.
4. Drive transformers.
5. Rectifier transformers.
6. Auto-transformers.
7. Uninterruptible power system transformers.
8. Impedance transformers.
9. Regulating transformers.
10. Sealed and nonventilating transformers.
11. Machine tool transformer.
12. Welding transformer.
13. Grounding transformer.
14. Testing transformer.

TABLE C405.6
MINIMUM NOMINAL EFFICIENCY LEVELS FOR 10 CFR 431 LOW VOLTAGE DRY-TYPE DISTRIBUTION TRANSFORMERS

Single Phase Transformers		Three Phase Transformers	
kVA[a]	Efficiency (%)[b]	kVA[a]	Efficiency (%)[b]
15	97.7	15	97.0
25	98.0	30	97.5
37.5	98.2	45	97.7
50	98.3	75	98.0
75	98.5	112.5	98.2
100	98.6	150	98.3

TABLE C405.6—continued
MINIMUM NOMINAL EFFICIENCY LEVELS FOR 10 CFR 431 LOW VOLTAGE DRY-TYPE DISTRIBUTION TRANSFORMERS

Single Phase Transformers		Three Phase Transformers	
kVA[a]	Efficiency (%)[b]	kVA[a]	Efficiency (%)[b]
167	98.7	225	98.5
250	98.8	300	98.6
333	98.9	500	98.7
		750	98.8
		1000	98.9

a. kiloVolt-Amp rating.
b. Nominal efficiencies shall be established in accordance with the DOE 10 CFR 431 test procedure for low voltage dry-type transformers.

C405.7 Dwelling unit electrical energy consumption (*Mandatory*). Each dwelling unit located in a Group R-2 building shall have a separate electrical meter. A utility tenant meter meets this requirement. See Section C409 for additional requirements for energy metering and energy consumption management.

C405.8 Electric motor efficiency (*Mandatory*). All electric motors, fractional or otherwise, shall meet the minimum efficiency requirements of Tables C405.8(1) through C405.8(4) when tested and rated in accordance with DOE 10 CFR. The efficiency shall be verified through certification under an *approved* certification program, or, where no certification program exists, the equipment efficiency rating shall be supported by data furnished by the motor manufacturer.

Fractional hp fan motors that are 1/12 hp or greater and less than 1 hp which are not covered by Tables C405.8(3) and C405.8(4) shall be electronically commutated motors or shall have a minimum motor efficiency of 70 percent when rated in accordance with DOE 10 CFR 431. These motors shall also have the means to adjust motor speed for either balancing or remote control. Belt-driven fans may use sheave adjustment for airflow balancing in lieu of a varying motor speed.

Exceptions:

1. Motors that are an integral part of specialized process equipment.
2. Where the motor is integral to a listed piece of equipment for which no complying motor has been *approved*.
3. Motors used as a component of the equipment meeting the minimum efficiency requirements of Section C403.2.3 and Tables C403.2.3(1) through C403.2.3(10), provided that the motor input is included when determining the equipment efficiency.
4. Motors in the airstream within fan coils and terminal units that operate only when providing heating to the space served.
5. Fan motors that are not covered by Tables C405.8(1) through C405.8(4) and are used to power heat recov-

ery ventilators, energy recovery ventilators, or local exhaust fans in Group R subject to the high efficacy requirements of Section C403.2.11.4.

6. Domestic clothes dryer booster fans, range hood exhaust fans, and domestic range booster fans that operate intermittently.
7. Radon and contaminated soil exhaust fans.
8. Group R heat recovery ventilator and energy recovery ventilator fans that are less than 400 cfm.

TABLE C405.8(1)
MINIMUM NOMINAL FULL-LOAD EFFICIENCY FOR 60 HZ NEMA GENERAL PURPOSE ELECTRIC MOTORS (SUBTYPE I) RATED 600 VOLTS OR LESS (Random Wound)[a]

	OPEN DRIP-PROOF MOTORS			TOTALLY ENCLOSED FAN-COOLED MOTORS		
NUMBER OF POLES	**2**	**4**	**6**	**2**	**4**	**6**
Synchronous Speed (RPM)	**3600**	**1800**	**1200**	**3600**	**1800**	**1200**
MOTOR HORSEPOWER						
1	77.0	85.5	82.5	77.0	85.5	82.5
1.5	84.0	86.5	86.5	84.0	86.5	87.5
2	85.5	86.5	87.5	85.5	86.5	88.5
3	85.5	89.5	88.5	86.5	89.5	89.5
5	86.5	89.5	89.5	88.5	89.5	89.5
7.5	88.5	91.0	90.2	89.5	91.7	91.0
10	89.5	91.7	91.7	90.2	91.7	91.0
15	90.2	93.0	91.7	91.0	92.4	91.7
20	91.0	93.0	92.4	91.0	93.0	91.7
25	91.7	93.6	93.0	91.7	93.6	93.0
30	91.7	94.1	93.6	91.7	93.6	93.0
40	92.4	94.1	94.1	92.4	94.1	94.1
50	93.0	94.5	94.1	93.0	94.5	94.1
60	93.6	95.0	94.5	93.6	95.0	94.5
75	93.6	95.0	94.5	93.6	95.4	94.5
100	93.6	95.4	95.0	94.1	95.4	95.0
125	94.1	95.4	95.0	95.0	95.4	95.0
150	94.1	95.8	95.4	95.0	95.8	95.8
200	95.0	95.8	95.4	95.4	96.2	95.8
250	95.0	95.8	95.4	95.8	96.2	95.8
300	95.4	95.8	95.4	95.8	96.2	95.8
350	95.4	95.8	95.4	95.8	96.2	95.8
400	95.8	95.8	95.8	95.8	96.2	95.8
450	95.8	96.2	96.2	95.8	96.2	95.8
500	95.8	96.2	96.2	95.8	96.2	95.8

a. Nominal efficiencies shall be established in accordance with DOE 10 CFR 431.

TABLE C405.8(2)
MINIMUM NOMINAL FULL-LOAD EFFICIENCY OF GENERAL PURPOSE ELECTRIC MOTORS (SUBTYPE II) AND ALL DESIGN B MOTORS GREATER THAN 200 HORSEPOWER[a]

	OPEN DRIP-PROOF MOTORS				TOTALLY ENCLOSED FAN COOLED MOTORS			
NUMBER OF POLES	**2**	**4**	**6**	**8**	**2**	**4**	**6**	**8**
Synchronous Speed (RPM)	**3600**	**1800**	**1200**	**900**	**3600**	**1800**	**1200**	**900**
MOTOR HORSEPOWER								
1	NR	82.5	80.0	74.0	75.5	82.5	80.0	74.0
1.5	82.5	84.0	84.0	75.5	82.5	84.0	85.5	77.0
2	84.0	84.0	85.5	85.5	84.0	84.0	86.5	82.5
3	84.0	86.5	86.5	86.5	85.5	87.5	87.5	84.0
5	85.5	87.5	87.5	87.5	87.5	87.5	87.5	85.5
7.5	87.5	88.5	88.5	88.5	88.5	89.5	89.5	85.5
10	88.5	89.5	90.2	89.5	89.5	89.5	89.5	88.5
15	89.5	91.0	90.2	89.5	90.2	91.0	90.2	88.5
20	90.2	91.0	91.0	90.2	90.2	91.0	90.2	89.5
25	91.0	91.7	91.7	90.2	91.0	92.4	91.7	89.5
30	91.0	92.4	92.4	91.0	91.0	92.4	91.7	91.0
40	91.7	93.0	93.0	91.0	91.7	93.0	93.0	91.0
50	92.4	93.0	93.0	91.7	92.4	93.0	93.0	91.7
60	93.0	93.6	93.6	92.4	93.0	93.6	93.6	91.7
75	93.0	94.1	93.6	93.6	93.0	94.1	93.6	93.0
100	93.0	94.1	94.1	93.6	93.6	94.5	94.1	93.0
125	93.6	94.5	94.1	93.6	94.5	94.5	94.1	93.6
150	93.6	95.0	94.5	93.6	94.5	95.0	95.0	93.6
200	94.5	95.0	94.5	93.6	95.0	95.0	95.0	94.1
250	94.5	95.4	95.4	94.5	95.4	95.0	95.0	94.5
300	95.0	95.4	95.4	NR	95.4	95.4	95.0	NR
350	95.0	95.4	95.4	NR	95.4	95.4	95.0	NR
400	95.4	95.4	NR	NR	95.4	95.4	NR	NR
450	95.8	95.8	NR	NR	95.4	95.4	NR	NR
500	95.8	95.8	NR	NR	95.4	95.8	NR	NR

NR = No requirement.

a. Nominal efficiencies shall be established in accordance with DOE 10 CFR 431.

TABLE C405.8(3)
MINIMUM AVERAGE FULL LOAD EFICIENCY POLYPHASE SMALL ELECTRIC MOTORS[a]

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

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

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

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

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

C405.9 Vertical and horizontal transportation systems and equipment (*Mandatory*). Vertical and horizontal transportation systems and equipment shall comply with this section.

C405.9.1 Elevator cabs. For the luminaires in each elevator cab, not including signals and displays, the sum of the lumens divided by the sum of the watts shall be not less than 35 lumens per watt. Ventilation fans in elevators that do not have their own air-conditioning system shall not consume more than 0.33 watts/cfm at the maximum rated speed of the fan. Controls shall be provided that will de-energize ventilation fans and lighting systems when the elevator is stopped, unoccupied and with its doors closed for over 15 minutes.

C405.9.2 Escalators and moving walks. Escalators and moving walks shall comply with ASME A17.1/CSA B44 and shall have *automatic* controls configured to reduce speed to the minimum permitted speed in accordance with ASME A17.1/CSA B44 or applicable local code when not conveying passengers.

Exception: A power factor controller that reduces operating voltage in response to light loading conditions ((~~may~~)) is permitted to be provided in ((~~place~~)) lieu of the variable speed function.

C405.9.3 Regenerative drive. An escalator designed either for one-way down operation only or for reversible operation shall have a variable frequency regenerative drive that supplies electrical energy to the building electrical system when the escalator is loaded with passengers whose combined weight exceeds 750 pounds.

C405.10 Controlled receptacles (*Mandatory*). At least 50 percent of all 125 volt 15- and 20-ampere receptacles installed in private offices, open offices, conference rooms, rooms used primarily for printing and/or copying functions, break rooms, individual workstations and classrooms, including those installed in modular partitions and modular office workstation systems, shall be controlled as required by this section. ((~~In rooms larger than 200 square feet (19 m^2),~~)) Either split receptacles shall be provided, with the top receptacle(s) controlled, or a *controlled receptacle* shall be located within ((~~72~~)) 12 inches (((~~1.8~~)) 0.3 m) of each uncontrolled

receptacle. *Controlled receptacles* shall be visibly differentiated from standard receptacles using the standard symbol required by the *Seattle Electrical Code* and shall be controlled by one of the following *automatic control devices*:

1. An occupant sensor that turns receptacle power off when no occupants have been detected for a maximum of 20 minutes.
2. A time-of-day operated control device that turns receptacle power off at specific programmed times and can be programmed separately for each day of the week. The control device shall be configured to provide an independent schedule for each portion of the building not to exceed 5,000 square feet (465 m^2) and not to exceed one full floor. The device shall be capable of being overridden for periods of up to two hours by a timer *accessible* to occupants. Any individual override switch shall control the *controlled receptacles* for a maximum area of 5,000 square feet (465 m^2). Override switches for *controlled receptacles* are permitted to control the lighting within the same area.

Exceptions:

1. Receptacles designated for specific equipment requiring 24-hour operation, for building maintenance functions, or for specific safety or security equipment are not required to be controlled by an *automatic control device* and are not required to be located within ((~~72~~)) 12 inches of a *controlled receptacle*.
2. Within a single modular office workstation, non-*controlled receptacles* are permitted to be located more than 12 inches, but not more than 72 inches, from the *controlled receptacles* serving that workstation.

* **C405.11 Reserved.**

C405.12 Reserved.

C405.13 ((~~Electrical power~~)) Controlled receptacles and lighting systems commissioning and completion requirements (*Mandatory*). ((~~Electrical power~~)) *Controlled receptacles* and lighting systems shall be commissioned and completed in accordance with Section C408.

SECTION C406
ADDITIONAL EFFICIENCY PACKAGE OPTIONS

C406.1 Requirements. Buildings shall comply with no less than two of the following:

1. More efficient HVAC performance in accordance with Section C406.2.
2. Reduced lighting power in accordance with Section C406.3.
3. Enhanced lighting controls in accordance with Section C406.4.
4. On-site supply of renewable energy in accordance with Section C406.5.
5. Provision of a dedicated outdoor air system for certain HVAC equipment in accordance with Section C406.6.
6. High-efficiency service water heating in accordance with Section C406.7.
7. Enhanced envelope performance in accordance with Section C406.8.
8. Reduced air infiltration in accordance with Section C406.9.

C406.1.1 Tenant spaces. Tenant spaces shall comply with Section C406.2, C406.3, C406.4, C406.6 or C406.7, where applicable. Where an entire building complies with Section C406.5, C406.8 or C406.9, tenant spaces within the building shall be deemed to comply with this section.

SDCI Informative Note: In this section "tenant space" means any conditioned area within a new building that is constructed for first occupancy under a separate permit from the shell and core permits.

C406.2 More efficient HVAC equipment and fan performance. Buildings shall comply with Sections C406.2.1 through C406.2.3.

C406.2.1 HVAC system selection. No less than 90 percent of the total HVAC capacity serving the building shall be provided by equipment that is listed in Tables C403.2.3(1) through C403.2.3(9) or a combination thereof.

Exception: Air-to-water heat pumps or heat recovery chillers are also permitted to be utilized for Option C406.2.

C406.2.2 Minimum equipment efficiency. Equipment shall exceed the minimum efficiency requirements listed in Tables C403.2.3(1) through C403.2.3(9) by 15 percent, in addition to the requirements of Section C403. Where multiple performance requirements are provided, the equipment shall exceed all requirements by 15 percent. Where exception 1 for Section C411 is also being used, the equipment shall exceed all requirements by 25 percent.

Exception: Equipment that is larger than the maximum capacity range indicated in Tables C403.2.3(1) through C403.2.3(9) shall utilize the values listed for the largest capacity equipment for the associated equipment type shown in the table.

C406.2.3 Minimum fan efficiency. Stand-alone supply, return and exhaust fans designed for operating with motors over 750 watts (1 hp) shall have an energy efficiency classification of not less than FEG 71 as defined in AMCA 205. The total efficiency of the fan at the design point of operation shall be within 10 percentage points of either the maximum total efficiency of the fan or the static efficiency of the fan.

C406.3 Reduced lighting power. Buildings shall comply with Sections C406.3.1 and, where applicable, C406.3.2.

C406.3.1 Reduced lighting power density. The total interior lighting power (watts) of the building shall be 75 percent or less of the lighting power values specified in Table C405.4.2(1) times the floor area for the building

types, or by using 75 percent of the interior lighting power allowance calculated by the Space-by-Space Method in Section C405.4.2.

C406.3.2 Lamp fraction. Not less than 95 percent of the interior lighting power (watts) from lamps in permanently installed light fixtures in dwelling units and *sleeping units* shall be provided by lamps with a minimum efficacy of 60 lumens per watt.

C406.4 Enhanced digital lighting controls. Interior lighting shall be located, scheduled and operated in accordance with Section C405.2 and ((~~no~~)) not less than 90 percent of the total installed interior lighting power shall be configured with the following enhanced control functions.

1. Luminaires shall be configured for continuous dimming.
2. Each luminaire shall be individually addressed.

Exceptions:

1. Multiple luminaires mounted on no more than 12 linear feet of a single lighting track and addressed as a single luminaire.
2. Multiple linear luminaires that are ganged together to create the appearance of a single longer fixture and addressed as a single luminaire, where the total length of the combined luminaires is not more than 12 feet.

3. Not more than eight luminaires within a *daylight zone* are permitted to be controlled by a single *daylight responsive control*.
4. Luminaires shall be controlled by a digital control system configured with the following capabilities:
   - 4.1. Scheduling and illumination levels of individual luminaires and groups of luminaires are capable of being reconfigured through the system.
   - 4.2. Load shedding.
   - 4.3. In open and enclosed offices, the illumination level of overhead general illumination luminaires are configured to be individually adjusted by occupants.
   - 4.4. Occupancy sensors and *daylight responsive controls* are capable of being reconfigured through the system.
5. Construction documents shall include submittal of a Sequence of Operations, including a specification outlining each of the functions required by this section.
6. These control functions shall be commissioned in accordance with Sections C408.1 and C408.3.

C406.5 On-site renewable energy. In addition to the renewable energy required by Section C411 and to renewable energy used to comply with any other requirements of this code, buildings ((~~Buildings~~)) shall be provided with *on-site renewable energy* systems with a total peak system rating per square foot of *conditioned floor area* of the building of not less than 0.25 watts (or 0.85 BTU/h) per square foot of *conditioned space* ((~~the value specified in Table C406.5~~)).

((~~TABLE C406.5 ON-SITE RENEWABLE ENERGY SYSTEM RATING (PER SQUARE FOOT)~~

~~Building Area Type~~	~~kBTU~~	~~kWh~~
~~Assembly~~	~~1.8~~	~~0.53~~
~~Dining~~	~~10.7~~	~~3.14~~
~~Hospital~~	~~3.6~~	~~1.06~~
~~Hotel/Motel~~	~~2.0~~	~~0.59~~
~~Multi-family residential~~	~~0.50~~	~~0.15~~
~~Office~~	~~0.82~~	~~0.24~~
~~Other~~	~~2.02~~	~~0.59~~
~~Retail~~	~~1.31~~	~~0.38~~
~~School/University~~	~~1.17~~	~~0.34~~
~~Supermarket~~	~~5.0~~	~~1.47~~
~~Warehouse~~	~~0.43~~	~~0.13~~))

C406.6 Dedicated outdoor air system (DOAS). Not less than 90% of the building *conditioned floor area*, excluding floor area of unoccupied spaces that do not require ventilation per the *International Mechanical Code*, shall be served by DOAS installed in accordance with Section C403.6. This option is available to both buildings subject to and not subject to the prescriptive requirements of Section C403.6.

C406.7 Reduced energy use in service water heating. Buildings shall comply with Sections C406.7.1 and C406.7.2.

C406.7.1 Building type. Not less than 90 percent of the *conditioned floor area* shall be of the following types:

1. Group R-1: Boarding houses, hotels or motels.
2. Group I-2: Hospitals, psychiatric hospitals and nursing homes.
3. Group A-2: Restaurants and banquet halls or buildings containing food preparation areas.
4. Group F: Laundries.
5. Group R-2: Buildings with residential occupancies.
6. Group A-3: Health clubs and spas.
7. Buildings with a service hot water load of 10 percent or more of total building energy loads, as shown with an energy analysis as described in Section C407.

C406.7.2 Load fraction. Not less than 60 percent of the annual building service hot water heating energy use, or not less than 100 percent of the annual building service hot water heating energy use in buildings subject to the requirements of Section C403.5.4, shall be provided by one or more of the following:

1. Service hot water system delivering heating requirements using heat pump technology with a minimum COP of 3.0.
2. Waste heat recovery from service hot water, heat recovery chillers, building equipment, process

equipment, a combined heat and power system, or other *approved* system.

3. Solar water-heating systems, where those systems are in addition to the renewable energy required by Section C411 or renewable energy used to comply with any other requirements of this code.

C406.8 Enhanced envelope performance. The total UA of the *building thermal envelope* shall be 15 percent lower than the maximum allowable UA for a building of identical configuration and *fenestration area* in accordance with Section C402.1.5 and Equation 4-2, where UA equals the sum of the *U*-values of each distinct envelope assembly multiplied by the area in square feet of that assembly. Where exception 1 for Section C411 is also being used, the UA shall be 30 percent lower than the maximum allowable UA.

C406.9 Reduced air ((~~infiltration~~)) leakage. Air ((~~infiltration~~)) leakage shall be verified by whole building pressurization testing conducted in accordance with ASTM E779 or ASTM E1827, or an equivalent method *approved* by the code official, by an independent third party. The measured air leakage rate of the *building envelope* shall not exceed 0.25 cfm/ft^2 (((~~2.0 L/s•m^2~~))) (1.2 L/s•m^2) for Group R occupancy buildings and 0.22 cfm/ft^2 (1.1 L/s•m^2) for all other occupancies under a pressure differential of 0.3 in. water (75 Pa), with the calculated surface area being the sum of the above and below grade *building envelope*. A report that includes the tested surface area, floor area, air by volume, stories above grade, and leakage rates shall be submitted to the code official and the building owner.

((~~**Exception:** Where the *conditioned floor area* of the building is not less than 250,000 ft^2 (25,000 m^2), air leakage testing shall be permitted to be conducted on representative above-grade sections of the building provided the *conditioned floor area* of tested areas is no less than 25 percent of the *conditioned floor area* of the building and are tested in accordance with this section.~~))

SECTION C407
TOTAL BUILDING PERFORMANCE

C407.1 Scope. This section establishes criteria for compliance using total building performance. All systems and loads shall be included in determining the total building performance including, but not limited to: Heating systems, cooling systems, service water heating, fan systems, lighting power, receptacle loads and process loads.

C407.2 *Mandatory* requirements. Compliance with ((~~this section~~)) Section C407 also requires that the criteria of Sections C402.5, C403.2, C404, ((~~and~~)) C405.2, C405.3, C405.5, C405.6, C405.7, C405.8, C405.9, C405.10, C408, C409, C410 and C412 be met.

The building permit application for projects utilizing this method shall include in one submittal all building and mechanical drawings and all information necessary to verify that the building envelope and mechanical design for the project corresponds with the annual energy analysis. If credit is proposed to be taken for lighting energy savings, then an electrical permit application shall also be submitted and *approved* prior to the issuance of the building permit. If credit is proposed to be taken for energy savings from other components, then the corresponding permit application (e.g., plumbing, boiler, etc.) shall also be submitted and *approved* prior to the building permit application. Otherwise, components of the project that would not be *approved* as part of a building permit application shall be modeled the same in both the proposed building and the *standard reference design* and shall comply with the requirements of this code.

C407.2.1 Cap on vertical fenestration area. *Vertical fenestration area* shall not exceed 45 percent of the above-grade wall area.

Exceptions:

1. This cap shall not apply to projects for which the complete building permit application was submitted prior to January 1, 2018.
2. *Vertical fenestration area* may exceed 45 percent of the above-grade wall area, where the annual energy consumption of the *proposed design* is 0.33 percent lower than that permitted by the selected option in Section C407.3, for each 1 percent increase in *vertical fenestration area* above 45 percent of the above-grade wall area.

C407.3 Performance-based compliance. Compliance based on total building performance requires that a proposed building (*proposed design*) be shown to have an annual energy consumption based on site energy expressed in Btu and Btu per square foot of *conditioned floor area* that complies with one of the following three options:

1. Is less than or equal to 87 percent of the annual energy consumption of the *standard reference design*.
2. Is less than or equal to 90 percent of the annual energy consumption of the *standard reference design* and the project complies with one additional energy efficiency package option in Section C406. The standard reference design shall include the selected Section C406 additional efficiency package option unless the option selected is DOAS per Section C406.6, in which case the HVAC system used in the standard reference design shall be one of the following:
   2.1. For office, retail, education, libraries and fire stations that comply with the DOAS requirements in Section C403.6 with or without exceptions, the standard reference design shall select the HVAC system per Table C407.5.1(2).
   2.2. Other buildings occupancy types that comply with the DOAS requirements in Section C403.6 shall select the standard reference design for the HVAC system from Table C407.5.1(3).
3. Is less than or equal to 93 percent of the annual energy consumption of the standard reference design and the project complies with two additional efficiency package options in Section C406. The standard reference design shall include ((~~the~~)) both selected Section C406 additional efficiency package options, unless one of the options selected is DOAS per Section C406.6, in which

case the HVAC system used in the standard reference design shall be one of the following:

3.1 For office, retail, education, libraries and fire stations that comply with the DOAS requirements in Section C403.6 with or without exceptions, the standard reference design shall select the HVAC system per Table C407.5.1(2).

3.2 Other buildings occupancy types that comply with the DOAS requirements in Section C403.6 shall select the standard reference design for the HVAC system from Table C407.5.1(3).

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

C407.4.1 Compliance report. Building permit submittals shall include a report that documents that the *proposed design* has annual energy consumption less than or equal to the annual energy consumption of the *standard reference design*. The compliance documentation shall include the information listed in Appendix ((~~D~~))E ((~~following information:~~

~~1. Address of the building;~~

~~2. An inspection checklist documenting the building component characteristics of the proposed design as listed in Table C407.5.1(1). The inspection checklist shall show the estimated annual energy consumption for both the standard reference design and the proposed design;~~

~~3. Name of individual completing the compliance report; and~~

~~4. Name and version of the compliance software tool.~~

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

~~1. Documentation of the building component characteristics of the standard reference design;~~

~~2. Thermal zoning diagrams consisting of floor plans showing the thermal zoning scheme for standard reference design and proposed design;~~

~~3. Input and output report(s) from the energy analysis simulation program containing the complete input and output files, as applicable. The output file shall include energy use totals and energy use by energy source and end-use served, total hours that space conditioning loads are not met and any errors or warning messages generated by the simulation tool as applicable;~~

~~4. An explanation of any error or warning messages appearing in the simulation tool output; and~~

~~5. A certification signed by the builder providing the building component characteristics of the proposed design as given in Table C407.5.1(1).~~))

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

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

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

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

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

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

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

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

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

C407.5.3 Equipment efficiencies. All HVAC equipment in the standard reference design shall be modeled at the minimum efficiency levels, both part load and full load, in accordance with Section C403.2.3. Chillers shall use Path A efficiencies as shown in Table C403.2.3(7). Where efficiency ratings include supply fan energy, the efficiency rating shall be adjusted to remove the supply fan energy. For Baseline Systems HVAC Systems 3, 4, 6, 8, 9, 10 and 11, calculate the minimum $COP_{nfcooling}$ and $COP_{nfheating}$ using the equation for the applicable performance rating as indicated in Tables C403.2.3(1) through C403.2.3(3). Where a full- and part-load efficiency rating is provided in Tables C403.2.3(1) through C403.2.3(3), use Equation 4-12.

(Equation 4-12)

$COP_{nfcooling} = 7.84E\text{-}8 \times EER \times Q + 0.338 \times EER$

$COP_{nfcooling} = -0.0076 \times SEER^2 + 0.3796 \times SEER$

$COP_{nfheating} = 1.48E\text{-}7 \times COP_{47} \times Q + 1.062 \times COP_{47}$
(applies to heat pump heating efficiency only)

$COP_{nfheating} = -0.0296 \times HSPF^2 + 0.7134 \times HSPF$

Where:

$COP_{nfcooling}$ = The packaged HVAC equipment cooling energy efficiency

$COP_{nfheating}$ = The packaged HVAC equipment heating energy efficiency

Q = The AHRI-rated cooling capacity in Btu/h.

COP_{47} = Heat pump COP with 47°F db outdoor air rating condition in Tables C403.2.3(1) through C403.2.3(3).

EER, SEER, COP and HSPF shall be at AHRI test conditions. Fan energy shall be modeled separately according to Table C407.5.1(1).

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

BUILDING COMPONENT CHARACTERISTICS	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Space use classification	Same as proposed	The space use classification shall be chosen in accordance with Table C405.5.2 for all areas of the building covered by this permit. Where the space use classification for a building is not known, the building shall be categorized as an office building.
Roofs	Type: Insulation entirely above deck	As proposed
	Gross area: same as proposed	As proposed
	U-factor: as specified in Table C402.1.4	As proposed
	Solar absorptance: 0.75	As proposed
	Emittance: 0.90	As proposed
Walls, above-grade	Type: Mass wall where proposed wall is mass; otherwise steel-framed wall	As proposed
	Gross area: same as proposed	As proposed
	U-factor: as specified in Table C402.1.4	As proposed
	Solar absorptance: 0.75	As proposed
	Emittance: 0.90	As proposed
Walls, below-grade	Type: Mass wall	As proposed
	Gross area: same as proposed	As proposed
	U-Factor: as specified in Table C402.1.4 with insulation layer on interior side of walls	As proposed
Floors, above-grade	Type: joist/framed floor	As proposed
	Gross area: same as proposed	As proposed
	U-factor: as specified in Table C402.1.4	As proposed
Floors, slab-on-grade	Type: Unheated	As proposed
	F-factor: as specified in Table C402.1.4	As proposed
Opaque doors	Type: Swinging	As proposed
	Area: Same as proposed	As proposed
	U-factor: as specified in Table C402.1.4	As proposed
Vertical fenestration other than *opaque doors*	Area 1. The proposed *vertical fenestration area*; where the proposed *vertical fenestration area* is less than 30 percent of above-grade wall area. 2. 30 percent of above-grade wall area; where the proposed *vertical fenestration area* is 30 percent or more of the above-grade wall area.	As proposed
	U-factor: From Table C402.4 for the same framing material as proposed	As proposed
	SHGC: From Table C402.4 except that for climates with no requirement (NR) SHGC = 0.40 shall be used	As proposed
	External shading and PF: None	As proposed

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

BUILDING COMPONENT CHARACTERISTICS	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Skylights	Area 1. The proposed skylight area; where the proposed skylight area is less than 3 percent of gross area of roof assembly. 2. 3 percent of gross area of roof assembly; where the proposed skylight area is 3 percent or more of gross area of roof assembly *U*-factor: From Table C402.4 SHGC: From Table C402.4 except that for climates with no requirement (NR) SHGC = 0.40 shall be used	As proposed As proposed As proposed
Air Leakage	For infiltration, the air leakage rate as determined below shall be modeled at 100% when the building fan system is off, and at 25% when the building fan system is on, unless otherwise *approved* by the building official for unusually pressurized buildings. Per PNNL Report 18898, *Infiltration Modeling Guidelines for Commercial Building Energy Analysis*, the building air leakage rates as determined in accordance with Section C402.5.1.2 at 0.30 in. w.g. (75 Pa) shall be converted for modeling in annual energy analysis programs by being multiplied by 0.112 unless other multipliers are *approved* by the building official (e.g., a tested air leakage of 0.40 cfm/ft^2 of total building envelope area at 0.30 in. w.g. (75 Pa) would be calculated at 0.045 cfm/ft^2 of building envelope area). The calculated infiltration rate shall be normalized to the input required by the modeling software.	The Proposed Design air-leakage shall be the same as the Standard Design.
Lighting, interior	The interior lighting power shall be determined in accordance with Table C405.4.2. As proposed when the occupancy of the space is not known. *Automatic* lighting controls (e.g., programmable controls or *automatic* controls for daylight utilization) shall be modeled in *the standard reference design* as required by Section C405.	As proposed; where the occupancy of the space is not known, the lighting power density shall be based on the space classification as offices in Table C405.4.2(1).
Lighting, exterior	The lighting power shall be determined in accordance with Table C405.5.2(2). Areas and dimensions of tradable and nontradable surfaces shall be the same as proposed.	As proposed
Internal gains	Same as proposed	Receptacle, motor and process loads shall be modeled and estimated based on the space use classification. All end-use load components within and associated with the building shall be modeled to include, but not be limited to, the following: Exhaust fans, parking garage ventilation fans, exterior building lighting, swimming pool heaters and pumps, elevators, escalators, refrigeration equipment and cooking equipment.

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

BUILDING COMPONENT CHARACTERISTICS	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Schedules	Same as proposed	Operating schedules shall include hourly profiles for daily operation and shall account for variations between weekdays, weekends, holidays and any seasonal operation. Schedules shall model the time-dependent variations in occupancy, illumination, receptacle loads, thermostat settings, mechanical ventilation, HVAC equipment availability, service hot water usage and any process loads. The schedules shall be typical of the proposed building type as determined by the designer and *approved* by the jurisdiction.
Outdoor airflow rates	Same as proposed, or no higher than those allowed by Section C403.2.6 (without exception 1), whichever is less. *Demand Control Ventilation*: Shall be modeled as required by Section ((~~C403.6~~)) C403.2.6.2 including reduction to the minimum ventilation rate when unoccupied.	As proposed, in accordance with Section C403.2.6. As proposed
Heating systems	Fuel type: Same as proposed design Equipment type[a]: From Tables C407.5.1(2), C407.5.1(3) and C407.5.1(4) Efficiency: From Tables C.403.2.3.(1)C, C403.2.3(2), C403.2.3(3), C403.2.3(4) and C403.2.3(5) Preheat coils: For HVAC system numbers 1 through 4, a preheat coil shall be modeled controlled to a fixed setpoint 20°F less than the design room heating temperature setpoint. Capacity[b]: Sized proportionally to the capacities in the proposed design based on sizing runs, i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be the same for both the proposed design and *standard reference design*, and shall be established such that no smaller number of unmet heating load hours and no larger heating capacity safety factors are provided than in the proposed design. Weather conditions used in sizing runs to determine *standard reference design* equipment capacities may be based either on hourly historical weather files containing typical peak conditions or on design days developed using 99.6% heating design temperatures and 1% dry-bulb and 1% wet-bulb cooling design temperatures.	As proposed As proposed As proposed As proposed

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

BUILDING COMPONENT CHARACTERISTICS	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Cooling systems	Fuel type: Same as proposed design	As proposed
	Equipment type[c]: From Tables C407.5.1(2), C407.5.1(3) and C407.5.1(4)	As proposed
	Efficiency: From Tables C403.2.3(1), C403.2.3(2) and C403.2.3(3). Chillers shall use Path A efficiency.	As proposed
	Capacity[b]: Sized proportionally to the capacities in the proposed design based on sizing runs, i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be the same for both the proposed design and standard reference design, and shall be established such that no smaller number of unmet cooling load hours and no larger cooling capacity safety factors are provided than in the proposed design.	As proposed
	Economizer[d]: ((~~Same as proposed, in~~)) In accordance with Section C403.3. The high-limit shutoff shall be a dry-bulb switch with a setpoint as determined by Table C403.3.3.3.	As proposed
Energy recovery	*Standard reference design* systems shall be modeled where required in Section C403.5.	As proposed
Fan systems	Airflow rate: System design supply airflow rates for the *standard reference design* shall be based on a supply-air-to-room-air temperature difference of 20°F or the required ventilation air or makeup air, whichever is greater. If return or relief fans are specified in the proposed design, the *standard reference design* shall also be modeled with fans serving the same functions and sized for the *standard reference design* system supply fan air quantity less the minimum outdoor air, or 90% of the supply fan air quantity, whichever is larger.	As proposed
	Motor brake horsepower: System fan electrical power for supply, return, exhaust, and relief (excluding power to fan-powered VAV boxes) shall be calculated using the following formulas: For systems 5, 6, 7, 8 and 10 in Table C407.5.1(4), Pfan = CFMS × 0.3 For all other systems, including DOAS, Pfan = bhp × 746/Fan Motor Efficiency Where: Pfan = Electric power to fan motor (watts) bhp = Brake horsepower of *standard reference design* fan motor from Table ((~~C403.2.12.1(1)~~)) C403.2.11.1(1) – Option 2 Fan motor = The efficiency from Tables C405.8(1) through C405.8(4) for the efficiency of the next motor size greater than the bhp using the enclosed motor at 1800 rpm CFM_S = The *standard reference design* system maximum design supply fan airflow rate in cfm ((~~DOAS fan power shall be calculated separately from the brake horsepower allowance.~~)) Fan efficiency, including that of fractional horsepower fans, shall conform to the requirements of Section C405.8.	As proposed

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

BUILDING COMPONENT CHARACTERISTICS	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
On-site renewable energy	No *on-site renewable energy* shall be modeled in the standard reference design, except that required by Section C411, without the exceptions.	As proposed
Shading from adjacent structures/terrain	Same as proposed.	For the standard reference design and the proposed building, shading by permanent structures and terrain shall be taken into account for computing energy consumption whether or not these features are located on the building site. A permanent fixture is one that is likely to remain for the life of the proposed design.
Service water heating	Fuel type: Same as proposed	As proposed
	Efficiency: From Table C404.2 and per Section C404.2.1	For Group R, as proposed multiplied by SWHF. For other than Group R, as proposed multiplied by efficiency as provided by the manufacturer of the DWHR unit.
	Capacity: Same as proposed	As proposed
	Demand: Same as proposed	Service hot-water energy consumption shall be calculated explicitly based upon the volume of service hot water required and the entering makeup water and the leaving service hot water temperatures. Entering (municipal cold) water temperatures shall be ((~~estimated based upon the location~~)) specified using the following monthly temperature schedule (in degrees Fahrenheit): J-54, F-53, M-54, A-56, M-59, J-62, J-64, A-65, S-65, O-63, N-60, D-57. Leaving temperatures shall be based upon the end-use requirements. Service water loads and usage shall be the same for both the *standard reference design* and the proposed design and shall be documented by the calculation procedures recommended by the manufacturer's specifications or generally accepted engineering methods.
	Where no service water hot water system exists or is specified in the proposed design, no service hot water heating shall be modeled.	As proposed
	Drain water heat recovery: Not required.	As proposed. Drain water heat recovery modeling shall take into account manufacturer's rated efficiencies per ((~~C404.9~~)) C404.10, quantity of connected drains, the proportional flow rates between the waste stream and the preheated stream. Reductions in service water heating energy use for drain water heat recovery shall be demonstrated by calculations.

a. Where no heating system exists or has been specified, the heating system shall be modeled as fossil fuel. The system characteristics shall be identical in both the standard reference design and proposed design.
b. The ratio between the capacities used in the annual simulations and the capacities determined by sizing runs shall be the same for both the standard reference design and proposed design.

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

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

SDCI Informative Note: SDCI interprets "fixture" in "Shading from adjacent structures/terrain" as a typographical error for "feature."

TABLE C407.5.1(2)
HVAC SYSTEMS MAP FOR BUILDINGS GOVERNED BY SECTION C403.6[d]

CONDENSER COOLING SOURCE[a]	HEATING SYSTEM CLASSIFICATION[b]	STANDARD REFERENCE DESIGN HVC SYSTEM TYPE((~~e~~))	
		((~~Single-zone Residential System~~	~~All Other~~))
Water/ground	Electric resistance	((~~System 5~~	System 5
	Heat pump	~~System 6~~	System 6
	Fossil fuel	~~System 7~~	System 7
Air/none	Electric resistance	~~System 8~~	System 9
	Heat pump	~~System 8~~	System 9
	Fossil fuel	~~System 10~~))	System 11

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

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

c. Reserved. ((~~Select the *standard reference design* HVAC system category: The system under "single-zone residential system" shall be selected if the HVAC system in the proposed design is a single-zone system and serves a residential space. The system under "all other" shall be selected for all other cases.~~))

d. This table covers those building types required by Section C403.6 to install Dedicated Outdoor Air Systems: office, retail, education, libraries and fire stations.

TABLE C407.5.1(3)
HVAC SYSTEMS MAP

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

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

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

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

TABLE C407.5.1(4)
SPECIFICATIONS FOR THE STANDARD REFERENCE DESIGN HVAC SYSTEM DESCRIPTIONS

SYSTEM NO.	SYSTEM TYPE	FAN CONTROL	COOLING TYPE	HEATING TYPE (Column A)[m]	HEATING TYPE (Column B)[n]
1	Variable air volume with parallel fan-powered boxes[a]	VAV[d]	Chilled water[e]	Electric resistance	Hot water with electric heat pump[o]
2	Variable air volume with reheat[b]	VAV[d]	Chilled water[e]	Hot water fossil fuel boiler[f]	Hot water with electric heat pump[o]
3	Packaged variable air volume with parallel fan-powered boxes[a]	VAV[d]	Direct expansion[c]	Electric resistance	Hot water with electric heat pump[o]
4	Packaged variable air volume with reheat[b]	VAV[d]	Direct expansion[c]	Hot water fossil fuel boiler[f]	Hot water with electric heat pump[o]
5[k]	Two-pipe fan coil	Constant volume[i, j]	Chilled water[e]	Electric resistance	Hot water with electric heat pump[o]
6[k]	Water-source heat pump	Constant volume[i, j]	Direct expansion[c]	Electric heat pump and boiler[g]	Electric heat pump and boiler[g]
7[k]	Four-pipe fan coil	Constant volume[i, j]	Chilled water[e]	Hot water fossil fuel boiler[f]	Hot water with electric heat pump[o]
8[k]	Packaged terminal heat pump	Constant volume[i, j]	Direct expansion[c]	Electric heat pump[h]	Electric heat pump[h]
9[k]	Packaged rooftop heat pump	Constant volume[i, j]	Direct expansion[c]	Electric heat pump[h]	Electric heat pump[h]
10[k]	Packaged terminal air conditioner	Constant volume[i, j]	Direct expansion	Hot water fossil fuel boiler[f]	Hot water with electric heat pump[o]
11[k]	Packaged rooftop air conditioner	Constant volume[i, j]	Direct expansion	Fossil fuel furnace	Hot water with electric heat pump[o]

Keys for Table C407.5.1(4)

For SI: 1 foot = 304.8 mm, 1 cfm/ft$_2$ = 0.0004719

1 Btu/h = 0.293/W, °C = [(°F) -32/1.8].

Footnotes for Table C407.5.1(4)

a. **VAV with parallel boxes:** Fans in parallel VAV fan-powered boxes shall be sized for 50 percent of the peak design flow rate and shall be modeled with 0.35 W/cfm fan power. Minimum volume setpoints for fan-powered boxes shall be equal to the minimum rate for the space required for ventilation consistent with Section C403.4.4, Exception 4. Supply air temperature shall be reset based on zone demand. Design airflow rates shall be sized for the maximum reset supply air temperature. The air temperature for cooling shall be reset higher by 5°F under the minimum cooling load conditions.

b. **VAV with reheat:** Minimum volume setpoints for VAV reheat boxes shall be 0.4 cfm/ft^2 of floor area. Supply air temperature shall be reset based on zone demand. Design airflow rates shall be sized for the maximum reset supply air temperature. The air temperature for cooling shall be reset higher by 5°F under the minimum cooling conditions.

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

d. **VAV:** When the proposed design system has a supply, return or relief fan motor horsepower (hp) requiring variable flow controls as required by Section C403.2.11.5, the corresponding fan in the VAV system of the standard reference design shall be modeled assuming a variable speed drive. For smaller fans, a forward-curved centrifugal fan with inlet vanes shall be modeled. If the proposed design's system has a direct digital control system at the zone level, static pressure setpoint reset based on zone requirements in accordance with Section C403.4.1 shall be modeled.

e. **Chilled water:** For systems using purchased chilled water, the chillers are not explicitly modeled. Otherwise, the standard reference design's chiller plant shall be modeled with chillers having the number as indicated in Table C407.5.1(5) as a function of standard reference building chiller plant load and type as indicated in Table C407.5.1(6) as a function of individual chiller load. Where chiller fuel source is mixed, the system in the standard reference design shall have chillers with the same fuel types and with capacities having the same proportional capacity as the proposed design's chillers for each fuel type. Chilled water supply temperature shall be modeled at 44°F design supply temperature and 56°F return temperature. Piping losses shall not be modeled in either building model. Chilled water supply water temperature shall be reset in accordance with Section C403.4.2.4. Pump system power for each pumping system shall be the same as the proposed design; if the proposed design has no chilled water pumps, the standard reference design pump power shall be 22 W/gpm (equal to a pump operating against a 75-foot head, 65-percent combined impeller and motor efficiency). The chilled water system shall be modeled as primary-only variable flow with flow maintained at the design rate through each chiller using a bypass. Chilled water pumps shall be modeled as riding the pump curve or with variable-speed drives when required in Section C403.4.2.4. The heat rejection device shall be an axial fan cooling tower with variable speed fans if required in Section C403.4.3. Condenser water design supply temperature shall be 85°F or 10°F approach to design wet-bulb temperature, whichever is lower, with a design temperature rise of 10°F. The tower shall be controlled to maintain a 70°F leaving water temperature where weather permits, floating up to leaving water temperature at design conditions. Pump system power for each pumping system shall be the same as the proposed design; if the proposed design has no condenser water pumps, the standard reference design pump power shall be 19 W/gpm (equal to a pump operating against a 60-foot head, 60-percent combined impeller and motor efficiency). Each chiller shall be modeled with separate condenser water and chilled water pumps interlocked to operate with the associated chiller.

f. **Fossil fuel boiler:** For systems using purchased hot water or steam, the boilers are not explicitly modeled. Otherwise, the boiler plant shall use the same fuel as the proposed design and shall be natural draft. The standard reference design boiler plant shall be modeled with a single boiler if the standard reference design plant load is 600,000 Btu/h and less and with two equally sized boilers for plant capacities exceeding 600,000 Btu/h. Boilers shall be staged as required by the load. Hot water supply temperature shall be modeled at 180°F design supply temperature and 130°F return temperature. Piping losses shall not be

modeled in either building model. Hot water supply water temperature shall be reset in accordance with Section C403.4.2.4. Pump system power for each pumping system shall be the same as the proposed design; if the proposed design has no hot water pumps, the standard reference design pump power shall be 19 W/gpm (equal to a pump operating against a 60-foot head, 60-percent combined impeller and motor efficiency). The hot water system shall be modeled as primary only with continuous variable flow. Hot water pumps shall be modeled as riding the pump curve or with variable speed drives when required by Section C403.4.2.4.

g. **Electric heat pump and boiler:** Water-source heat pumps shall be connected to a common heat pump water loop controlled to maintain a heating setpoint of 60°F and a cooling setpoint of 90°F. Heat rejection from the loop shall be provided by an axial fan closed-circuit evaporative fluid cooler with variable speed fans if required in Section C403.4.2.1 or C403.2.13. Heat addition to the loop shall be provided by a boiler that uses the same fuel as the proposed design and shall be natural draft. If no boilers exist in the proposed design, the standard reference building boilers shall be fossil fuel. The standard reference design boiler plant shall be modeled with a single boiler if the standard reference design plant load is 600,000 Btu/h or less and with two equally sized boilers for plant capacities exceeding 600,000 Btu/h. Boilers shall be staged as required by the load. Piping losses shall not be modeled in either building model. Pump system power shall be the same as the proposed design; if the proposed design has no pumps, the standard reference design pump power shall be 22 W/gpm, which is equal to a pump operating against a 75-foot head, with a 65-percent combined impeller and motor efficiency. Loop flow shall be variable with flow shutoff at each heat pump when its compressor cycles off as required by Section C403.4.2.3. Loop pumps shall be modeled as riding the pump curve or with variable speed drives when required by Section C403.4.2.4.

h. **Electric heat pump:** Electric air-source heat pumps shall be modeled with electric auxiliary heat and an outdoor air thermostat. The system shall be controlled to energize auxiliary heat only when outdoor air temperature is less than 40°F. The air-source heat pump shall be modeled to continue to operate while auxiliary heat is energized. The air-source heat pump shall be modeled to operate down to a minimum outdoor air temperature of 35°F for System No. 8 or 0°F for System No. 9. If the Proposed Design utilizes the same system type as the Standard Design (PTHP or PSZ-HP), the Proposed Design shall be modeled with the same minimum outdoor air temperature for heat pump operation as the Standard Design. For temperatures below the stated minimum outdoor air temperatures, the electric auxiliary heat shall be controlled to provide the full heating load.

i. **Constant volume:** For building types governed by Section C403.6, fans shall be controlled to cycle with load, i.e., fan operation cycled on calls for heating and cooling. If the fan is modeled as cycling and the fan energy is included in the energy efficiency rating of the equipment, fan energy shall ((~~not be modeled explicitly~~)) be modeled per C407.5.3. For all other buildings, fans shall be controlled in the same manner as in the proposed design, i.e., fan operation whenever the space is occupied or fan operation cycled on calls for heating and cooling. If the ((~~man~~)) fan is modeled as cycling and the fan energy is included in the energy efficiency rating of the equipment, fan energy ((~~not be modeled explicitly~~)) be modeled per C407.5.3.

j. **Fan speed control**: Fans shall operate as one- or two-speed as required by Section C403.2.11.5, regardless of the fan speed control used in the proposed building.

k. **Outside air:** For building types governed by Section C403.6, outside air shall be supplied by a separate dedicated outside air system (DOAS) operating in parallel with terminal equipment. The terminal equipment fan system cycle calls for heating and cooling. DOAS shall include an *Energy Recovery Ventilation System* with a minimum effectiveness in accordance with Section C403.5.

l. (reserved)

m. **Heating type Column A:** Used for buildings with area-weighted average fenestration U-values that comply with Column A of Table C402.4, or buildings that comply with exception 1 to Section C402.4.

n. **Heating type Column B:** Used for buildings with area-weighted average fenestration U-values that do not comply with the values in Column A of Table C402.4, and that do not comply with exception 1 to Section C402.4.

o. **Air-to-water Heat pump:** For systems using purchased hot water or steam, the heat pumps are not explicitly modeled. The standard reference design heat pump plant shall be modeled with a single air-to-water heat pump and an auxiliary electric boiler. The heat pump capacity shall be equal to 50% of the building's heating load at design conditions, and modeled such that 100% of the design capacity is available under all conditions. The heat pump energy consumption shall be modeled such that coefficient of performance (COP) only varies as a function of outdoor air temperature, per the following: 20°F & less: COP=2.0, 30°F: COP=2.25, 40°F: COP=2.5, 50°F: COP= 3.0, 60°F & greater: COP=3.5. The heating plant equipment shall be staged such that the heat pump is used first to meet the heating load, with the auxiliary electric boiler only used when the plant load exceeds the heat pump capacity. Hot water supply temperature shall be modeled at 120°F design supply temperature and 105°F return temperature. Piping losses shall not be modeled in either building model. Hot water supply water temperature shall be reset in accordance with Section C403.4.2.4. Pump system power for each pumping system shall be the same as the proposed design; if the proposed design has no hot water pumps, the standard reference design pump power shall be 19 W/GPM (equal to a pump operating against a 60-foot head, 60-percent combined impeller and motor efficiency). The hot water system shall be modeled as primary only with continuous variable flow. Hot water pumps shall be modeled as riding the pump curve or with variable speed drives when required by Section C403.4.2.4.

TABLE C407.5.1(5)
NUMBER OF CHILLERS

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

For SI: 1 ton = 3517 W.

TABLE C407.5.1(6)
WATER CHILLER TYPES

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

For SI: 1 ton = 3517 W.

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

1. Building operation for a full calendar year (8,760 hours).
2. Climate data for a full calendar year (8,760 hours) and shall reflect *approved* coincident hourly data for temperature, solar radiation, humidity and wind speed for the building location.
3. Ten or more thermal zones.
4. Thermal mass effects.
5. Hourly variations in occupancy, illumination, receptacle loads, thermostat settings, mechanical ventilation, HVAC equipment availability, service hot water usage and any process loads.
6. Part-load performance curves for mechanical equipment.
7. Capacity and efficiency correction curves for mechanical heating and cooling equipment.
8. Printed *code official* inspection checklist listing each of the *proposed design* component characteristics from Table C407.5.1(1) determined by the analysis to provide compliance, along with their respective performance ratings (e.g., *R*-value, *U*-factor, SHGC, HSPF, AFUE, SEER, EF, etc.).
9. Air-side economizers with integrated control.
10. *Standard reference design* characteristics specified in Table C407.5.1(1).

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

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

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

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

SECTION C408
SYSTEM COMMISSIONING

C408.1 General. A *building commissioning* process led by a *certified commissioning professional* shall be completed for mechanical systems in Section C403, service water heating systems in Section C404, ((~~electrical power~~)) *controlled receptacles* and lighting systems in Section C405, ((~~and~~)) energy metering in Section C409, and refrigeration in Section C410.

Exception: Buildings, or portions thereof, which are exempt from Sections C408.2 through C408.6 may be excluded from the commissioning process.

C408.1.1 Commissioning in construction documents. Construction document notes shall clearly indicate provisions for commissioning and completion requirements in accordance with this section and are permitted to refer to specifications for further requirements.

C408.1.2 Commissioning plan. A *commissioning plan* shall be developed by the project's *certified commissioning professional* and shall outline the organization, schedule, allocation of resources, and documentation requirements of the commissioning process. Items 1 through 4 shall be included with the construction documents, and items 5 through 8 shall be submitted prior to the first mechanical inspection. For projects where no mechanical inspection is required, items 5 through 8 shall be submitted prior to the first electrical inspection:

1. A narrative description of the activities that will be accomplished during each phase of commissioning, including the personnel intended to accomplish each of the activities.
2. Roles and responsibilities of the commissioning team, including statement of qualifications of the *certified commissioning professional*.
3. A schedule of activities including systems testing and balancing, functional performance testing, and verification of the building documentation requirements in Section C103.6.
4. Where the *certified commissioning professional* is an employee of one of the registered design professionals of record or an employee or subcontractor of the project contractor, an In-House Commissioning

Disclosure and Conflict Management Plan shall be submitted with the commissioning plan. This plan shall disclose the *certified commissioning professional's* contractual relationship with other team members and provide a conflict management plan demonstrating that the *certified commissioning professional* is free to identify any issues discovered and report directly to the owner.

5. A listing of the specific equipment, appliances or systems to be tested and a description of the tests to be performed.
6. Functions to be tested.
7. Conditions under which the test will be performed.
8. Measurable criteria for performance.

C408.1.3 Final commissioning report. A final commissioning report shall be completed and certified by the *certified commissioning professional* and delivered to the building owner or owner's authorized agent. The report shall be organized with mechanical, lighting, *controlled receptacles*, service water heating and metering findings in separate sections to allow independent review. The report shall record the activities and results of the commissioning process and be developed from the final commissioning plan with all of its attached appendices. The report shall include:

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

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

C408.1.4 Commissioning process completion requirements. Prior to the final mechanical, plumbing and electrical inspections or obtaining a certificate of occupancy, the *certified commissioning professional* ((~~or approved agency~~)) shall provide evidence of systems *commissioning* and completion in accordance with the provisions of this section.

Copies of all documentation shall be given to the owner and made available to the *code official* upon request in accordance with Section C408.1.4.3

C408.1.4.1 Commissioning progress report for code compliance. A ((~~preliminary~~)) report of commissioning test procedures and results shall be completed and certified by the *certified commissioning professional* ((~~or approved agency~~)) and provided to the building owner or owner's authorized agent. The report shall be organized with mechanical, lighting, service water heating and metering findings in separate sections to allow independent review. The report shall be identified as "((~~Preliminary~~)) Commissioning Report" and shall identify:

1. Itemization of deficiencies found during testing required by this code that have not been corrected at the time of report preparation.
2. Deferred tests that cannot be performed at the time of report preparation because of climatic conditions, with anticipated date of completion.
3. Climatic conditions required for performance of the deferred tests.
4. Status of the project's record documents, manuals and systems operation training with respect to requirements in Section C103.6.
5. List and description of any deferred tests which cannot be completed at the time of report preparation because of climatic conditions, including anticipated date of completion, climatic conditions required for performance of the deferred tests, including timeframe for completion and parties to be involved, in checklist format.
6. List and description of any unresolved deficiencies found in the course of the commissioning work or incomplete commissioning tasks, in checklist format.
7. A copy of a Commissioning Permit issued for the completion and resolution of items identified in the lists required by Items 5 and 6 above. The permit shall stipulate that all such work shall be completed within one year of issuance of the certificate of occupancy.

   Exception. If there are no deferred tests, unresolved deficiencies or incomplete tasks to be listed under Items 5 and 6, the Commissioning Permit is not required.
8. Completed Commissioning Compliance Checklist (Figure C408.1.4.2).
9. Other information required by the code official.

C408.1.4.2 Acceptance of report. Buildings, or portions thereof, shall not be considered acceptable for a final inspection pursuant to Section C104.2 until the *code official* has received a letter of transmittal from the building owner acknowledging that the building owner or owner's authorized agent has received the ((~~Preliminary~~)) Commissioning Report. Completion of the Commissioning Compliance Checklist (Figure C408.1.4.2) is deemed to satisfy this requirement.

C408.1.4.3 Copy of report. The *code official* shall be permitted to require that a copy of the ((~~Preliminary~~)) Commissioning Report be made available for review by the code official.

C408.2 Mechanical and refrigeration systems commissioning. Mechanical equipment and controls subject to Section C403 and Section C410 shall be included in the commissioning process required by Section C408.1. ((~~The commissioning process shall minimally include all energy code requirements for which the code states that equipment~~

~~or controls shall "be capable of" or "configured to" perform specific functions.~~)) The configuration and function of mechanical systems required by this code shall be tested and shall comply with Section C408.2. Walk-in coolers, walk-in freezers, refrigerated warehouse coolers, and refrigerated warehouse freezers shall comply with Section C408.2.

Exception: Mechanical systems are exempt from the commissioning process where the building's total mechanical equipment capacity is less than 240,000 Btu/h cooling capacity and less than 300,000 Btu/h heating capacity.

C408.2.1 Reserved.

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

C408.2.2.1 Air systems balancing. Each supply air outlet and *zone* terminal device shall be equipped with means for air balancing in accordance with the requirements of Chapter 6 of the *International Mechanical Code*. Discharge dampers used for air system balancing are prohibited on constant volume fans and variable volume fans with motors 10 hp (18.6 kW) and larger. Air systems shall be balanced in a manner to first minimize throttling losses then, for fans with system power of greater than 1 hp (0.74 kW), fan speed shall be adjusted to meet design flow conditions.

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

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

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

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

C408.2.3 Functional performance testing. Functional performance testing specified in Sections C408.2.3.1 through C408.2.3.3 shall be conducted. Written procedures which clearly describe the individual systematic test procedures, the expected systems' response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion shall be followed. Testing shall affirm operation during actual or simulated winter and summer design conditions and during full outside air conditions.

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

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

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

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

C408.3 ((~~Electrical power~~)) Controlled receptacles and lighting systems commissioning. ((~~Electrical power~~)) *Controlled receptacles* and lighting systems subject to Section C405 shall be included in the commissioning process required by Section C408.1. ((~~The commissioning process shall minimally include all energy code requirements for which the code requires specific *daylight responsive controls*, "control functions," and where the code states that equipment shall be "configured to" perform specific functions.~~)) The configuration and function of *controlled receptacles* and lighting control systems required by this code shall be tested and shall comply with Section C408.3.1.

Exception: Lighting control systems and *controlled receptacles* are exempt from the commissioning process in buildings where:

1. The total installed lighting load is less than 20 kW; and
2. Where the lighting load controlled by occupancy sensors or *automatic* daylighting controls is less than 10 kW.

SDCI Informative Note: An *approved* Commissioning Compliance Checklist is available on the SDCI Seattle Energy Code web site, to replace the state code checklist that is stricken below.

NOTE: See SDCI online version of this form.

((FIGURE C408.1.4.2
COMMISSIONING COMPLIANCE CHECKLIST

Project Information	**Project Name:**
	Project Address:
	Certified Commissioning Professional:
	Certifying Body:
Commissioning Plan (Section C408.1.2)	❑ **Commissioning Plan was used during construction and included items below** ▪ A narrative description of activities and the personnel intended to accomplish each one ▪ Measurable criteria for performance ▪ Functions to be tested
Commissioned Systems (Sections C408.2, C408.3, C408.4 and C408.6)	❑ **Mechanical Systems were included in the commissioning process** (Section C408.2) Building mechanical systems have been tested to demonstrate the installation and operation of components, systems and system-to-system interfacing relationships in accordance with approved plans and specifications ❑ There are unresolved deficiencies with the mechanical systems. These are described in the Preliminary Commissioning Report submitted to the Owner. The following items are not in compliance with energy code:
	❑ **Service Water Heating Systems were included in the commissioning process** (Section C408.3) Service water heating systems have been tested to demonstrate that control devices, components, equipment, and systems are calibrated, adjusted and operate in accordance with approved plans and specifications ❑ There are unresolved deficiencies with the service water heating systems. These are described in the Preliminary Commissioning Report submitted to the Owner. The following items are not in compliance with energy code:
	❑ **Electrical Power or Lighting Systems were included in the commissioning process** (Section C408.4) Electrical power and automatic lighting controls have been tested to demonstrate the installation and operation of components, systems, and system-to-system interfacing relationships in accordance with approved plans and specifications ❑ There are unresolved deficiencies with the electrical power and/or automatic lighting controls. These are described in the Preliminary Commissioning Report submitted to the Owner. The following items are not in compliance with energy code:
	❑ **Additional systems included in the commissioning process** (Section C408.5) If additional items were included, list them here: ❑ There are unresolved deficiencies with systems required by C406 or C407. These are described in the Preliminary Commissioning Report submitted to the Owner. The following items are not in compliance with energy code:
	❑ **Metering System Functional Testing has been completed** (Section C408.6) Energy source meters, energy end-use meters, the energy metering data acquisition system and required display are calibrated adjusted and operate to minimally meet code requirements. ❑ There are unresolved deficiencies with the metering system. These are described in the Preliminary Commissioning Report submitted to the Owner. The following items are not in compliance with energy code:

((~~FIGURE C408.1.4.2 – continued~~
~~COMMISSIONING COMPLIANCE CHECKLIST~~

~~Supporting Documents~~ (~~Section C103.6~~)	❑ ~~Manuals, record documents and training have been completed or are scheduled~~ ▲ ~~System documentation has been provided to the owner or scheduled date: _____~~ ▲ ~~Record documents have been submitted to owner or scheduled date: _____~~ ▲ ~~Training has been completed or scheduled date: _____~~
~~Preliminary Commissioning Report~~ (~~Section C408.1.4.1~~)	❑ ~~Preliminary Commissioning Report submitted to Owner and includes items below~~ ❑ ~~Itemization of deficiencies found during testing that are part of the energy code and that have not been corrected at the time of report preparation.~~ ❑ ~~Deferred tests that cannot be performed at the time of report preparation with anticipated date of completion.~~ ❑ ~~Status of the project's record documents, manuals, and systems operation training with respect to requirements in Section 103.6.~~
~~Certification~~	❑ ~~I hereby certify that all requirements for Commissioning have been completed in accordance with the Washington State Energy Code, including all items above.~~ _____ ~~Building Owner or Owner's Representative~~ ~~Date~~))

C408.3.1 Functional testing. Prior to passing final inspection, the *certified commissioning professional* shall provide evidence that the *controlled receptacles* and lighting control systems have been tested to ensure that control hardware and software are calibrated, adjusted, programmed and in proper working condition in accordance with the construction documents and manufacturer's instructions. Written procedures which clearly describe the individual systematic test procedures, the expected systems' response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion shall be followed. Functional testing shall comply with Section C408.3.1.1 through C408.3.1.3. for the applicable control type.

C408.3.1.1 Occupant sensor controls. Where occupancy sensors are provided for lighting and *controlled receptacles*, the following procedures shall be performed:

1. Certify that the occupancy sensor has been located and aimed in accordance with manufacturer recommendations.
2. For projects with seven or fewer occupancy sensors, each sensor shall be tested. For projects with more than seven occupancy sensors, testing shall be done for each unique combination of sensor type and space geometry. Where multiples of each unique combination of sensor type and space geometry are provided, no fewer than the greater of one or 10 percent of each combination shall be tested unless the code official or design professional requires a higher percentage to be tested. Where 30 percent or more of the tested controls fail, all remaining identical combinations shall be tested.
3. For each occupancy sensor to be tested, verify the following:
   3.1. Where occupancy sensors include status indicators, verify correct operation.
   3.2. The controlled lights and receptacles turn off or down to the permitted level within the required time.
   3.3. For auto-on occupancy sensors, the lights turn on to the permitted level within the required time.
   3.4. For manual on sensors, the lights turn on only when manually activated.
   3.5. The controlled lights and receptacles are not incorrectly turned on by movement in adjacent areas or by HVAC operation.

C408.3.1.2 Time switch controls. Where *automatic* time switches are provided for lighting and *controlled receptacles*, the following procedures shall be performed:

1. Confirm that the *automatic* time switch control is programmed with accurate weekday, weekend and holiday schedules, and set-up and preference program settings.
2. Provide documentation to the owner of *automatic* time switch programming, including weekday, weekend, holiday schedules and set-up and preference program settings.
3. Verify the correct time and date in the time switch.
4. Verify that any battery backup is installed and energized.
5. Verify that the override time limit is set to not more than two hours.
6. Simulate occupied conditions. Verify and document the following:
   6.1. All lights can be turned on and off by their respective area control switch.

6.2. The switch only operates lighting in the *enclosed space* in which the switch is located.

7. Simulate unoccupied condition. Verify the following:

7.1. All nonexempt lighting and *controlled receptacles* ((~~turns~~)) turn off.

7.2. Manual override switch allows only the lights and receptacles in the *enclosed space* where the override switch is located to turn on or remain on until the next scheduled shut off occurs.

8. Additional testing as specified by the *certified commissioning professional*.

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

1. All control devices have been properly located, field-calibrated and set for accurate setpoints and threshold light levels.

2. Daylight controlled lighting loads adjusted to light level setpoints in response to available daylight.

3. The locations of calibration adjustment equipment are readily accessible only to authorized personnel.

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

C408.4 Service water heating systems commissioning requirements. Service water heating equipment and controls subject to Section C404 shall be included in the commissioning process required by Section C408.1. ((~~The commissioning process shall minimally include all energy code requirements for which the code states that equipment or controls shall "be capable of" or "configured to" perform specific functions.~~)) The configuration and function of service water heating systems required by this code shall be tested and shall comply with Section C408.4.

Exception: Service water heating systems are exempt from the commissioning process in buildings where the largest service water heating system capacity is less than 200,000 Btu/h (58,562 W) and where there are no pools or permanent spas.

C408.4.1 Functional performance testing. Functional performance testing specified in Sections C408.4.1.1 through C408.4.1.3 shall be conducted. Written procedures which clearly describe the individual systematic test procedures, the expected systems' response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion shall be followed. Testing shall affirm operation with the system under 50 percent water heating load.

C408.4.1.1 Equipment. Equipment functional performance testing shall demonstrate the installation and operation of components, systems, and system-to-system interfacing relationships in accordance with *approved* plans and specifications such that operation, function, and maintenance serviceability for each of the commissioned systems is confirmed. Testing shall include all modes and *sequence of operation*, including under full-load, part-load and the following emergency conditions:

1. Redundant or *automatic* back-up mode;

2. Performance of alarms; and

3. Mode of operation upon a loss of power and restoration of power.

C408.4.1.2 Controls. Service water heating controls shall be tested to document that control devices, components, equipment, and systems are calibrated, adjusted and operate in accordance with *approved* plans and specifications. Sequences of operation shall be functionally tested to document they operate in accordance with *approved* plans and specifications.

C408.4.1.3 Pools and spas. Service water heating equipment, time switches, and heat recovery equipment which serve pools and permanent spas shall undergo a functional test to determine that they operate in accordance with manufacturer's specifications.

C408.5 Systems installed to meet Section C406 or C407. Equipment, components, controls or configuration settings for mechanical, service water heating, ((~~electrical power or~~)) *controlled receptacles* and lighting systems which are included in the project to comply with Section C406 or C407 shall be included in the commissioning process required by Section C408.1.

C408.6 Metering system commissioning. Energy metering systems required by Section C409 shall comply with Section C408.6 and be included in the commissioning process required by Section C408.1. The configuration and function of metering and monitoring systems required by this code shall be tested. ((~~The commissioning process shall include all energy metering equipment and controls required by Section C409.~~))

C408.6.1 Functional performance testing. Functional performance testing shall be conducted by following written procedures which clearly describe the individual systematic test procedures, the expected systems' response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion. Functional testing shall document that energy source meters, energy end-use meters, the energy metering *data acquisition system*, and required energy consumption display are calibrated, adjusted and operate in accordance with *approved* plans and specifications. At a minimum, testing shall confirm that:

1. The metering system devices and components work properly under low and high load conditions.

2. The metered data is delivered in a format that is compatible with the data collection system.

3. The energy display is *accessible* to building operation and management personnel.
4. The energy display meets code requirements regarding views required in Section C409.4.3. The display shows energy data in identical units (e.g., kWh).

SECTION C409
ENERGY METERING AND ENERGY CONSUMPTION MANAGEMENT

C409.1 General. New buildings and additions with a gross *conditioned floor area* over ((~~50,000~~)) 20,000 square feet shall comply with Section C409. Buildings shall be equipped to measure, monitor, record and display energy consumption data for each energy source and end use category per the provisions of this section, to enable effective energy management. For Group R-2 ((~~multi-family~~)) buildings, the floor area of dwelling units and *sleeping units* shall be excluded from the total *conditioned floor area* for the purposes of determining the 20,000 square foot threshold. Alterations and additions to existing buildings shall conform to Section C506.

Exceptions:

1. Tenant spaces smaller than ((~~50,000~~)) 20,000 square feet within buildings if the tenant space has its own utility service and utility meters.
2. Buildings in which there is no gross *conditioned floor area* over ((~~25,000~~)) 10,000 square feet, including building common area, that is served by its own utility services and meters.

C409.1.1 Alternate metering methods. Where *approved* by the building official, energy use metering systems may differ from those required by this section, provided that they are permanently installed and that the source energy measurement, end use category energy measurement, data storage and data display have similar accuracy to and are at least as effective in communicating actionable energy use information to the building management and users, as those required by this section.

C409.1.2 Conversion factor. Any threshold stated in kW or kVA shall include the equivalent BTU/h heating and cooling capacity of installed equipment at a conversion factor of 3,412 Btu per kW or 2,730 Btu per kVA ((~~at 50 percent demand~~)).

SDCI Informative Note: Seattle's "Building Tune-ups" ordinance will be phased in during the effective period of the 2015 Seattle Energy Code, requiring buildings with over 50,000 square feet of *conditioned floor area* to periodically assess and optimize the functioning of energy-consuming systems. The cost and complexity of these tune-ups can potentially be minimized by careful configuration of the metering system.

C409.2 Energy source metering. Buildings shall have a meter at each energy source. For each energy supply source listed in Section C409.2.1 through C409.2.4, meters shall collect data for the whole building or for each separately metered portion of the building where not exempted by the exceptions to Section C409.1.

Exceptions:

1. Energy source metering is not required where end use metering for an energy source accounts for all usage of that energy type within a building, and the *data acquisition system* accurately totals the energy delivered to the building or separately metered portion of the building.
2. Solid fuels such as coal, firewood or wood pellets that are delivered via mobile transportation do not require metering.

C409.2.1 Electrical energy. This category shall include all electrical energy supplied to the building and its associated site, including site lighting, parking, recreational facilities, and other areas that serve the building and its occupants.

Exception: Where site lighting and other exterior non-building electrical loads are served by an electrical service and meter that are separate from the building service and meter, the metering data from those loads is permitted to be either combined with the building's electrical service load data or delivered to a separate *data acquisition system*.

C409.2.2 Gas and liquid fuel supply energy. This category shall include all natural gas, fuel oil, propane and other gas or liquid fuel energy supplied to the building and site.

C409.2.3 District energy. This category shall include all net energy extracted from district steam systems, district chilled water loops, district hot water systems, or other energy sources serving multiple buildings.

C409.2.4 Site-generated renewable energy. This category shall include all net energy generated from on-site solar, wind, geothermal, tidal or other natural sources, and waste heat reclaimed from sewers or other off-site sources.

C409.3 End-use metering. Meters shall be provided to collect energy use data for each end-use category listed in Sections C409.3.1 through ((~~C409.3.2~~)) C409.3.6. These meters shall collect data for the whole building or for each separately metered portion of the building where not exempted by the exception to Section C409.1. Multiple meters may be used for any end-use category, provided that the *data acquisition system* totals all of the energy used by that category. Not more than 10 percent of the total connected load of any of the end-use metering categories C409.3.1 through C409.3.5 is permitted to be excluded from that end-use data collection. Not more than 10 percent of the total connected load of any of the end-use metering categories C409.3.1 through C409.3.5 is permitted to consist of loads not part of that category. Multiple meters may be used for any end-use category, provided that the *data acquisition system* totals all of the energy used by that category. Full-floor tenant space submetering data shall be provided to the tenant in accordance with Section C409.3.6, and the data shall not be required to be included in other end-use categories.

Exceptions:

1. HVAC and water heating equipment serving only an individual dwelling unit or *sleeping unit* does not require end-use metering.
2. Separate metering is not required for fire pumps, stairwell pressurization fans or other life safety systems that operate only during testing or emergency.
3. End use metering is not required for individual tenant spaces not exceeding 2,500 square feet in floor area when a dedicated source meter meeting the requirements of Section C409.4.1 is provided for the tenant space.
4. Healthcare facilities with loads in excess of 150 kVA are permitted to have submetering that measures electrical energy usage in accordance with the normal and essential electrical systems identified in Article 517 of the Seattle Electrical Code, except that submetering is required for the following load categories:
   4.1. HVAC system energy use per the requirements of Section C409.3.1.
   4.2. Water heating energy use per the requirements of Section C409.3.2.
   4.3. Process load system energy per the requirements of Section C409.3.5 for each significant facility not used in direct patient care, including but not limited to food service, laundry and sterile processing facilities, where the total connected load of that facility exceeds 100 kVA.
5. End-use metering is not required for electrical circuits serving only sleeping rooms and guest suites within Group R-1 occupancies. This exception does not apply to common areas or to equipment serving multiple sleeping rooms.

C409.3.1 HVAC system energy use. This category shall include all energy including electrical, gas, liquid fuel, district steam and district chilled water that is used by boilers, chillers, pumps, fans and other equipment used to provide space heating, space cooling, dehumidification and ventilation to the building, but not including energy that serves process loads, water heating or miscellaneous loads as defined in Section C409.3. Multiple HVAC energy sources, such as gas, electric and steam, are not required to be summed together.

Exceptions: This category shall not be required to include electrical energy consumed by:

1. ((~~All~~)) 120 volt equipment.
2. An HVAC branch circuit where the total MCA of equipment served equates to less than 10 kVA. ((~~208/120 volt equipment in a building where the main service is 480/277 volt power.~~))
3. Individual fans or pumps that are not on a VFD. ((~~Electrical energy fed through variable frequency drives that are connected to the energy metering data acquisition center.~~))

C409.3.2 Water heating energy use. This category shall include all energy used for heating of domestic and service hot water, but not energy used for space heating.

Exception: Water heating energy use less than 50 ((~~kW~~)) kVA does not require end-use metering.

C409.3.3 Lighting system energy use. This category shall include all energy used by interior and exterior lighting, including lighting in parking structures and lots, but not including plug-in task lighting.

C409.3.4 Plug load system energy use. This category shall include all energy used by appliances, computers, plugged-in task lighting, and other equipment and devices, but not including vertical transportation equipment or equipment covered by other end-use metering categories listed in C409.3. In a building where the main service is 480/277 volt, each 208/120 volt panel is permitted to be assumed to serve only plug load for the purpose of Section C409, unless it serves nonresidential refrigeration or cooking equipment.

Exception: Where the total connected load of all plug load circuits is less than 50 kVA, end-use metering is not required.

C409.3.5 Process load system energy use. This category shall include all energy used by any non-building process load, including but not limited to nonresidential refrigeration and cooking equipment, laundry equipment, industrial equipment and stage lighting.

Exception: Where process load energy use is less than 50 kVA, end-use metering is not required.

C409.3.6 Full-floor tenant space electrical sub-metering. In a multi-tenant building, where more than 90 percent of the leasable area of a floor is occupied by a single tenant, an electrical energy use display shall be provided to the tenant in accordance with the requirements of Section C409.4.3. Electrical loads from areas outside of the tenant space or from equipment that serves areas outside of the tenant space shall not be included in the tenant space sub-metering. A single display is permitted to serve multiple floors occupied by the same tenant.

C409.4 Measurement devices, data acquisition system and energy display.

C409.4.1 Meters. Meters and other measurement devices required by this section shall have local displays or be configured to automatically communicate energy data to a *data acquisition system*. Source meters may be any digital-type meters. Current sensors or flow meters are allowed for end use metering, provided that they have an accuracy of +/- 5%. All required metering systems and equipment shall provide at least hourly data that is fully integrated into the data acquisition and display system per the requirements of Section C409.

C409.4.2 Data acquisition system. The *data acquisition system* shall store the data from the required meters and other sensing devices for a minimum of 36 months. For each energy supply and end use category required by C409.2 and C409.3, it shall provide real-time energy con-

sumption data and logged data for any hour, day, month or year.

C409.4.3 Energy display. For each building subject to Section C409.2 and C409.3, either a readily accessible and visible display, or a web page or other electronic document *accessible* to building management or to a third-party energy data analysis service shall be provided in the building *accessible* by building operation and management personnel. The display shall graphically provide the current energy consumption rate for each whole building energy source, plus each end use category, as well as the ((~~average~~)) total and ((~~peak~~)) maximum hourly consumption values for any day, week, month or year.

The display shall be capable of and configured to graphically display the energy use data for any source or end use category or any combination of sources and end uses for any selected daily, weekly, monthly or annual time period, and to view the selected time period simultaneously with another selected time period or a reference benchmark time period. The display shall be capable of weather-normalizing data in the comparison time periods, and facilitate display of energy use trends and identification of anomalies.

C409.4.4 Commissioning. The entire system shall be commissioned in accordance with Section ((~~C408~~)) C408.6. Deficiencies found during testing shall be corrected and retested and the commissioning report shall be updated to confirm that the entire metering and data acquisition and display system is fully functional.

((~~C409.5 Existing buildings that were constructed subject to the requirements of this section.~~ ~~Where new or replacement systems or equipment are installed in an existing building that was constructed subject to the requirements of this section, metering shall be provided for such new or replacement systems or equipment so that their energy use is included in the corresponding end-use category defined in Section C409.2. This includes systems or equipment added in conjunction with additions or alterations to existing buildings.~~

~~**C409.5.1 Small existing buildings.** Metering and *data acquisition systems* shall be provided for additions over 25,000 square feet to buildings that were constructed in accordance with the requirements of sections C409.2 and C409.3.~~))

SDCI Informative Note: Section C409.5 relating to existing buildings is relocated to Section 506.1.

SECTION C410
REFRIGERATION SYSTEM REQUIREMENTS

C410.1 General (*prescriptive*). Walk-in coolers, walk-in freezers, refrigerated warehouse coolers, refrigerated warehouse freezers, and refrigerated display cases shall comply with this Section.

C410.1.1 Refrigeration equipment performance. Refrigeration equipment shall have an energy use in kWh/day not greater than the values of Tables ((~~C410.2(1) and C410.2(2)~~)) C410.1.1(1) and C410.1.1(2) when tested and rated in accordance with AHRI Standard 1200. The energy use shall be verified through certification under an *approved* certification program or, where a certification program does not exist, the energy use shall be supported by data furnished by the equipment manufacturer.

TABLE C410.1.1(1)
MINIMUM EFFICIENCY REQUIREMENTS: COMMERCIAL REFRIGERATION

EQUIPMENT TYPE	APPLICATION	ENERGY USE LIMITS (kWh per day)[a]	TEST PROCEDURE
Refrigerator with solid doors	Holding Temperature	0.10 x V + 2.04	AHRI 1200
Refrigerator with transparent doors		0.12 x V + 3.34	
Freezers with solid doors		0.40 x V + 1.38	
Freezers with transparent doors		0.75 x V + 4.10	
Refrigerator/freezers with solid doors		The greater of 0.12 x V + 3.34 or 0.70	
Commercial refrigerators	Pulldown	0.126 x V + 3.51	

a. V = Volume of the chiller for frozen compartment as defined in AHAM-HRF-1.

TABLE C410.1.1(2)
MINIMUM EFFICIENCY REQUIREMENTS: COMMERCIAL REFRIGERATORS AND FREEZERS

EQUIPMENT TYPE				ENERGY USE LIMITS (kWh per day)[a,b]	TEST PROCEDURE
Equipment Class[c]	Family Code	Operating Mode	Rating Temperature		
VOP.RC.M	Vertical open	Remote condensing	Medium	0.82 x TDA + 4.07	AHRI 1200
SVO.RC.M	Semivertical open	Remote condensing	Medium	0.83 x TDA + 3.18	
HZO.RC.M	Horizontal open	Remote condensing	Medium	0.35 x TDA + 2.88	
VOP.RC.L	Vertical open	Remote condensing	Low	2.27 x TDA + 6.85	
HZO.RC.L	Horizontal open	Remote condensing	Low	0.57 x TDA + 6.88	
VCT.RC.M	Vertical transparent door	Remote condensing	Medium	0.22 x TDA + 1.95	
VCT.RC.L	Vertical transparent door	Remote condensing	Low	0.56 x TDA + 2.61	
SOC.RC.M	Service over counter	Remote condensing	Medium	0.51 x TDA + 0.11	
VOP.SC.M	Vertical open	Self-contained	Medium	1.74 x TDA + 4.71	
SVO.SC.M	Semivertical open	Self-contained	Medium	1.73 x TDA + 4.59	
HZO.SC.M	Horizontal open	Self-contained	Medium	0.77 x TDA + 5.55	
HZO.SC.L	Horizontal open	Self-contained	Low	1.92 x TDA + 7.08	
VCT.SC.I	Vertical transparent door	Self-contained	Ice cream	0.67 x TDA + 3.29	
VCS.SC.I	Vertical solid door	Self-contained	Ice cream	0.38 x V + 0.88	
HCT.SC.I	Horizontal transparent door	Self-contained	Ice cream	0.56 x TDA + 0.43	
SVO.RC.L	Semivertical open	Remote condensing	Low	2.27 x TDA + 6.85	
VOP.RC.I	Vertical open	Remote condensing	Ice cream	2.89 x TDA + 8.7	
SVO.RC.I	Semivertical open	Remote condensing	Ice cream	2.89 x TDA + 8.7	
HZO.RC.I	Horizontal open	Remote condensing	Ice cream	0.72 x TDA + 8.74	
VCT.RC.I	Vertical transparent door	Remote condensing	Ice cream	0.66 x TDA + 3.05	
HCT.RC.M	Horizontal transparent door	Remote condensing	Medium	0.16 x TDA + 0.13	
HCT.RC.L	Horizontal transparent door	Remote condensing	Low	0.34 x TDA + 0.26	
HCT.RC.I	Horizontal transparent door	Remote condensing	Ice cream	0.4 x TDA + 0.31	
VCS.RC.M	Vertical solid door	Remote condensing	Medium	0.11 x V + 0.26	
VCS.RC.L	Vertical solid door	Remote condensing	Low	0.23 x V + 0.54	
VCS.RC.I	Vertical solid door	Remote condensing	Ice cream	0.27 x V + 0.63	
HCS.RC.M	Horizontal solid door	Remote condensing	Medium	0.11 x V + 0.26	

TABLE C410.1.1(2)—continued
MINIMUM EFFICIENCY REQUIREMENTS: COMMERCIAL REFRIGERATORS AND FREEZERS

EQUIPMENT TYPE				ENERGY USE LIMITS (kWh per day)[a,b]	TEST PROCEDURE
Equipment Class[c]	Family Code	Operating Mode	Rating Temperature		
HCS.RC.L	Horizontal solid door	Remote condensing	Low	0.23 x V + 0.54	AHRI 1200
HCS.RC.I	Horizontal solid door	Remote condensing	Ice cream	0.27 x V + 0.63	
SOC.RC.L	Service over counter	Remote condensing	Low	1.08 x TDA + 0.22	
SOC.RC.I	Service over counter	Remote condensing	Ice cream	1.26 x TDA + 0.26	
VOP.SC.L	Vertical open	Self-contained	Low	4.37 x TDA + 11.82	
VOP.SC.I	Vertical open	Self-contained	Ice cream	5.55 x TDA + 15.02	
SVO.SC.L	Semivertical open	Self-contained	Low	4.34 x TDA + 11.51	
SVO.SC.I	Semivertical open	Self-contained	Ice cream	5.52 x TDA + 14.63	
HZO.SC.I	Horizontal open	Self-contained	Ice cream	2.44 x TDA + 9.0	
SOC.SC.I	Service over counter	Self-contained	Ice cream	1.76 x TDA + 0.36	
HCS.SC.I	Horizontal solid door	Self-contained	Ice cream	0.38 x V + 0.88	

a V = Volume of the case, as measured in accordance with Appendix C of AHRI 1200.
b TDA = Total display area of the case, as measured in accordance with Appendix D of AHRI 1200.
c Equipment class designations consist of a combination [(in sequential order separated by periods (AAA).(BB).(C))] of:
(AAA) An equipment family code where:
VOP = Vertical open
SVO = Semi-vertical open
HZO = Horizontal open
VCT = Vertical transparent doors
VCS = Vertical solid doors
HCT = Horizontal transparent doors
HCS = Horizontal solid doors
SOC = Service over counter
(BB) An operating mode code:
RC = Remote condensing
SC = Self-contained
(C) A rating temperature code:
M = Medium temperature (38°F)
L = Low temperature (0°F)
I = Ice cream temperature (15°F)
For example, "VOP.RC.M" refers to the "vertical-open, remote-condensing, medium-temperature" equipment class.

C410.2 Walk-in coolers, walk-in freezers, refrigerated warehouse coolers and refrigerated warehouse freezers. *Refrigerated warehouse coolers* and *refrigerated warehouse freezers* shall comply with this section and shall comply with Section C402, using the *R*-values or *U*-values listed in this section. Section C402.1.5 component performance alternative may be used if *approved* by the code official. *Walk-in coolers* and *walk-in freezers* that are not either site assembled or site constructed shall comply with the following:

1. Be equipped with *automatic* door-closers that firmly close walk-in doors that have been closed to within 1 inch (25 mm) of full closure.

   Exception: *Automatic* closers are not required for doors more than 45 inches (1143 mm) in width or more than 7 feet (2134 mm) in height.

2. Doorways shall have strip doors, curtains, spring-hinged doors or other method of minimizing infiltration when doors are open.

3. *Walk-in coolers* and *refrigerated warehouse coolers* shall contain wall, ceiling, and door insulation of not less than R-25 or have wall, ceiling and door assembly *U*-factors no greater than *U*-0.039. *Walk-in freezers* and *refrigerated warehouse freezers* shall contain wall, ceiling and door insulation of not less than R-32 or have wall, ceiling and door assembly *U*-factors no greater than *U*-0.030.

   Exception: Glazed portions of doors or structural members need not be insulated.

4. The floor of *walk-in freezers* shall contain floor insulation of not less than R-28 or have a floor assembly *U*-factor no greater than *U*-0.035.

5. Transparent reach-in doors for *walk-in freezers* and windows in *walk-in freezer* doors shall be of triple-pane glass, either filled with inert gas or with heat-reflective treated glass.
6. Windows and transparent reach-in doors for *walk-in coolers* doors shall be of double-pane or triple-pane, inert gas-filled, heat-reflective treated glass.
7. Evaporator fan motors that are less than 1 hp (0.746 kW) and less than 460 volts shall use electronically commutated motors, brushless direct-current motors, or 3-phase motors.
8. Condenser fan motors that are less than 1 hp (0.746 kW) shall use electronically commutated motors, permanent split capacitor-type motors or 3-phase motors.
9. Where antisweat heaters without antisweat heater controls are provided, they shall have a total door rail, glass and frame heater power draw of not more than 7.1 W/ft^2 (76 W/m^2) of door opening for *walk-in freezers* and 3.0 W/ft^2 (32 W/m^2) of door opening for *walk-in coolers*.
10. Where antisweat heater controls are provided, they shall reduce the energy use of the antisweat heater as a function of the relative humidity in the air outside the door or to the condensation on the inner glass pane.
11. Lights in *walk-in coolers*, *walk-in freezers*, *refrigerated warehouse coolers* and *refrigerated warehouse freezers* shall either use light sources with an efficacy of not less than 40 lumens per watt, including ballast losses, or shall use light sources with an efficacy of not less than 40 lumens per watt, including ballast losses, in conjunction with a device that turns off the lights within 15 minutes when the space is not occupied.
12. Evaporator fans in refrigerated warehouses shall be variable speed, and the speed shall be controlled in response to space conditions.

    EXCEPTION. Evaporators served by a single compressor without unloading capability.

C410.2.1 Walk-in coolers and walk-in freezers. Site-assembled or site-constructed *walk-in coolers* and *walk-in freezers* shall comply with the following:

1. *Automatic* door closers shall be provided that fully close walk-in doors that have been closed to within 1 inch (25 mm) of full closure.

   Exception: Closers are not required for doors more than 45 inches (1143 mm) in width or more than 7 feet (2134 mm) in height.
2. Doorways shall be provided with strip doors, curtains, spring-hinged doors or other method of minimizing infiltration when the doors are open.
3. Walk-in cooler walls, ceilings and doors shall be provided with insulation having a thermal resistance of not less than R-25 or have wall, ceiling and door assembly *U*-factors no greater than *U*-0.039. *Walk-in freezers* walls, ceilings and doors shall be provided with insulation having a thermal resistance of not less than R-32 or have wall, ceiling, door and slab assembly *U*-factors no greater than *U*-0.030.

   Exception: Insulation is not required for glazed portions of doors or at structural members associated with the walls, ceiling or door frame.
4. The floor of *walk-in freezers* shall be provided with insulation having a thermal resistance of not less than R-28 or have a floor assembly *U*-factor no greater than *U*-0.035.
5. Transparent reach-in doors for and windows in opaque *walk-in freezer* doors shall be provided with triple-pane glass having the interstitial spaces filled with inert gas or provided with heat-reflective treated glass.
6. Transparent reach-in doors, walk-in doors ((~~for~~)) and windows in opaque *walk-in cooler* doors shall be double-pane heat-reflective treated glass having the interstitial space gas filled.
7. Evaporator fan motors that are less than 1 hp (0.746 kW) and less than 460 volts shall be electronically commutated motors or 3-phase motors.
8. Condenser fan motors that are less than 1 hp (0.746 kW) in capacity shall be of the electronically commutated or permanent split capacitor-type or shall be 3-phase motors.

   Exception: Fan motors in *walk-in coolers* and *walk-in freezers* combined in a single enclosure greater than 3,000 square feet (279 m^2) in floor area are exempt.
9. Antisweat heaters that are not provided with antisweat heater controls shall have a total door rail, glass and frame heater power draw not greater than 7.1 W/ft^2 (76 W/m^2) of door opening for *walk-in freezers*, and not greater than 3.0 W/ft^2 (32 W/m^2) of door opening for *walk-in coolers*.
10. Antisweat heater controls shall be capable of reducing the energy use of the antisweat heater as a function of the relative humidity in the air outside the door or to the condensation on the inner glass pane.
11. Light sources shall have an efficacy of not less than 40 lumens per watt, including any ballast losses, or shall be provided with a device that automatically turns off the lights within 15 minutes of when the *walk-in cooler* or *walk-in freezer* was last occupied.

C410.2.2 Refrigerated display cases. Site-assembled or site-constructed refrigerated display cases shall comply with the following:

1. Lighting and glass doors in refrigerated display cases shall be controlled by one of the following:

   1.1. Time switch controls to turn off lights during nonbusiness hours. Timed overrides for display cases shall turn the lights on for up to 1 hour and shall automatically time out to turn the lights off.

1.2. Motion sensor controls on each display case section that reduce lighting power by at least 50 percent within 3 minutes after the area within the sensor range is vacated.

2. Low-temperature display cases shall incorporate temperature-based defrost termination control with a time-limit default. The defrost cycle shall terminate first on an upper temperature limit breach and second upon a time limit breach.

3. Antisweat heater controls shall reduce the energy use of the antisweat heater as a function of the relative humidity in the air outside the door or to the condensation on the inner glass pane.

C410.3 Refrigeration systems. Refrigerated display cases, *walk-in coolers* or *walk-in freezers* that are served by remote ((~~compressor~~)) compressors and remote condensers not located in a *condensing unit*, shall comply with Sections ((~~C410.4.1 and C410.4.2~~)) C410.3.1, C410.3.2 and C403.5.3.

Exception: Systems where the working fluid in the refrigeration cycle goes through both subcritical and supercritical states (transcritical) or that use ammonia refrigerant are exempt.

C410.3.1 Condensers serving refrigeration systems. Fan-powered condensers shall comply with the following:

1. The design *saturated condensing temperatures* for air-cooled condensers shall not exceed the design dry-bulb temperature plus 10°F (5.6°C) for low-*temperature refrigeration systems*, and the design dry-bulb temperature plus 15°F (8°C) for *medium temperature refrigeration systems* where the *saturated condensing temperature* for blend refrigerants shall be determined using the average of liquid and vapor temperatures as converted from the condenser drain pressure.

2. Condenser fan motors that are less than 1 hp (0.75 kW) shall use electronically commutated motors, permanent split-capacitor-type motors or 3-phase motors.

3. Condenser fans for air-cooled condensers, evaporatively cooled condensers, air- or water-cooled fluid coolers or cooling towers shall reduce fan motor demand to not more than 30 percent of design wattage at 50 percent of design air volume, and incorporate one of the following continuous variable speed fan control approaches:

3.1. Refrigeration system condenser control for air-cooled condensers shall use variable setpoint control logic to reset the condensing temperature setpoint in response to ambient dry-bulb temperature.

3.2. Refrigeration system condenser control for evaporatively cooled condensers shall use variable setpoint control logic to reset the condensing temperature setpoint in response to ambient wet-bulb temperature.

4. Multiple fan condensers shall be controlled in unison.

5. The minimum condensing temperature setpoint shall be not greater than 70°F (21°C).

C410.3.2 Compressor systems. Refrigeration compressor systems shall comply with the following:

1. Compressors and multiple-compressor system suction groups shall include control systems that use floating suction pressure control logic to reset the target suction pressure temperature based on the temperature requirements of the attached refrigeration display cases or walk-ins.

Exception: Controls are not required for the following:

1.1. Single-compressor systems that do not have variable capacity capability.

1.2. Suction groups that have a design saturated suction temperature of 30°F (-1.1°C) or higher, suction groups that comprise the high stage of a two-stage or cascade system, or suction groups that primarily serve chillers for secondary cooling fluids.

2. Liquid subcooling shall be provided for all low-temperature compressor systems with a design cooling capacity equal to or greater than 100,000 Btu/hr (29.3 kW) with a design-saturated suction temperature of -10°F (-23°C) or lower. The subcooled liquid temperature shall be controlled at a maximum temperature setpoint of 50°F (10°C) at the exit of the subcooler using either compressor economizer (interstage) ports or a separate compressor suction group operating at a saturated suction temperature of 18°F (-7.8°C) or higher.

2.1. Insulation for liquid lines with a fluid operating temperature less than 60°F (15.6°C) shall comply with Table ((~~C403.2.10~~)) C403.2.9.

3. Compressors that incorporate internal or external crankcase heaters shall provide a means to cycle the heaters off during compressor operation.

4. Compressor systems utilized in refrigerated warehouses shall conform to the following:

4.1. Compressors shall be designed to operate at a minimum condensing temperature of 70°F or less.

4.2. The compressor speed of a screw compressor greater than 50 hp shall be controllable in response to the refrigeration load or the input power to the compressor shall be controlled to be less than or equal to 60 percent of full load input power when operated at 50 percent of full refrigeration capacity.

EXCEPTION. Refrigeration plants with more than one dedicated compressor per suction group.

SECTION C411
RENEWABLE ENERGY

C411.1 On-site renewable energy systems. Each new building or addition larger than 5,000 square feet of gross *conditioned floor area* shall include a renewable energy generation system consisting of at least 70 Watts rated peak photovoltaic energy production, or 240 BTU of annual solar water heating energy production, per 1,000 square feet of *conditioned space* or fraction thereof. For buildings over 5 stories in height, the conditioned area for this calculation shall be based on the conditioned area of the largest 5 above-grade stories in the building. Renewable energy used to comply with this section shall be in addition to any renewable energy used to comply with other provisions of this code. This system is permitted to be mounted either within the allocated *solar zone* required by Section C412.1, or elsewhere on the building or site.

Exceptions.

1. Higher-efficiency mechanical equipment is permitted to be provided in lieu of *on-site renewable energy* systems, where the capacity-weighted equipment efficiency for the total capacity of the space heating and space cooling equipment is a minimum of 1.10 times the corresponding minimum efficiency in Tables C403.2.3(1) through C403.2.3(9) for both part load and full load. For the purposes of this calculation, the efficiency of water-cooled chillers shall be defined as the inverse of the corresponding minimum efficiency listed in Table C403.2.3(7) in units of kW/ton. All factors used in the calculation shall first be converted to like units. The minimum efficiency for this exception shall be in excess of that required elsewhere in this code, including Section C403.3 (economizers). The Standard Reference Design determination from Section C407 shall be used to establish the baseline case for determination of the 1.10 factor.
2. Additional heat recovery systems beyond those required by this code are permitted to be provided in lieu of *on-site renewable energy systems*, where the calculated net annual energy savings from the heat recovery systems exceed the calculated net annual energy production of the required *on-site renewable energy systems*. Acceptable heat recovery systems include but are not limited to: exhaust air heat recovery in excess of that required by this code, waste water or sewer heat recovery, ground source heating and cooling, or heat recovered from other on-site or off-site sources that would otherwise be lost into the sewer or atmosphere.
3. Buildings that are primarily served by electric resistance heating, and that are not primarily served by a central HVAC system, are permitted to provide a higher-performing building envelope in lieu of the renewable energy required by Section C410.1. To qualify for this alternative compliance pathway, the building envelope must have a total Design UA value that is at least 15 percent below the Target UA value, using the component performance calculation methodology in Section C402.1.5.

SECTION C412
SOLAR READINESS (*MANDATORY*)

C412.1 General. In addition to the requirements of C411, a *solar zone* shall be provided on non-residential buildings that are 20 stories or less in height above grade plane. The *solar zone* shall be located on the roof of the building or on another structure elsewhere on the site. The *solar zone* shall be in accordance with Sections C412.2 through C412.8 and the *International Fire Code*.

EXCEPTION. A *solar zone* is not required where the solar exposure of the building's roof area is less than 75 percent of that of an unshaded area, as defined in Section C412.5, in the same location, as measured by one of the following:

a. Incident solar radiation expressed in kWh/ft²-yr using typical meteorological year (TMY) data;

b. Annual sunlight exposure expressed in cumulative hours per year using TMY data;

c. Shadow studies indicating that the roof area is more than 25 percent in shadow, on September 21 at 10am, 11am, 12pm, 1pm, and 2pm solar time.

C412.2 Minimum Area. The minimum area of the *solar zone* shall be determined by one of the following methods, whichever results in the smaller area:

1. 40 percent of roof area. The roof area shall be calculated as the horizontally-projected gross roof area less the area covered by skylights, occupied roof decks and planted areas.
2. 20 percent of electrical service size. The electrical service size is the rated capacity of the total of all electrical services to the building, and the required *solar zone* size shall be based upon 10 peak watts of photovoltaic per square foot.

   EXCEPTION. Subject to the approval of the *code official*, buildings with extensive rooftop equipment that would make full compliance with this section impractical shall be permitted to reduce the size of the *solar zone* required by Section C412.2 to the maximum practicable area.

Example: A building with a 10,000 SF total roof area, 1,000 SF skylight area, and a 400 Amp, 240 volt single phase electrical service is required to provide a *solar zone* area of the smaller of the following:

1. [40% x (10,000 SF roof area – 1,000 SF skylights)] = 3,600 SF; or
2. [400 Amp x 240 Volts x 20% / 10 watts per SF] = 1,920 SF

Therefore, a *solar zone* of 1,920 square feet is required.

C412.3 Contiguous area. The *solar zone* is permitted to be comprised of separated sub-zones. Each sub-zone shall be at least 5 feet wide in the narrowest dimension.

C412.4 Obstructions. The *solar zone* shall be free of pipes, vents, ducts, HVAC equipment, skylights and other obstructions, except those serving photovoltaic or solar water heating

systems within the *solar zone*. Photovoltaic or solar water heating systems are permitted to be installed within the *solar zone*. The *solar zone* is permitted to be located above any such obstructions, provided that the racking for support of the future system is installed at the time of construction, the elevated *solar zone* does not shade other portions of the *solar zone*, and its height is permitted by the *International Building Code* and the Seattle Land Use Code.

C412.5 Shading. The *solar zone* shall be set back from any existing or new object on the building or site that is located south, east, or west of the *solar zone* a distance at least two times the object's height above the nearest point on the roof surface. Such objects include but are not limited to taller portions of the building itself, parapets, chimneys, antennas, signage, rooftop equipment, trees and roof plantings. No portion of the *solar zone* shall be located on a roof slope greater than 2:12 that faces within 45° of true north.

C412.6 Access. Areas contiguous to the *solar zone* shall provide access pathways and provisions for emergency smoke ventilation as required by the *International Fire Code*.

C412.7 Structural integrity. The as-designed dead load and live load for the *solar zone* shall be clearly marked on the record drawings, and shall accommodate future photovoltaic or solar water heating systems arrays at an assumed dead load of 4 pounds per square foot in addition to other required live and dead loads. For photovoltaics, a location for future inverters shall be designated either within or adjacent to the *solar zone*, with a minimum area of 2 square feet for each 1000 square feet of *solar zone* area, and shall accommodate an assumed dead load of 175 pounds per square foot. Where photovoltaic or solar water heating systems are installed in the *solar zone*, structural analysis shall be based upon calculated loads, not upon these assumed loads.

C412.8 Photovoltaic or solar water heating interconnection provisions. Buildings shall provide for the future interconnection of either photovoltaics in accordance with Section C412.8.1 or solar water heating in accordance with Section C412.8.2.

C412.8.1 Photovoltaic interconnection. A capped roof penetration sleeve shall be provided in the vicinity of the future inverter, sized to accommodate the future photovoltaic system conduit. The capped roof penetration shall be sized to accommodate a conductor and conduit for 10 peak watts per square foot of the required *solar zone* area. Interconnection of the future photovoltaic system shall be provided for at the main service panel, either ahead of the service disconnecting means or at the end of the bus opposite the service disconnecting means, in one of the following forms:

a. A space for the mounting of a future overcurrent device, sized to accommodate the largest standard rated overcurrent device that is less than 20 percent of the bus rating.

b. Lugs sized to accommodate conductors with an ampacity of at least 20 percent of the bus rating, to enable the mounting of an external overcurrent device for interconnection.

The electrical construction documents shall indicate the following:

a. *Solar zone* boundaries and access pathways;

b. Location for future inverters and metering equipment; and

c. Route for future wiring between the photovoltaic panels and the inverter, and between the inverter and the main service panel.

C412.8.2 Solar water heating interconnection. Two capped pipe tees shall be provided upstream of the domestic water heating equipment to provide plumbing interconnections between a future solar water heating system and the domestic water heating system. Two roof penetration sleeves shall be provided in the vicinity of the *solar zone*, capable of accommodating supply and return piping for a future solar water heating system.

The plumbing construction documents shall indicate the following:

a. *Solar zone* boundaries and access pathways;

b. Location for future hot water storage tanks; and

c. Route for future piping between the *solar zone* and the plumbing interconnection point, following the shortest feasible pathway.