CHAPTER 4 [CE]

COMMERCIAL ENERGY EFFICIENCY

SECTION C401 GENERAL

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

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

1. The requirements of Sections C402, C403, C404, C405, C408 ((~~and~~)) C409 and C410.
2. The requirements of Sections C402.4, C403.2, C404, C405.2, C405.3, C405.4, C405.6, C405.7, C407, C408, ((~~and~~)) C409 and C410. The building energy consumption shall be equal to or less than 93 percent of the standard reference design building.
3. The requirements of C402.1.5.

C401.2.1 Application to existing buildings. Additions, alterations and repairs to existing buildings shall comply with Sections C402, C403, C404 and C405, C408 and C409.

SECTION C402 BUILDING ENVELOPE REQUIREMENTS

C402.1 General (Prescriptive). The building thermal envelope shall comply with Section C402.1.1. Section C402.1.2 or Section C402.1.3 shall be permitted as an alternative to the *R*-values specified in Section C402.1.1. Walk-in coolers and walk-in freezers shall comply with Section C402.5. Refrigerated warehouse coolers and refrigerated warehouse freezers shall comply with Section C402.6.

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

C402.1.1 Insulation and fenestration criteria. The *building thermal envelope* shall meet the requirements of Tables C402.2 and C402.3 based on the climate zone specified in Chapter 3. Commercial buildings or portions of commercial buildings enclosing Group R occupancies shall use the *R*-values from the "Group R" column of Table C402.2. Commercial buildings or portions of commercial buildings enclosing occupancies other than Group R shall use the *R*-values from the "All other" column of Table C402.2.

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.

C402.1.2 *U*-factor alternative. An assembly with a *U*-factor, *C*-factor, or *F*-factor equal or less than that specified in Table C402.1.2 shall be permitted as an alternative to the *R*-value in Table C402.2. Commercial buildings or portions of commercial buildings enclosing Group R occupancies shall use the *U*-factor, *C*-factor, or *F*-factor from the "Group R" column of Table C402.1.2. Commercial buildings or portions of commercial buildings enclosing occupancies other than Group R shall use the *U*-factor, *C*-factor or *F*-factor from the "All other" column of Table C402.1.2. 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 of Fundamentals* using the framing factors listed in Appendix A where applicable and shall include the thermal bridging effects of framing materials. The *U*-values and *R*-values of foam insulation products used for the purpose of compliance with this code shall be based on the aged Long-Term Thermal Resistance (LTTR) values of the insulation.

C402.1.3 Component performance building envelope option.

C402.1.3.1 General. Buildings or structures whose design heat loss rate (UA_p) and solar heat gain coefficient rate ($SHGC \cdot A_p$) are less than or equal to the target heat loss rate (UA_t) and solar heat gain coefficient rate ($SHGC \cdot A_t$) shall be considered in compliance with this section. The stated *U*-factor, *F*-factor or allowable area of any component assembly, listed in Table C402.1.2 and Table C402.3, such as roof/ceiling, opaque wall, opaque door, fenestration, floor over conditioned space, slab-on-grade floor, radiant floor or opaque floor may be increased and the *U*-factor or *F*-factor for other components decreased, provided that the total heat gain or loss for the entire building envelope does not exceed the total resulting from compliance to the *U*-factors, *F*-factors or allowable areas specified in this section. Compliance shall be calculated in total for the building envelope for nonresidential spaces and for residential spaces.

Exception: A design heat loss rate in compliance with Equation C402-5 is permitted in lieu of a calculation in compliance with Equations C402.1 and C402.2.

C402.1.3.2 Component *U*-factors. The *U*-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 of 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 of Fundamentals* where the metal framing is bonded on one or both sides to a metal skin or covering.

TABLE C402.1.2
OPAQUE THERMAL ENVELOPE ASSEMBLY REQUIREMENTS[a]

CLIMATE ZONE	5 AND MARINE 4	
	All Other	Group R
Roofs		
Insulation entirely above deck	((~~U-0.034~~)) U-0.026	((~~U-0.031~~)) U-0.026
Metal buildings	((~~U-0.031~~)) U-0.027	((~~U-0.031~~)) U-0.027
Attic and other	U-0.021	U-0.021
Walls, Above Grade		
Mass	((~~U-0.104~~[d])) U-0.057	((~~U-0.078~~)) U-0.057
Metal building	U-0.052	U-0.052
Steel framed	U-0.055	U-0.055
Wood framed and other	((~~U-0.054~~)) U-0.051	((~~U-0.054~~)) U-0.051
Walls, Below Grade		
Below-grade wall[b]	((~~Same as above grade~~)) U-0.070	((~~Same as above grade~~)) U-0.070
Floors		
Mass	((~~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-0.540	((~~F-0.54~~)) F-0.540
Heated slabs[c]	((~~F-0.55~~)) F-0.55	((~~F-0.55~~)) F-0.55

a. Use of opaque assembly *U*-factors, *C*-factors, and *F*-factors from Appendix A is required unless otherwise allowed by Section C402.1.2.

b. 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. **Exception:** Integral insulated concrete block walls complying with ASTM C 90 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 *U* factor from Table C402.1.2.~~))

3. The zone method as provided in ASHRAE *Handbook of Fundamentals*.
4. Effective framing/cavity *R*-values as provided in Appendix A. When return air ceiling plenums are employed, the roof/ceiling assembly shall:
   4.1. For thermal transmittance purposes, not include the ceiling proper nor the plenum space as part of the assembly; and
   4.2. For gross area purposes, be based upon the interior face of the upper plenum surface.
5. Tables in ASHRAE 90.1-2010 Normative Appendix A.

C402.1.3.3 UA calculations. The target UA_t and the proposed UA_p shall be calculated using Equations C402-1 and C402-2 and the corresponding areas and *U*-factors from Table C402.1.2 and Table C402.3. For the target UA_t calculation, the skylights shall be located in roof/ceiling area up to the maximum skylight area per Section C402.3.1 and the remainder of the fenestration allowed per Section C402.3.1 shall be located in the wall area.

C402.1.3.4 SHGC rate calculations. Solar heat gain coefficient shall comply with Table C402.3. The target $SHGCA_t$ and the proposed $SHGCA_p$ shall be calculated using Equations C402-3 and C402-4 and the corresponding areas and SHGCs from Table C402.3.

C402.1.4 Semi-heated spaces. All spaces shall comply with the requirements in Section C402 unless they meet the definition for semi-heated spaces. For semi-heated spaces, the building envelope shall comply with the same requirements as that for conditioned spaces in Section C402; however, for semi-heated spaces heated by other than electric resistance heating equipment, wall insulation is not required for those walls that separate semi-heated spaces from the exterior provided that the space meets all of the requirements of semi-heated space. Semi-heated spaces shall be calculated separately from other conditioned spaces for compliance purposes. Building envelope assemblies separating conditioned space from semi-heated space shall comply with exterior envelope insulation requirements. When choosing the uninsulated wall option, the wall shall not be included in Component Performance Building Envelope Option calculation.

C402.1.5 Target performance path.

C402.1.5.1 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 C402.1.5.3 below.

1. B-occupancy office
2. B-occupancy medical office
3. R-2 occupancy multifamily over three stories
4. S-1 and S-2 occupancy warehouse (nonrefrigerated)
5. E-occupancy school
6. M-occupancy retail
7. I-2 occupancy 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.

C402.1.5.2 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. B-occupancy office: 40 kBtu/ft^2/yr
2. B-occupancy medical office: 50 kBtu/ft^2/yr
3. R-2 occupancy multifamily: 35 kBtu/ft^2/yr
4. S-1 and S-2 occupancy warehouse: 25 kBtu/ft^2/yr
5. E-occupancy school: 45 kBtu/ft^2/yr
6. M-occupancy retail: 60 kBtu/ft^2/yr
7. I-2 occupancy 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.

C402.1.5.2.1 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 *DPD* showing daily, monthly and annual totals during the operational energy use demonstration period set forth in Section C402.1.5.6. Actual *IT energy* shall be adjusted in accordance with Section C402.1.5.7.

C402.1.5.3 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 for all *fenestration* less than 0.40; 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. C402.4 Air Leakage
   - 3.3. C403.2.4 Thermostatic Controls
   - 3.4. C404.9 Domestic hot water meters
   - 3.5. C408 System Commissioning
   - 3.6. C409 Energy Metering and Energy Consumption Management

C402.1.5.4 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 shall be 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 C402.1.5.4
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

Informative Note: Energy models completed for the sensitivity analysis are not required to meet the target EUI. The sensitivity analysis is intended to test the robustness of the results in the presence of uncertainty.

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

C402.1.5.5 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).

C402.1.5.6 Demonstration of operating energy use. Metered energy data shall be supplied directly via automated reporting from utilities to DPD 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 C402.1.5.2 or item 8 of Section 402.1.5.1 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 C402.1.5. The owner shall notify the *code official* when this 12-month period has been successfully completed.

C402.1.5.6.1 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 C402.1.5.6 based on the most recent one-year period and adjusted for the actual occupancy rate during that period.

C402.1.5.7 Adjustment for data center energy usage. Where data center *IT energy* use 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 C402.1.5.2.1, 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 Section C402.1.5.2.1, that shortfall shall be subtracted from the total allowable energy use.

C402.1.5.8 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 C402.1.5.2, 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.

C402.1.5.9 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.

C402.1.5.10 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.

C402.1.5.11 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 C402.1.5.6. The penalty shall be administered as provided in Section C110, except that the amount of the penalty shall be determined using Table C402.1.5.11 and not the amounts in Building Code Section 103. 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 C402.1.5, the applicant will comply with the requirements of this section.

   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 nonpayment.

If the owner provides evidence that the building has operated at or below its target energy performance level as provided in Section C402.1.5.6, 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.

C402.1.5.12 Procedure for noncompliance. If the owner fails to provide evidence that the building has operated as required under Section C402.1.5.6, 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 C402.1.5.11(3). The fine shall be in the amount shown in Table C402.1.5.12 and 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 per Table C402.1.5.12.

TABLE C402.1.5.12
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 C402.1.5.12
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

C402.1.5.13 Reimbursements. Where a financial security has been drawn down pursuant to item 1 in Section C402.1.5.12, or a fine has been levied pursuant to item 2 in Section C402.1.5.12, 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 C402.1.5.12. 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 C402.1.5.12, or a fine has been levied pursuant to item 2 in Section C402.1.5.12.

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

EQUATION C402-1
TARGET UA_t

$$UA_t = U_{radt}A_{radt} + U_{mrt}A_{mrt} + U_{rat}A_{rat} + U_{mwt}(A_{mwt} + A_{mwbgt}) + U_{mbwt}(A_{mbwt} + A_{mbwbgt}) + U_{sfwt}(A_{sfwt} + A_{sfwbgt}) + U_{wfwt}(A_{wfwt} + A_{wfwbgt}) + U_{fmt}A_{fmt} + U_{fjt}A_{fjt} + F_{st}P_{st} + F_{srt}P_{srt} + U_{dst}A_{dst} + U_{drt}A_{drt} + U_{vgt}A_{vgt} + U_{vgmt}A_{vgmt} + U_{vgmot}A_{vgmot} + U_{vgdt}A_{vgdt} + U_{ogt}A_{ogt}$$

UA_t = The target combined specific heat transfer of the gross roof/ceiling assembly, exterior wall and floor area.

where:

U_{radt} = The thermal transmittance value for roofs with the insulation entirely above deck found in Table C402.1.2.

U_{mrt} = The thermal transmittance value for metal building roofs found in Table C402.1.2.

U_{rat} = The thermal transmittance value for attic and other roofs found in Table C402.1.2.

U_{mwt} = The thermal transmittance value for opaque mass walls found in Table C402.1.2.

U_{mbwt} = The thermal transmittance value for opaque metal building walls found in Table C402.1.2.

U_{sfwt} = The thermal transmittance value for opaque steel-framed walls found in Table C402.1.2.

U_{wfwt} = The thermal transmittance value for opaque wood framed and other walls found in Table C402.1.2.

U_{fmt} = The thermal transmittance value for mass floors over unconditioned space found in Table C402.1.2.

U_{fjt} = The thermal transmittance value for joist floors over unconditioned space found in Table C402.1.2.

F_{st} = The *F*-factor for slab-on-grade floors found in Table C402.1.2.

F_{srt} = The *F*-factor for radiant slab floors found in Table C402.1.2.

U_{dst} = The thermal transmittance value for opaque swinging doors found in Table C402.2.

U_{drt} = The thermal transmittance value for opaque roll-up or sliding doors found in Table C402.2.

U_{vgt} = The thermal transmittance value for vertical fenestration with nonmetal framing found in Table C402.3 which corresponds to the proposed vertical fenestration area as a percent of gross exterior wall area. *Buildings utilizing Section C402.3.1.3 shall use the thermal transmittance value specified there.

U_{vgmt} = The thermal transmittance value for vertical fenestration with fixed metal framing found in Table C402.3 which corresponds to the proposed vertical fenestration area as a percent of gross exterior wall area. *Buildings utilizing Section C402.3.1.3 shall use the thermal transmittance value specified there.

U_{vgmot} = The thermal transmittance value for vertical fenestration with operable metal framing found in Table C402.3 which corresponds to the proposed vertical fenestration area as a percent of gross exterior wall area. *Buildings utilizing Section C402.3.1.3 shall use the thermal transmittance value specified there.

U_{vgdt} = The thermal transmittance value for entrance doors found in Table C402.3 which corresponds to the proposed vertical fenestration area as a percent of gross exterior wall area. *Buildings utilizing Section C402.3.1.3 shall use the thermal transmittance value specified there.

U_{ogt} = The thermal transmittance for skylights found in Table C402.3 which corresponds to the proposed skylight area as a percent of gross exterior roof area.

A_{fmt} = The proposed mass floor over unconditioned space area, A_{fm}

A_{fjt} = The proposed joist floor over unconditioned space area, A_{fj}

P_{st} = The proposed linear feet of slab-on-grade floor perimeter, P_s

P_{srt} = The proposed linear feet of radiant slab floor perimeter, P_{rs}

A_{dst} = The proposed opaque swinging door area, A_{ds}

A_{drt} = The proposed opaque roll-up or sliding door area, A_{dr}

and

If the vertical fenestration area as a percent of gross exterior above-grade wall area does not exceed the maximum allowed in Section C402.3.1:

A_{mwt} = The proposed opaque above grade mass wall area.

A_{mbwt} = The proposed opaque above grade metal building wall area.

A_{sfwt} = The proposed opaque above grade steel framed wall area.

A_{wfwt} = The proposed opaque above grade wall wood framed and other area.

(continued)

EQUATION C402-1—continued
TARGET UA_T

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.

or

If the vertical fenestration area as a percent of gross above-grade exterior wall area exceeds the maximum allowed in Section C402.3.1, the area of each vertical fenestration element shall be reduced in the base envelope design by the same percentage and the net area of each above-grade wall type increased proportionately by the same percentage so that the total vertical fenestration area is exactly equal to the allowed percentage per Section C402.3.1 of the gross above-grade wall area.

and

If the skylight area as a percent of gross exterior roof area does not exceed the maximum allowed in Section C402.3.1:

A_{radt} = The proposed roof area with insulation entirely above the deck, A_{rad}

A_{mrt} = The proposed roof area for metal buildings, A_{mr}

A_{rat} = The proposed attic and other roof area, A_{or}

A_{ogat} = The proposed skylight area, A_{ogor}

or

If the skylight area as a percent of gross exterior roof area exceeds the maximum allowed in Section C402.3.1, the area of each skylight element shall be reduced in the base envelope design by the same percentage and the net area of each roof type increased proportionately by the same percentage so that the total skylight area is exactly equal to the allowed percentage per Section C402.3.1 of the gross roof area.

*__NOTE:__ The vertical fenestration area does not include opaque doors and opaque spandrel panels.

EQUATION C402-2
PROPOSED UA_p

$$UA_p = U_{rad}A_{rad} + U_{mr}A_{mr} + U_{ra}A_{ra} + U_{mw}A_{mw} + U_{mbw}A_{mbw} + U_{sfw}A_{sfw} + U_{wfow}A_{wfow} + U_{fm}A_{fm} + U_{fj}A_{fj} + F_sP_s + F_{sr}P_{sr} + U_{ds}A_{ds} + U_{dr}A_{dr} + U_{vg}A_{vg} + U_{vgmf}A_{vgmf} + U_{vgmo}A_{vgmo} + U_{vgd}A_{vgd} + U_{og}A_{og}$$

where:

UA_p = The combined proposed specific heat transfer of the gross exterior wall, floor and roof/ceiling assembly area.

U_{rad} = The thermal transmittance of the roof area where the insulation is entirely above the roof deck.

A_{rad} = Opaque roof area where the insulation is entirely above the roof deck.

U_{mr} = The thermal transmittance of the metal building roof area.

A_{mr} = Opaque metal building roof area.

U_{ra} = The thermal transmittance of the roof over attic and other roof area.

A_{ra} = Opaque roof over attic and other roof area.

U_{mw} = The thermal transmittance of the opaque mass wall area.

A_{mw} = Opaque mass wall area (not including opaque doors).

U_{mbw} = The thermal transmittance of the opaque metal building wall area.

A_{mbw} = Opaque metal building wall area (not including opaque doors).

U_{sfw} = The thermal transmittance of the opaque steel framed wall area.

A_{sfw} = Opaque steel framed wall area (not including opaque doors).

U_{wfw} = The thermal transmittance of the opaque wood framed and other wall area.

A_{wfw} = Opaque wood framed and other wall area (not including opaque doors).

U_{fm} = The thermal transmittance of the mass floor over unconditioned space area.

A_{fm} = Mass floor area over unconditioned space.

U_{fj} = The thermal transmittance of the joist floor over unconditioned space area.

A_{fj} = Joist floor area over unconditioned space.

F_s = Slab-on-grade floor component *F*-factor.

P_s = Linear feet of slab-on-grade floor perimeter.

F_{sr} = Radiant floor component *F*-factor.

P_{sr} = Lineal feet of radiant floor perimeter.

U_{ds} = The thermal transmittance value of the opaque swinging door area.

A_{ds} = Opaque swinging door area.

U_{dr} = The thermal transmittance value of the opaque roll-up or sliding door area.

A_{dr} = Opaque roll-up or sliding door area.

U_{vg} = The thermal transmittance of the vertical fenestration area with nonmetal framing.*

A_{vg} = Vertical fenestration area with nonmetal framing.*

U_{vgmf} = The thermal transmittance of the vertical fenestration area with fixed metal framing.*

A_{vgmf} = Vertical fenestration area with fixed metal framing.*

U_{vgmo} = The thermal transmittance of the vertical fenestration area with operable metal framing.*

A_{vgmo} = Vertical fenestration area with operable metal framing.*

U_{vgd} = The thermal transmittance of the vertical fenestration area for entrance doors.*

A_{vgd} = Vertical fenestration area for entrance doors.*

U_{og} = The thermal transmittance for the skylights.

A_{og} = Skylight area.

NOTE: Where more than one type of wall, window, roof/ceiling, door and skylight is used, the U and A terms for those items shall be expanded into subelements as:

$U_{mw1}A_{mw1} + U_{mw2}A_{mw2} + U_{sfw1}A_{sfw1}$ + ...etc.

*__NOTE:__ The vertical fenestration area does not include opaque doors and opaque spandrel panels.

EQUATION C402-3
TARGET $SHGCA_t$

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

where:

$SHGCA_t$ = The target combined ((~~specific~~)) solar heat gain coefficient of the target fenestration area.

$SHGC_{ogt}$ = The solar heat gain coefficient for skylight fenestration found in Table C402.3 and A_{ogt} as defined in Equation C402-1.

$SHGC_{vgt}$ = The solar heat gain coefficient for vertical fenestration found in Table C402.3 and A_{vgt}, A_{vgmt}, A_{vgmot} and A_{vgdt} as defined in Equation C402-1.

NOTES: Buildings utilizing Section C402.3.1.3 shall use the SHGC value specified there. The SHGC may be adjusted for projection factors per the requirements of C402.3.3.

EQUATION C402-4
PROPOSED $SHGCA_P$

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

where:

$SHGCA_t$ = The combined proposed ((~~specific~~)) solar heat gain coefficient 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.

TABLE C402.2
OPAQUE THERMAL ENVELOPE REQUIREMENTS[a, f]

CLIMATE ZONE	5 AND MARINE 4 (SEATTLE)	
	All Other	Group R
Roofs		
Insulation entirely above deck	((~~R-30ci~~)) R-38ci	R-38ci
Metal buildings (with R-3.5 thermal blocks)[a, b]	((~~R-25 + R-11 LS~~)) R-25 + R-22 LS	((~~R-25 + R-11 LS~~)) R-25 + R-22 LS
Attic and other	R-49	R-49
Walls, Above Grade		
Mass	((~~R-9.5ci~~)) Exterior: R-16 c.i. Interior: R-13 + R-6 ci wood stud, or R-13 + R-10 ci metal stud	((~~R-13.3ci~~)) Exterior: R-16 c.i. Interior: R-13 + R-6 ci wood stud, or R-13 + R-10 ci metal stud
Metal building	R-13 + R-13ci	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
Roll-up or sliding	((~~R-4.75~~)) U-0.390	((~~R-4.75~~)) U-0.390

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.

(continued)

TABLE C402.2
OPAQUE THERMAL ENVELOPE REQUIREMENTS[a, f]—continued

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

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

c. Reserved. ((~~**Exception:** Integral insulated concrete block walls complying with ASTM C 90 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 C402.2 or *U*-factor from Table C402.1.2.~~))

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

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

f. For roof, wall or floor assemblies where the proposed assembly would not be continuous insulation, an alternate nominal *R*-value compliance option for assemblies with isolated metal penetrations of otherwise continuous insulation is shown in the right-hand column of the table below:

ASSEMBLIES WITH CONTINUOUS INSULATION (see definition)	ALTERNATE OPTION FOR ASSEMBLIES WITH METAL PENETRATIONS, GREATER THAN 0.04% BUT LESS THAN 0.08%
R-11.4ci	R-14.3ci
R-13.3ci	R-16.6ci
R-15.2ci	R-19.0ci
R-30ci	R-38ci
R-38ci	R-48ci
R-13 + R-7.5ci	R-13 + R-9.4ci
R-13 + R-10ci	R-13 + R-12.5ci
R-13 + R-12.5ci	R-13 + R-15.6ci
R-13 + R-13ci	R-13 + R-16.3ci
R-19 + R-8.5ci	R-19 + R-10.6ci
R-19 + R-14ci	R-19 + R-17.5ci
R-19 + R-16ci	R-19 + R-20ci
R-20 + R-3.8ci	R-20 + R-4.8ci
R-21 + R-5ci	R-21 + R-6.3ci

This alternate nominal *R*-value compliance option is 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%).
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 C402.1.2 for determination of *U*-factors for assemblies that include metal other than screws and nails.

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

Exceptions:

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

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

Informative Note: The section below regarding roof solar reflectance does not apply to Washington State, as it refers only to Climate Zones 1, 2 and 3. Seattle is in Zone 4.

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

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

1. Portions of roofs that include or are covered by:
   1.1. Photovoltaic systems or components.
   1.2. Solar air or water heating systems or components.
   1.3. Roof gardens or landscaped roofs.
   1.4. Above-roof decks or walkways.
   1.5. Skylights.
   1.6. HVAC systems, components, and other opaque objects mounted above the roof.
2. Portions of roofs shaded during the peak sun angle on the summer solstice by permanent features of the building, or by permanent features of adjacent buildings.
3. Portions of roofs that are ballasted with a minimum stone ballast of 17 pounds per square foot (psf) (74 kg/m^2) or 23 psf (117 kg/m^2) pavers.
4. Roofs where a minimum of 75 percent of the roof area meets a minimum of one of the exceptions above.

TABLE C402.2.1.1
MINIMUM ROOF REFLECTANCE AND EMITTANCE OPTIONS[a]

Three-year aged solar reflectance[b] of 0.55 and three-year aged thermal emittance[c] of 0.75
Initial solar reflectance[b] of 0.70 and initial thermal emittance[c] of 0.75
Three-year-aged solar reflectance index[d] of 64
Initial solar reflectance index[d] of 82

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

C402.2.2 Classification of walls. Walls associated with the building envelope shall be classified in accordance with Section C202.

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

"Mass walls" shall include walls weighing not less than:

1. 35 psf (170 kg/m^2) of wall surface area; or
2. 25 psf (120 kg/m^2) of wall surface area if the material weight is not more than 120 pounds per cubic foot (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 C402.2.

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

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

1. 35 psf (170 kg/m^2) of floor surface area; or
2. 25 psf (120 kg/m^2) of floor surface area if the material weight is not more than 120 pcf (1900 kg/m^3).

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

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

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

C402.2.8 Insulation of radiant heating systems. Radiant panels, and associated U-bends and headers, designed for sensible heating of an indoor space through heat transfer from the thermally effective panel surfaces to the occupants or indoor space by thermal radiation and natural convection and the bottom surfaces of floor structures incorporating radiant heating shall be insulated with a minimum of R-3.5 (0.62 $m^2/K \times W$). Adjacent envelope insulation counts towards this requirement.

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

Exception: Single glazing is permitted for security purposes and for revolving doors, provided that the total area of single glazing does not exceed 1 percent of the gross exterior wall area, and such glazing is included in the percentage of the total glazing area, *U*-factor and SHGC requirements in Section C402.3.

C402.3.1 Maximum area. The vertical fenestration area (not including opaque doors and opaque spandrel panels) shall not exceed 30 percent of the gross above-grade wall area. The skylight area shall not exceed ((~~3~~)) 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 utilized, 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 for other areas of the building.

TABLE C402.3
BUILDING ENVELOPE REQUIREMENTS—FENESTRATION

CLIMATE ZONE	5 AND MARINE 4
Vertical Fenestration	
***U*-factor**	
Nonmetal framing (all)[a]	0.30
Metal framing (fixed)[b]	0.38
Metal framing (operable)[c]	0.40
Metal framing (entrance doors)[d]	0.60
SHGC	
SHGC	((~~0.40~~)) 0.35
Skylights	
***U*-factor**	((~~0.50~~)) 0.45
SHGC	((~~0.35~~)) 0.32

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. Other doors which are not entrance doors, including sliding glass doors, are considered "operable."

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

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

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

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.

((**~~C402.3.1.2 Increased skylight area with daylighting controls.~~** ~~The skylight area shall be permitted to be a maximum of 5 percent of the roof area provided auto-~~

~~matic daylighting controls are installed in daylight zones under skylights.~~))

C402.3.1.2((~~3~~)) Increased vertical fenestration area with high-performance fenestration. 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 C402.1.2 or for the Target UA calculation in Equation C402-1 or C402-5, provided that each of the following conditions are met:

1. The vertical fenestration shall have the following maximum *U*-factors:
   a. Nonmetal framing (all) = 0.28
   b. Metal framing (fixed) = ((~~0.34~~)) 0.36
   c. Metal framing (operable) = 0.36
   d. Metal framing (entrance doors) = 0.60

   An area-weighted average shall be permitted to satisfy the *U*-factor requirements for each fenestration product category listed above. Individual fenestration products from different fenestration product categories shall not be combined in calculating the area-weighted average *U*-factor.
2. The SHGC of the vertical fenestration shall be less than or equal to 0.35, adjusted for projection factor in compliance with C402.3.3.1.

The compliance path described in this section C402.3.1.3 is not permitted to be used for the Total Building Performance compliance path as set out in Section C407.

C402.3.2 Minimum skylight fenestration area. For single-story buildings only, in an enclosed space greater than 10,000 square feet (929 m^2), directly under a roof with 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, the total daylight zone under skylights shall be not less than half the floor area and shall provide a minimum skylight area to daylight zone under skylights of either:

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

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

(Equation C4-1)

where:

Skylight area = Total fenestration area of skylights.

Skylight VT = Area weighted average visible transmittance of skylights.

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

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

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

1. Buildings in climate zones 6 through 8.
2. Spaces where the designed *general lighting* power densities are less than 0.5 W/ft^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 am and 4 pm.
4. Spaces where the daylight zone under rooftop monitors is greater than 50 percent of the enclosed space floor area.

C402.3.2.1 Lighting controls in daylight zones under skylights. All lighting in the daylight zone shall be controlled by automatic daylighting controls that comply with Section C405.2.2.3.2.

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

~~1. Buildings in Climate Zones 6 through 8.~~

~~2. Spaces where the designed *general lighting* power densities are less than 0.5 W/ft^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 am and 4 pm.~~

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

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

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

C402.3.3 Maximum *U*-factor and SHGC. For vertical fenestration, the maximum *U*-factor and solar heat gain

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

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

$PF = A/B$ **(Equation C4-2)**

where:

PF = Projection factor (decimal).

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

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

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

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

TABLE C402.3.3.1
SHGC ADJUSTMENT MULTIPLIERS

PROJECTION FACTOR	ORIENTED WITHIN 45 DEGREES OF TRUE NORTH	ALL OTHER ORIENTATION
$0.2 \le PF < 0.5$	1.1	1.2
$PF \ge 0.5$	1.2	1.6

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

C402.3.3.3 Reserved.

C402.3.3.4 Reserved.

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

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

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

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

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

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

1. The air barrier shall be continuous for all assemblies that are the thermal envelope of the building and across the joints and assemblies.
2. Air barrier joints and seams shall be sealed, including sealing transitions in places and changes in materials. Air barrier penetrations shall be sealed in accordance with Section C402.4.2. The joints and seals shall be securely installed in or on the joint for its entire length so as not to dislodge, loosen or otherwise impair its ability to resist positive and negative pressure from wind, stack effect and mechanical ventilation.
3. Recessed lighting fixtures shall comply with Section C402.4.8. Where similar objects are installed which penetrate the air barrier, provisions shall be made to maintain the integrity of the air barrier.
4. 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.

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

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 semiheated 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.

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

C402.4.1.2.1 Materials. Materials with an air permeability no greater than 0.004 cfm/ft^2 (0.02 L/s · m^2) under a pressure differential of 0.3 inches water gauge (w.g.) (75 Pa) when tested in accordance with ASTM E 2178 shall comply with this section. Materials in Items 1 through 15 shall be deemed to com-

ply with this section provided joints are sealed and materials are installed as air barriers in accordance with the manufacturer's instructions.

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

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

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

C402.4.1.2.3 Building test. The completed building shall be tested and the air leakage rate of the *building envelope* shall not exceed 0.40 cfm/ft^2 at a pressure differential of 0.3 inches water gauge (2.0 L/s · m^2 at 75 Pa) at the upper 96 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. *

The following modifications shall be made to ASTM E 779:

1. Tests shall be accomplished using either (1) both pressurization and depressurization or (2) pressurization alone, but not depressurization alone. If both pressurization and depressurization are not tested, the air leakage shall be plotted against the corrected P for pressurization in accordance with Section 9.4.
2. The test pressure range shall be from 25 Pa to 80 Pa per Section 8.10, 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, the test shall be rerun with additional readings over a longer time interval.

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.

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

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

Exceptions:

1. Field-fabricated fenestration assemblies that are sealed in accordance with Section C402.4.1. A field-fabricated *fenestration* product is a *fenestration* product (including glazed exterior doors) whose frame is made at the construction site of standard dimensional lumber or other materials

that were not previously cut, or otherwise formed with the specific intention of being used to fabricate a *fenestration* product or exterior door. Field-fabricated does not include curtain walls.

2. Fenestration in buildings that comply with Section C402.4.1.2.3 are not required to meet the air leakage requirements in Table C402.4.3.
3. Custom exterior windows and doors manufactured by a *small business* provided they meet the applicable provisions of Chapter 24 of the *International Building Code*. Once visual inspection has confirmed the presence of a gasket, operable windows and doors manufactured by small business shall be permitted to be sealed off at the frame prior to the test.

TABLE C402.4.3
MAXIMUM AIR INFILTRATION RATE FOR FENESTRATION ASSEMBLIES

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

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

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

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

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

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

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

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

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

C402.4.5.2 Outdoor air intakes and exhausts. *Outdoor air* supply, exhaust openings and relief outlets shall be provided with Class IA motorized dampers which close automatically when the system is off. Return air dampers shall be equipped with motorized dampers. Dampers shall have a maximum leakage rate of 4 cfm/ft^2 (20.3 L/s · m^2) at 1.0 inch water gauge (w.g.) (249 Pa) when tested in accordance with AMCA 500D. Gravity (nonmotorized) dampers for ventilation air intakes shall be protected from direct exposure to wind.

Exceptions:

1. Gravity (nonmotorized) dampers having a maximum leakage rate of 20 cfm/ft^2 (101.6 L/s · m^2) at 1.0 inch water gauge (w.g.) (249 Pa) when tested in accordance with AMCA 500D are permitted to be used for relief, outside air and exhaust openings in buildings ((~~less than three stories in height above grade~~)) if equipment has less than ((~~5,000~~)) 300 cfm (((~~2.36~~)) 0.14 m^3/s) total supply flow.
2. Reserved. ((~~Gravity (nonmotorized) dampers for ventilation air intakes shall be protected from direct exposure to wind.~~))
3. Gravity dampers smaller than 24 inches (610 mm) in either dimension shall be permitted to have a leakage of 40 cfm/ft^2 (203.2 L/s · m^2) at 1.0 inch water gauge (w.g.) (249 Pa) when tested in accordance with AMCA 500D.
4. Gravity (nonmotorized) dampers in Group R occupancies where the design outdoor air intake, relief or exhaust capacity does not exceed ((~~400~~)) 300 cfm (((~~189~~)) 141 L/s).
5. Systems serving areas which require continuous operation.
6. Combustion air intakes.
7. Type I kitchen exhaust hoods.

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

C402.4.7 Vestibules. All building entrances shall be protected with an enclosed vestibule, with all doors opening into and out of the vestibule equipped with self-closing devices.

Vestibules shall be designed so that in passing through the vestibule it is not necessary for the interior and exterior doors to open at the same time. The installation of one or more revolving doors in the building entrance shall not eliminate the requirement that a vestibule be provided on any doors adjacent to revolving doors.

Interior and exterior doors shall have a minimum distance between them of not less than 7 feet (2134 mm). 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.

Exceptions:

1. Buildings in Climate Zones 1 and 2.
2. Doors not intended to be used by the public, such as doors to mechanical or electrical equipment rooms, or intended solely for employee use.
3. Doors opening directly from a *sleeping unit* or dwelling unit.
4. Doors that open directly from a space less than 3,000 square feet (298 m^2) in area and are separate from the building entrance.
5. Revolving doors.
6. Doors used primarily to facilitate vehicular movement or material handling and adjacent personnel doors.
7. Building entrances in buildings that are less than four stories above grade and less than 10,000 ft^2 (930 m^2) in area.
8. Elevator doors in parking garages provided that the elevators have an enclosed lobby at each level of the garage.
9. Entrances to semi-heated spaces.

Informative Note: Building entrances are defined as the means ordinarily used to gain access to the building. Doors other than for building entrances, such as those leading to service areas, mechanical rooms, electrical equipment rooms, 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.

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

C402.5 Walk-in coolers and walk-in freezers. Walk-in coolers and walk-in freezers shall comply with all of the following:

1. Shall 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: Doors wider than 3 feet 9 inches (1143 mm) or taller than 7 feet (2134 mm).
2. Doorways shall have strip doors (curtains), spring-hinged doors, or other method of minimizing infiltration when doors are open.
3. *Walk-in coolers* shall contain wall, ceiling, and door insulation of at least R-25 and walk-in freezers at least R-32.

   Exception: Glazed portions of doors or structural members.
4. *Walk-in freezers* shall contain floor insulation of at least R-28.
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. Transparent reach-in doors for *walk-in coolers* and windows in *walk-in cooler* doors shall be double-pane glass with heat-reflective treated glass and gas filled; or triple-pane glass, either filled with inert gas or with heat-reflective treated glass.

Equation C402-5
Component Performance UxA

A + B + C + D + E ≤ Zero **(Equation 402-5)**

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.[a]

UA Proposed = Proposed *U*-value · Area.

UA Table = (*U*-factor from Table C402.1.2 or Table C402.3) · Area[a]

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 · Perimeter length.

FL Table = (*F*-factor specified in Table C402.1.2) · Perimeter length.

C = Sum of the (CA Dif) values for each distinct below-grade wall assembly type of the building thermal envelope.

CA Dif = CA Proposed – CA Table.

CA Proposed = Proposed *C*-value · Area.

CA Table = (Maximum allowable *C*-factor specified in Table C402.1.2) · Area.

If the proposed vertical glazing area is less than or equal to the maximum vertical glazing area allowed by Section

C402.3.1, the value of D (Excess Vertical Glazing Value) shall be zero. Otherwise:

D = (DA · UV) – (DA · U_{Wall}), but not less than zero.

DA = (Proposed Vertical Glazing Area) – (Vertical Glazing Area allowed by Section C402.3.1).

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

U_{Wall} = Area-weighted average *U*-value of all above-grade wall assemblies.

UAV = Sum of the (UA Proposed) values for each vertical glazing assembly.

UV = UAV/total vertical glazing area.

If the proposed skylight area is less than or equal to the skylight area allowed by Section C402.3.1, the value of E (Excess Skylight Value) shall be zero. Otherwise:

E = (EA · US) – (EA · U_{Roof}), but not less than zero.

EA = (Proposed Skylight Area) – (Allowable Skylight Area from Section C402.3.1).

U_{Roof} = Area-weighted average *U*-value of all roof assemblies.

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

US = UAS/total skylight area.

Footnote:

a. Fenestration *U*-factors in Table C402.3 may be modified by the exceptions to Sections C402.3, C402.3.1 and C402.3.1.1, and must use the factors in C402.3.3 where that section is utilized for compliance.

C402.6 Refrigerated warehouse coolers and refrigerated warehouse freezers. Refrigerated warehouse coolers and refrigerated warehouse freezers shall comply with all of the following:

1. Shall 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: Doors wider than 3 feet 9 inches (1143 mm) or taller than 7 feet (2134 mm).

2. Doorways shall have strip doors (curtains), spring-hinged doors, or other method of minimizing infiltration when doors are open.

3. *Refrigerated warehouse coolers* shall contain wall, ceiling, and door insulation of at least R-((~~25~~)) 38 and *refrigerated warehouse freezers* at least R-((~~32~~)) 38.

   Exception: Glazed portions of doors or structural members.

4. *Refrigerated warehouse freezers* shall contain floor insulation of at least R-((~~28~~)) 38.

5. Transparent reach-in doors for *refrigerated warehouse freezers* and windows in *refrigerated warehouse freezer* doors shall be of triple-pane glass, either filled with inert gas or with heat-reflective treated glass.

6. Transparent reach-in doors for *refrigerated warehouse coolers* and windows in *refrigerated warehouse cooler* doors shall be double-pane glass with heat-reflective treated glass and gas filled; or triple-pane glass, either filled with inert gas or with heat-reflective treated glass.

SECTION C403
MECHANICAL SYSTEMS

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

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

   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 C403.2.1 (1) through (9) inclusive, C403.2.4.5, C403.2.5.4, C403.2.8, C403.2.13, C403.4.6, C403.5, C403.6, C404.2, or Table C404.2. Data center HVAC equipment is not covered by this exception.

Walk-in coolers and walk-in freezers shall comply with Section C403.5. Refrigerated warehouse coolers and refrigerated warehouse freezers shall comply with Section C403.6.

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

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

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

Exceptions:

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.

3. The output capacity of heating and cooling equipment and systems may exceed the loads calculated in accordance with Section C403.2.1, provided that the smallest-capacity equipment available from a selected manufacturer that is capable of serving the heating and cooling loads is utilized and that the equipment capacity does not exceed 150 percent of the calculated loads.

C403.2.3 HVAC equipment performance requirements. Equipment shall meet the minimum efficiency requirements of Tables C403.2.3(1), C403.2.3(2), C403.2.3(3), C403.2.3(4), C403.2.3(5), C403.2.3(6), C403.2.3(7) and C403.2.3(8) when tested and rated in accordance with the applicable test procedure. Plate-type liquid-to-liquid heat exchangers shall meet the minimum requirements of Table C403.2.3(9). The efficiency shall be verified through certification 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. 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 greater than or equal to 225,000 Btu/h (65 kW) 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 greater than or equal to 225,000 Btu/h (65 kW), 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 (176 kw) total capacity shall not have more than 100 tons (35 kw) 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 85°F (29°C) entering condenser water temperature with 3 gpm/ton (0.054 l/s · kW) condenser water flow shall have maximum full-load kW/ton and *NPLV* ratings adjusted using Equations C4-3 and C4-4.

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

Adjusted minimum NPLV rating = (IPLV from Table 6.8.1C of AHRI Standard 550/590) × K_{adj} **(Equation C4-4)**

where:

K_{adj} = A × B

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

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

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

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

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

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

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

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

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

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

C403.2.3.3 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 20,000 Btu/h shall be a heat pump.

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

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 where WAC 246-320-525 allows only steam injection humidifiers in duct work downstream of final filters.
2. Systems with water economizer.
3. 100 percent outside air systems with no provisions for air recirculation to the central supply fan.
4. Nonadiabatic humidifiers cumulatively serving no more than 10 percent 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. Each heating and cooling system shall be provided with thermostatic controls as specified in Section C403.2.4.1, C403.2.4.2, C403.2.4.3, C403.2.4.4, C403.4.1, C403.4.2, C403.4.3, C403.4.4, C403.4.5, C403.4.6, C403.4.7, C403.4.8, C403.4.9, or C403.4.10.

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*. 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 or C403.4.1 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.

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

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

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 (4°C). 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 (4°C).

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

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

C403.2.4.3 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. 14 14 14 14

Exceptions:

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

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

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

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

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 6/1/2011	As of 6/1/2011	
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	13.0 SEER	
Through-the-wall (air cooled)	≤ 30,000 Btu/h[b]	All	Split system	12.0 SEER	12.0 SEER	
			Single Package	12.0 SEER	12.0 SEER	
Air conditioners, air cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.2 EER 11.4 IEER	11.2 EER 11.4 IEER	AHRI 340/360
		All other	Split System and Single Package	11.0 EER 11.2 IEER	11.0 EER 11.2 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	11.0 EER 11.2 IEER	
		All other	Split System and Single Package	10.8 EER 11.0 IEER	10.8 EER 11.0 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 10.1 IEER	10.0 EER 10.1 IEER	
		All other	Split System and Single Package	9.8 EER 9.9 IEER	9.8 EER 9.9 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 9.8 IEER	9.7 EER 9.8 IEER	
		All other	Split System and Single Package	9.5 EER 9.6 IEER	9.5 EER 9.6 IEER	
Air conditioners, water cooled	< 65,000 Btu/h[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	11.5 EER 11.7 IEER	12.1 EER 12.3 IEER	AHRI 340/360
		All other	Split System and Single Package	11.3 EER 11.5 IEER	11.9 EER 12.1 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	12.5 EER 12.7 IEER	
		All other	Split System and Single Package	10.8 EER 11.0 IEER	12.3 EER 12.5 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.1 IEER	12.4 EER 12.6 IEER	
		All other	Split System and Single Package	10.8 EER 10.9 IEER	12.2 EER 12.4 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.1 IEER	12.2 EER 12.4 IEER	
		All other	Split System and Single Package	10.8 EER 10.9 IEER	12.0 EER 12.2 IEER	

(continued)

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 6/1/2011	As of 6/1/2011	
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	11.5 EER 11.7 IEER	12.1 EER 12.3 IEER	AHRI 340/360
		All other	Split System and Single Package	11.3 EER 11.5 IEER	11.9 EER 12.1 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.2 IEER	12.0 EER 12.2 IEER	
		All other	Split System and Single Package	10.8 EER 11.0 IEER	11.8 EER 12.0 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.1 IEER	11.9 EER 12.1 IEER	
		All other	Split System and Single Package	10.8 EER 10.9 IEER	12.2 EER 11.9 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 11.1 IEER	11.7 EER 11.9 IEER	
		All other	Split System and Single Package	10.8 EER 10.9 IEER	11.5 EER 11.7 IEER	
Condensing units, air cooled	≥ 135,000 Btu/h			10.1 EER 11.4 IEER	10.5 EER 11.8 IEER	AHRI 365
Condensing units, water cooled	≥ 135,000 Btu/h			13.1 EER 13.6 IEER	13.5 EER 14.0 IEER	
Condensing units, evaporatively cooled	≥ 135,000 Btu/h			13.1 EER 13.6 IEER	13.5 EER 14.0 IEER	

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

a. Chapter 5 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

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

TABLE C403.2.3(1)B
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 (≥ 19kW 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	ANSI/ASHRAE 127
	≥ 65,000 Btu/h and < 240,000 Btu/h (≥19kW 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	ANSI/ASHRAE 127
	≥ 65,000 Btu/h and < 240,000 Btu/h (≥19kW 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	ANSI/ASHRAE 127
	≥ 65,000 Btu/h and < 240,000 Btu/h (≥19kW 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	ANSI/ASHRAE 127
	≥ 65,000 Btu/h and < 240,000 Btu/h (≥19kW 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(1)C
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED VARIABLE REFRIGERANT FLOW AIR CONDITIONERS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE
VRF Air Conditioners, Air Cooled	< 65,000 Btu/h	All	VRF Multi-split System	13.0 SEER	AHRI 1230
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	11.2 EER 13.1 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	11.0 EER 12.9 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	10.0 EER 11.6 IEER	

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

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

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE
VRF Air Cooled, (cooling mode)	< 65,000 Btu/h	All	VRF Multi-split System	13.0 SEER	AHRI 1230
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	11.0 EER 12.9 IEER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System with Heat Recovery	10.8 EER 12.7 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	10.6 EER 12.3 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System with Heat Recovery	10.4 EER 12.1 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	9.5 EER 11.0 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System with Heat Recovery	9.3 EER 10.8 IEER	
VRF Water source (cooling mode)	< 65,000 Btu/h	All	VRF Multi-split systems 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	

(continued)

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

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE
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	
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	

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

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]
Air cooled (cooling mode)	< 65,000 Btu/h[b]	All	Split System	13.0 SEER	AHRI 210/240
			Single Package	13.0 SEER	
Through-the-wall, air cooled (cooling mode)	≤ 30,000 Btu/h[b]	All	Split System	12.0 SEER	
			Single Package	12.0 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	AHRI 340/360
		All other	Split System and Single Package	10.8 EER 11.0 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.6 EER 10.7 IEER	
		All other	Split System and Single Package	10.4 EER 10.5 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 9.6 IEER	
		All other	Split System and Single Package	9.3 EER 9.4 IEER	
Water source (cooling mode)	< 17,000 Btu/h	All	86°F entering water	11.2 EER	ISO 13256-1
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	12.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	12.0 EER	
Ground water source (cooling mode)	< 135,000 Btu/h	All	59°F entering water	16.2 EER	
Ground water source (cooling mode)	< 135,000 Btu/h	All	77°F entering water	13.4 EER	
Water-source water to water (cooling mode)	< 135,000 Btu/h	All	86°F entering water	10.6 EER	ISO 13256-2
			59°F entering water	16.3 EER	
Ground water source Brine to water (cooling mode)	< 135,000 Btu/h	All	77°F entering fluid	12.1 EER	
Air cooled (heating mode)	< 65,000 Btu/h[b]	—	Split System	7.7 HSPF	AHRI 210/240
		—	Single Package	7.7 HSPF	
Through-the-wall, (air cooled, heating mode)	≤ 30,000 Btu/h[b] (cooling capacity)	—	Split System	7.4 HSPF	
		—	Single Package	7.4 HSPF	
Small-duct high velocity (air cooled, heating mode)	< 65,000 Btu/h[b]	—	Split System	6.8 HSPF	

(continued)

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

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

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

a. Chapter 5 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

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

TABLE C403.2.3(3)
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED PACKAGED TERMINAL AIR CONDITIONERS,
PACKAGED TERMINAL HEAT PUMPS, SINGLE-PACKAGE VERTICAL AIR CONDITIONERS,
SINGLE-PACKAGE 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]
			Before 10/08/2012	As of 10/08/2012	
PTAC (cooling mode) new construction	All Capacities	95°F db outdoor air	12.5 - (0.213 × Cap/1000) EER	13.8 - (0.300 × Cap/1000) EER	AHRI 310/380
PTAC (cooling mode) replacements[b]	All Capacities	95°F db outdoor air	10.9 - (0.213 × Cap/1000) EER	10.9 - (0.213 × Cap/1000) EER	
PTHP (cooling mode) new construction	All Capacities	95°F db outdoor air	12.3 - (0.213 × Cap/1000) EER	14.0 - (0.300 × Cap/1000) EER	
PTHP (cooling mode) replacements[b]	All Capacities	95°F db outdoor air	10.8 - (0.213 × Cap/1000) EER	10.8 - (0.213 × Cap/1000) EER	
PTHP (heating mode) new construction	All Capacities	—	3.2 - (0.026 × Cap/1000) COP	3.7 - (0.052 × Cap/1000) COP	
PTHP (heating mode) replacements[b]	All Capacities	—	2.9 - (0.026 × Cap/1000) COP	2.9 - (0.026 × Cap/1000) COP	
SPVAC (cooling mode)	< 65,000 Btu/h	95°F db/ 75°F wb outdoor air	9.0 EER	9.0 EER	AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h	95°F db/ 75°F wb outdoor air	8.9 EER	8.9 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95°F db/ 75°F wb outdoor air	8.6 EER	8.6 EER	
SPVHP (cooling mode)	< 65,000 Btu/h	95°F db/ 75°F wb outdoor air	9.0 EER	9.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	95°F db/ 75°F wb outdoor air	8.9 EER	8.9 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95°F db/ 75°F wb outdoor air	8.6 EER	8.6 EER	
SPVHP (heating mode)	<65,000 Btu/h	47°F db/ 43°F wb outdoor air	3.0 COP	3.0 COP	AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h	47°F db/ 43°F wb outdoor air	3.0 COP	3.0 COP	
	≥ 135,000 Btu/h and < 240,000 Btu/h	47°F db/ 43°F wb outdoor air	2.9 COP	2.9 COP	

(continued)

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

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

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

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

a. Chapter 5 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

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

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

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY[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 5 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	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.

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

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

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

c. Includes oil-fired (residual).

TABLE C403.2.3(6)
RESERVED

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

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

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

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

a. The centrifugal chiller equipment requirements, after adjustment in accordance with Section C403.2.3.1 or Section C403.2.3.2, do not apply to chillers used in low-temperature applications where the design leaving fluid temperature is less than 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.

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 5 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	PERFORMANCE REQUIRED[b, c, d]	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 closed circuit cooling towers	All	102°F Entering Water 90°F Leaving Water 75°F Entering wb	≥ 7.0 gpm/hp	CTI ATC-105S and CTI STD-201
Air-cooled condensers	All	125°F Condensing Temperature R-22 Test Fluid 190°F Entering Gas Temperature 15°F Subcooling 95°F Entering db	≥ 176,000 Btu/h·hp	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 5 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

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

TABLE C403.2.3(9)
HEAT TRANSFER EQUIPMENT

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

NR = No Requirement

a. Chapter 5 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

C403.2.4.4 Shutoff damper controls. ((~~Both o~~)) Outdoor air supply, relief and exhaust ducts shall be equipped with motorized dampers complying with Section C402.4.5.2 that will automatically shut when the systems or spaces served are not in use or during building warm-up, cooldown, and setback.

Exceptions:

1. Gravity relief dampers complying with exception 1 to Section C402.4.5.2 serving systems with a design outdoor air intake, relief or exhaust capacity of less than ((~~5,000~~)) 300 cfm (((~~2360~~)) 141 L/s) total supply shall be permitted ((~~in buildings less than three stories in height~~)).
2. Gravity dampers shall be permitted for buildings of any height located in Climate Zones 1, 2 and 3.
3. Gravity (nonmotorized) dampers in Group R occupancies where the design outdoor air intake or exhaust capacity does not exceed ((~~400~~)) 300 cfm (((~~189~~)) 141 L/s).

4. Systems serving areas which require continuous operation.
5. Combustion air intakes.
6. Operation of dampers shall be allowed during ventilation prepurge one hour before expected occupancy and for unoccupied period precooling during the cooling season.
7. Dampers are not required in systems where specifically prohibited by the *International Mechanical Code*.

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

C403.2.4.6 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.

C403.2.4.7 Group R-1 hotel/motel guestrooms. For hotel and motel guestrooms, a minimum of one of the following control technologies shall be required in hotels/motels with over 50 guestrooms such that the space temperature would automatically setback (winter) or set up (summer) by no less than 5°F (3°C) ((~~or hotel and motel guestrooms, a minimum of~~)) 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.

C403.2.4.8 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 capable of shutting 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 capable of operating 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: When used to control heating only: 55°F to 75°F (13°C to 24°C); when used to control cooling only: 70°F to 85°F (21°C to 29°C); all other: 55°F to 85°F (13°C to 29°C) with an adjustable deadband of not less than10°F (5°C).

C403.2.4.9 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 capable of shutting 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 capable of operating 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: When used to control heating only: 55°F to 75°F (13°C to 24°C); when used to control cooling only: 70°F to 85°F (21°C to 29°C); all other: 55°F to 85°F (13°C to 29°C) with an adjustable deadband of not less than 10°F (5°C).

C403.2.4.10 Direct digital control system capabilities. All complex systems equipped with direct digital control (DDC) systems and all buildings with total cooling capacity exceeding 780,000 Btu/h (2,662 kW) shall have the following capability:

1. Trending: All control system input and output points shall be accessible and programmed for trending, and a graphic trending package shall be provided with the control system.
2. Demand Response Setpoint Adjustment: Control logic shall increase the cooling zone set points by at least 2°F (1°C) and reduce the heating zone set points by at least 2°F (1°C) when activated by a demand response signal. The demand response signal shall be a binary input to the control system or other interface approved by the serving electric utility.

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

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

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

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

1. Systems with energy recovery complying with Section C403.2.6.
2. Multiple-*zone* systems without direct digital control of individual *zones* communicating with a central control panel.
3. System with a design outdoor airflow less than 1,000 cfm (472 L/s).
4. Spaces where the supply airflow rate minus any makeup or outgoing transfer air requirement is less than 1,200 cfm (600 L/s).
5. Ventilation provided for process loads only.

C403.2.5.2 Occupancy sensors. Classrooms, gyms, auditoriums and conference rooms larger than 500 square feet (50 m^2) 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.

C403.2.5.3 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 upon detection of vehicle operation or the presence of occupants by approved automatic detection devices. Each of the following types of controllers shall be capable of shutting off fans or modulating fan speed. Control devices shall not reduce airflow rates below the minimum requirement in accordance with the *International Mechanical Code* during scheduled periods of occupied operation.

1. 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. 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.
2. Occupant detection sensors used to activate the system shall detect entry ((~~into the parking garage~~)) along both the vehicle and pedestrian pathways.

C403.2.5.3.1 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 404.2 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.

C403.2.5.3.2 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 (3775 L/s) may use occupant sensors to activate the full required ventilation rate.

C403.2.5.4 Exhaust systems.

C403.2.5.4.1 Kitchen hoods. Each kitchen area with total exhaust capacity larger than 2,000 cfm (944 L/s) shall be provided with makeup air sized so that at least 50 percent of exhaust air volume be (a) unheated or heated to no more than 60°F (16°C) and

(b) uncooled or cooled without the use of mechanical cooling.

Exceptions:

1. Where hoods are used to exhaust ventilation air which would otherwise exfiltrate or be exhausted by other fan systems. A detailed accounting of exhaust airflows that accounts for the impact of any required demand controlled ventilation shall be provided on the plans.
2. Certified grease extractor hoods that require a face velocity no greater than 60 fpm (18.3 m/s).

C403.2.5.4.2 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 precondition((~~ed~~)) 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) in Climate Zones 4C/5B and 35°F (19.4°C) in Climate Zone 6B. A provision shall be made to bypass or control the heat recovery system to permit air economizer operation as required by Section C403.4.

Exceptions:

1. Variable air volume laboratory exhaust and room supply systems capable of reducing exhaust and makeup air volume to 50 percent or less of design values; or
2. Direct makeup (auxiliary) air supply equal to at least 75 percent of the exhaust rate, heated no warmer than 2°F (1.1°C) below room 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 capable of reducing 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 percent 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:

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

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

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

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.

C403.2.6 Energy recovery.

C403.2.6.1 Energy recovery ventilation systems. Any system with minimum outside air requirements at design conditions greater than 5,000 cfm (2360 L/s) or any system required by Table C403.2.6 shall include an energy recovery system. The energy recovery system shall have the capability to provide a change in the enthalpy of the outdoor air supply of not less than 50 percent of the difference between the outdoor air and return air enthalpies, at design conditions. Where an air economizer is required, the energy recovery system shall include a bypass or controls which permit operation of the economizer as required by Section C403.4. 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. <u>The return/exhaust air stream temperature for heat recovery device selection shall be 70°F (21°C).</u>

<u>**Informative Note:** In Seattle, the outdoor design air temperature is 24°F as specified in Appendix C. The difference between 24°F and 65°F is 41 degrees. One-half of 41 degrees is 20.5 degrees. Therefore, to provide 50 percent heat recovery effectiveness in Seattle, the heat recovery system shall raise the outside supply air temperature to a minimum of 44.5°F (24°F + 20.5°F) at the outdoor design conditions.</u>

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

1. Where energy recovery systems are prohibited by the *International Mechanical Code*.
2. Laboratory fume hood systems that include at least one of the following features, <u>and also comply with Section 403.2.5.4.2:</u>

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

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

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

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

5. Heating energy recovery in Climate Zones 1 and 2.

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

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

8. Multi-zone systems with cold deck supply air and zone reheat where the minimum outdoor air is less than 70 percent of total supply air.

9. Systems serving residential multifamily spaces 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.

10. Type I kitchen exhaust hoods.

C403.2.6.2 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.

C403.2.6.3 Condenser heat recovery. Facilities having food service, meat or deli departments and having 500,000 Btu/h (146 kw) 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 square feet (3716 m^2) or greater and 1,000,000 Btu/h (293 kw) 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.

C403.2.7 Duct and plenum insulation and sealing.

C403.2.7.1 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

TABLE C403.2.6
ENERGY RECOVERY REQUIREMENT

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

NR = not required

Informative Note: For Climate Zone 4C (Seattle), Table C403.2.6 requires energy recovery for HVAC systems that have a design supply fan airflow rate greater than 5000 cfm (2360 L/s) and have a minimum requirement for 70 percent or more outside air. Thus a system with a 5000 cfm (2360 L/s) fan and an 80 percent outside air requirement for ventilation, providing just 4000 cfm (1888 L/s) of outside air, would require energy recovery.

In addition, the first sentence of Section C403.2.6.1 states that any system requiring more than 5000 cfm (2360 L/s) of outside air, no matter what percentage of the total supply air that represents, also requires energy recovery. Thus a 12,000 cfm (5663 L/s) fan with a 50 percent outside air requirement would require energy recovery.

damper or heating or cooling equipment. For the purposes of building envelope insulation requirements, such duct surfaces shall meet the requirements for metal framed walls per Table C402.1.2. Duct surfaces included as part of the building envelope shall not be used in the calculation of maximum glazing area as described in Section C402.3.1.

Exceptions:

1. Outside air ducts serving individual supply air units with less than 2,800 cfm (1321 L/s) 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.

C403.2.7.2 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 a minimum of R-8 insulation where located outside the building. Where located within a building envelope assembly, the duct or plenum shall be separated from the building exterior or unconditioned or exempt spaces by a minimum insulation value as required for exterior walls by Section C402.2.3.

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).

Supply ducts which convey supply air at temperatures less than 55°F (12.8°C) or greater than 105°F (40°C) shall be insulated with a minimum of R-3.3 insulation where located within conditioned space.

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

C403.2.7.3 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.

C403.2.7.3.1 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.

C403.2.7.3.2 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 C403.2.7. Pressure classifications specific to the duct system shall be clearly indicated on the construction documents in accordance with the *International Mechanical Code*.

C403.2.7.3.3 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 ductwork located outside the building envelope shall be insulated and sealed in accordance with Section C403.2.7. In addition, ducts and plenums shall be leak-tested in accordance with the SMACNA *HVAC Air Duct Leakage Test Manual* with the rate of air leakage (*CL*) less than or equal to 6.0 as determined in accordance with Equation C4-5.

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

where:

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

P = The static pressure of the test.

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

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

Exceptions:

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

5. Strainers, control valves, and balancing valves associated with piping 1 inch (25 mm) or less in diameter.
6. Direct buried piping that conveys fluids at or below 60°F (15°C).

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

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

C403.2.10 Air system design and control. Each HVAC system having a total fan system motor nameplate horsepower (hp) exceeding 5 horsepower (hp) (3.7 kW) shall meet the provisions of Sections C403.2.10.1 through C403.2.10.((~~2~~))5. All motors less than 1 horsepower shall meet the provisions of Sections C403.2.10.3.

C403.2.10.1 Allowable fan motor horsepower. Each HVAC system at fan system design conditions shall not exceed the allowable *fan system motor nameplate hp* (Option 1) or *fan system bhp* (Option 2) as shown in Table C403.2.10.1(1). This includes supply fans, return/relief fans, exhaust 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. 14 14

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

1. Hospital, vivarium and laboratory systems that utilize flow control devices on exhaust and/or return to maintain space pressure relationships

TABLE C403.2.8
MINIMUM PIPE INSULATION THICKNESS (thickness in inches)[a, c]

FLUID OPERATING TEMPERATURE RANGE AND USAGE (°F)	INSULATION CONDUCTIVITY		NOMINAL PIPE OR TUBE SIZE (inches)				
	Conductivity Btu · in./(h · ft² · °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	75	0.5	1.0	1.0	1.0	1.5

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

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

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

where:

T = minimum insulation thickness,
r = actual outside radius of pipe,
t = insulation thickness listed in the table for applicable fluid temperature and pipe size,
K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (Btu × in/h × ft² × °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)].

TABLE C403.2.10.1(1)
FAN POWER LIMITATION

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

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

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 $[PD \times CFM_D / 4131]$

For SI: 1 cfm = 0.471 L/s.

where:

PD = Each applicable pressure drop adjustment from Table C403.2.10.1(2) in. w.c.
CFM_D = The design airflow through each applicable device from Table C403.2.10.1(2) in cubic feet per minute.

TABLE C403.2.10.1(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 air flow control devices	0.5 inch w.c.
Exhaust filters, scrubbers, or other exhaust treatment	The pressure drop of device calculated at fan system design condition
Particulate filtration credit: MERV 9 thru 12	0.5 inch w.c.
Particulate filtration credit: MERV 13 thru 15	0.9 inch. w.c.
Particulate filtration credit: MERV 16 and greater and electronically enhanced filters	Pressure drop calculated at 2x clean filter pressure drop at fan system design condition
Carbon and other gas-phase air cleaners	Clean filter pressure drop at fan system design condition
Biosafety cabinet	Pressure drop of device at fan system design condition
Energy recovery device, other than coil runaround loop	(2.2 × energy recovery effectiveness) – 0.5 inch w.c. for each airstream
Coil runaround loop	0.6 inch w.c. for each airstream
Evaporative humidifier/cooler in series with another cooling coil	Pressure drop of device at fan system design conditions
Sound attenuation section	0.15 inch w.c.
Exhaust system serving fume hoods	0.35 inch w.c.
Laboratory and vivarium exhaust systems in high-rise buildings	0.25 inch w.c./100 feet of vertical duct exceeding 75 feet

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

necessary for occupant health and safety or environmental control shall be permitted to use variable volume fan power limitation.

2. Individual exhaust fans with motor nameplate horsepower of 1 hp or less.

C403.2.10.2 Motor nameplate horsepower. For each fan, the selected fan motor shall be no larger than the first available motor size greater than the brake horsepower (bhp). The fan brake horsepower (bhp) shall be indicated on the design documents to allow for compliance verification by the *code official*.

Exceptions:

1. For fans less than 6 bhp (4413 W), where the first available motor larger than the brake horsepower has a nameplate rating within 50 percent of the bhp, selection of the next larger nameplate motor size is allowed.
2. For fans 6 bhp (4413 W) and larger, where the first available motor larger than the bhp has a nameplate rating within 30 percent of the bhp, selection of the next larger nameplate motor size is allowed.
3. For fans used only in *approved* life safety applications such as smoke evacuation.

C403.2.10.3 Fractional hp fan motors. Motors for fans that are $^{1}/_{12}$ hp or greater and less than 1 hp shall be electronically commutated motors or shall have a minimum motor efficiency of 70 percent when rated in accordance with DOE 10 C.F.R. 431. These motors shall also have the means to adjust motor speed for either balancing or remote control. Belt-driven fans may use sheave adjustments for airflow balancing in lieu of a varying motor speed.

Exceptions:

1. Motors in the airstream within fan-coils and terminal units that operate only when providing heating to the space served.
2. Motors installed in space conditioning equipment certified under Section C403.2.3.

C403.2.10.4 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.

C403.2.10.5 Multiple-zone VAV system outdoor airflow control. Multiple-zone VAV systems with a minimum outside air requirement of 5,000 cfm (2360 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 zonal systems as required by Sections C403.2.10.4 and C403.2.5.1.

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 C403.2.5.1.
   1.2. The system meets one of the exceptions to Section C403.2.10.4.
   1.3. The system complies with Section 403.6 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.

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

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

C403.2.12 System criteria. For fan and pump motors ((~~7.5~~)) 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 one-third of 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.).

See *Seattle Building Code*, Section 3016.15 for energy efficiency requirements for ventilation fan systems in elevators.

C403.2.12.1 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.

Hydronic heat pump and other cooling and refrigeration equipment, including but not limited to icemakers and walk-in coolers, shall not use domestic water only one time before dumping it to waste (no single pass water cooling systems are allowed).

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.

C403.2.12.1.1 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.

C403.2.12.1.2 Limitation on centrifugal fan cooling towers. Open cooling towers with a combined rated capacity of 1,100 gpm (69 L/s) and greater at 95°F (35°C) condenser water return, 85°F (29°C) condenser water supply and 75°F (24°C) 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.

C403.2.12.2 Large volume fan systems. Single or multiple fan systems serving a *zone* or adjacent *zones* without separating walls with total air flow over 10,000 cfm (4710 L/s) are required to reduce airflow based on space thermostat heating and cooling demand. A variable speed drive shall reduce airflow to a maximum 75 percent of peak airflow or minimum ventilation air requirement as required by Section 403 of the *International Mechanical Code*, whichever is greater.

Exceptions:

1. Systems where the function of the supply air is for purposes other than temperature control, such as maintaining specific humidity levels or supplying an exhaust system.
2. Dedicated outdoor air supply unit(s) with heat recovery where airflow is equal to the minimum ventilation requirements and other fans cycle off unless heating or cooling is required.
3. An area served by multiple units where designated ventilation units have 50 percent or less of total area airflow and nonventilation unit fans cycle off when heating or cooling is not required.

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

1. Two-thirds of the full fan speed; or
2. The volume of outdoor air required to meet the ventilation requirements of Section 403 of the *International Mechanical Code*.

C403.2.13 Electric motor efficiency. Design A and B squirrel-cage, T-frame induction permanently wired polyphase motors of 1 hp or more having synchronous speeds of 3,600, 1,800 and 1,200 rpm shall have a nominal full-load motor efficiency no less than the corresponding values for energy efficient motors provided in NEMA Standard MG-1.

Exceptions:

1. Motors used in systems designed to use more than one speed of a multi-speed motor.
2. Motors used as a component of the equipment meeting the minimum equipment efficiency requirements of Section C403.2.3 and Tables C403.2.3(1) through C403.2.3(9) provided that the motor input is included when determining the equipment efficiency.
3. Motors that are an integral part of specialized process equipment.
4. Where the motor is integral to a listed piece of equipment for which no complying motor has been approved.

Fan motors less than 1 hp in series terminal units and in fan-coil units shall be electronically commutated motors, or shall have a minimum motor efficiency of ((~~65~~)) 70 percent when rated in accordance with NEMA Standard MG-1 at full load rating conditions.

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

To qualify as a simple system, systems shall have no active humidification or simultaneous heating and cooling and shall be one of the following:

1. Air cooled, constant volume packaged equipment, which provide heating, cooling or both, and require only external connection to duct work and energy services with cooling capacity of 135,000 Btu/h (39 568 W) or less.
2. Air cooled, constant volume split systems, which provide heating, cooling or both, with cooling capacity of 84,000 Btu/h (24 620 W) or less.
3. Heating only systems which have a capacity of less than 1,000 cfm (471 L/s) or which have a minimum outside air supply of less than 30 percent of the total air circulation.

The combined airflow rate of all simple systems serving single rooms must be less than 10,000 cfm (4710 L/s) or they do not qualify as simple systems.

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

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

1. Qualifying small equipment: This exception shall not be used for unitary cooling equipment installed outdoors or in a mechanical room adjacent to the outdoors. This exception is allowed to be used for other cooling units and split systems with a total cooling capacity rated in accordance with Section C403.2.3 of less than 33,000 Btu/h (9672 W) (hereafter referred to as qualifying small systems) provided that these are high-efficiency cooling equipment with 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. Equipment shall be listed in the appropriate certification program to qualify for this exception. The total capacity of

all qualifying small equipment without economizers shall not exceed 72,000 Btu/h (21 103 W) per building, or 5 percent of its air economizer capacity, whichever is greater. That portion of the equipment serving residential occupancies is not included in determining the total capacity of all units without economizers in a building. Redundant units are not counted in the capacity limitations. This exception shall not be used for the shell-and-core permit or for the initial tenant improvement or for Total Building Performance.

2. Systems with dehumidification that affect other systems so as to increase the overall building energy consumption. New humidification equipment shall comply with Section C403.2.3.4.
3. For residential occupancies, cooling units installed outdoors or in a mechanical room adjacent to outdoors with a total cooling capacity less than 20,000 Btu/h (5862 W) and other cooling units with a total cooling capacity less than 54,000 Btu/h (15 827 W) provided that these are high-efficiency cooling equipment with IEER, SEER, and EER values more than 15 percent higher than minimum efficiencies listed in Tables C403.2.3(1) through (10), 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.
4. Where the cooling efficiency meets or exceeds the efficiency requirements in Table C403.3.1(2).
5. Equipment used to cool any dedicated server room, electronic equipment room or telecom switch room provided the system complies with Exception 5 of Section C403.4.1. The total allowance for equipment utilizing Exception 5 of Section C403.4.1 includes the sum of both simple and complex systems.

TABLE C403.3.1(1)
RESERVED

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

CLIMATE ZONES	COOLING EQUIPMENT PERFORMANCE IMPROVEMENT (EER OR IPLV)
2B	10% Efficiency Improvement
3B	15% Efficiency Improvement
4B	20% Efficiency Improvement
4C	64% Efficiency Improvement

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

C403.3.1.1.1 Design capacity. Air economizer systems shall be capable of modulating *outdoor air* and return air dampers to provide up to 100 percent of the design supply air quantity as *outdoor air* for cooling.

C403.3.1.1.2 Control signal. Economizer dampers shall be capable of being sequenced with the mechanical cooling equipment and shall not be controlled by only mixed air temperature. Air economizers on systems with cooling capacity greater than 65,000 Btu/h (19 051 W) shall be capable of providing 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 (19 051 W).

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

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

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

C403.3.3 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 (32 kW) 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*.

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

For buildings with a total equipment cooling capacity of 300 tons (105 kw) and above, the equipment shall comply with one of the following:

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

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

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

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

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

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

For SI: °C = (°F - 32) × $^5/_9$, 1 Btu/lb = 2.33 kJ/kg.

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

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

C403.4.1 Economizers. 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 C403.4.1.1 through C403.4.1.4.

Exceptions:

1. 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 Sections C403.4.1 through C403.4.1.4. Water economizer capacity per building shall not exceed 500 tons (176 kw). This exception shall not be used for Total Building Performance.
2. Systems complying with all of the following criteria:
   2.1. Consist of multiple water source heat pumps connected to a common water loop;
   2.2. Have a minimum of 60 percent air economizer;
   2.3. Have water source heat pumps with an EER at least 15 percent higher for cooling and a COP at least 15 percent higher for heating than that specified in Section C403.2.3;
   2.4. 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 (58 327 W); and
   2.5. Provide heat recovery with a minimum 50 percent heat recovery effectiveness as defined in Section C403.2.6 to preheat the outside air supply.
3. Chilled water terminal units connected to systems with chilled water generation equipment with IPLV values more than 25 percent higher than 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 for this exception. The total capacity of all systems without economizers shall not exceed ((~~480,000~~)) 72,000 Btu/h (141 kw) per building, or ((~~20~~)) 5 percent of its air economizer capacity, whichever is greater. That portion of the equipment serving Group R Occupancy is not included in determining the total capacity of all units without economizers in a building. This exception shall not be used for the initial permit (this includes any initial permit for the space including, but not limited to, the shell-and-core permit, built-to-suit permit, and tenant improvement permit) or for Total Building Performance Method.
4. 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 (5862 W) and other cooling units with a total cooling capacity less than 54,000 Btu/h (15 827 W) provided that these are high-efficiency cooling equipment with 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 (2433 W) are permitted for the purposes of this exception if they have EER values a minimum of 4 percent higher than 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 and VRF systems, compliance is based on the cooling capacity of individual fan coil units.
5. Equipment used to cool any dedicated server room, electronic equipment room or telecom switch room provided that they completely comply with Option a, b, ((~~or~~)) c, d or e in the table below. The total capacity of all qualifying systems without economizers shall not exceed 240,000 Btu/h (70 344 W) per building or 10 percent of its air economizer capacity, whichever is greater. This exception shall not be used for Total Building Performance.
6. 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 common 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 indoor units operating in the other mode, and shall serve at least 20 percent internal [no perimeter wall within 12 feet (3658 mm)] and 20 percent perimeter zones (as determined by conditioned floor area) and the outdoor unit shall be at least 65,000 Btu/h (19 051 W) in total capacity. Systems utilizing this exception shall have 50 percent heat recovery effectiveness as defined by Section C403.2.6 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. This exception shall be limited to buildings of 60,000 square feet (5574 m^2) and less.
7. Medical and laboratory equipment that is directly water-cooled and is not dependent upon space air temperature.

C403.4.1 EXCEPTION 5 TABLE

	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]	+ 0%[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

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

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 (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) [1.15 × values 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) [1.05 × values 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 C403.4.1.2 through C403.4.1.4 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.

g. The cooling equipment subject to the ASHRAE Standard 127 shall have a((~~n EER value and an IPLV~~)) SCOP 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).

i. The cooling equipment shall have a 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)).

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

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

C403.4.1.2 Maximum pressure drop. Precooling coils and water-to-water heat exchangers used as part of a water economizer system shall either have a waterside 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.

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

Exceptions:

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

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

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

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

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

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

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

C403.4.3 Hydronic systems controls. The heating of fluids that have been previously mechanically cooled and the cooling of fluids that have been previously mechanically heated shall be limited in accordance with Sections C403.4.3.1 through C403.4.3.3. Hydronic heating systems comprised of multiple-packaged boilers and designed to deliver conditioned water or steam into a common distribution system shall include automatic controls capable of sequencing operation of the boilers. Hydronic heating systems comprised of a single boiler and greater than 500,000 Btu/h (146,550 W) input design capacity shall include either a multistaged or modulating burner.

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

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

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

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

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

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

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

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

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

C403.4.3.3.2.2 Climate Zones 5 through 8. For Climate Zones 5 through 8, if an open- or closed-circuit cooling tower is used, then a separate heat exchanger shall be provided to isolate the cooling tower from the heat pump loop, and heat loss shall be controlled by shutting down the circulation pump on the cooling tower loop and providing an automatic valve to stop the flow of fluid.

C403.4.3.3.3 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 C403.4.3.6.

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

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

Hydronic systems serving hydronic heat pumps are exempt from Item 1, and only those hydronic systems with a total pump system power greater than 3 hp (2.2 kW) shall have controls meeting the requirements of Item 2, above.

C403.4.3.5 Pump isolation. Chilled water plants including more than one chiller shall have the capability to reduce flow automatically through the chiller plant when a chiller is shut down 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 have the capability to reduce flow automatically through the boiler plant when a boiler is shut down and automatically shut off flow to ((~~chillers~~)) boilers that are shut down.

C403.4.3.6 Variable flow controls. Individual pumps requiring variable speed control per Section C403.2.12 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.

C403.4.4 Heat rejection equipment fan speed control. 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.

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

1. Thirty percent of the maximum supply air to each *zone*.
2. Three hundred cfm (142 L/s) or less where the maximum flow rate is less than 10 percent of the total fan system supply airflow rate.
3. The minimum ventilation requirements of Chapter 4 of the *International Mechanical Code.*
4. Minimum flow rates required by applicable codes or standards for occupant health and safety.

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

1. Reserved.
2. *Zones* or supply air systems where at least 75 percent of the energy for reheating or for providing warm air in mixing systems is provided from a site-recovered or site-solar energy source.
3. *Zones* where special humidity levels are required to satisfy process needs.
4. *Zones* with a peak supply air quantity of 300 cfm (142 L/s) or less and where the flow rate is less than 10 percent of the total fan system supply airflow rate.
5. *Zones* where the volume of air to be reheated, recooled or mixed is no greater than the volume of outside air required to meet the minimum ventilation requirements of Chapter 4 of the *International Mechanical Code*.
6. *Zones* or supply air systems with thermostatic and humidistatic controls capable of operating in

sequence the supply of heating and cooling energy to the *zones* and which are capable of preventing reheating, recooling, mixing or simultaneous supply of air that has been previously cooled, either mechanically or through the use of economizer systems, and air that has been previously mechanically heated.

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

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

C403.4.5.3 Reserved.

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

Exceptions:

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

C403.4.6 Heat recovery for service water heating. Condenser heat recovery shall be installed for heating or reheating of service hot water provided the facility operates 24 hours a day, the total installed heat capacity of water-cooled systems exceeds 1,500,000 Btu/hr (440 kw) of heat rejection, and the design service water heating load exceeds 250,000 Btu/hr (73 275 W).

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

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

Exceptions:

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

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

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

TABLE C403.4.7
MAXIMUM HOT GAS BYPASS CAPACITY

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

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

C403.4.8 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 C403.4.8 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 C403.4.8 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.

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

C403.5 Walk-in coolers and walk-in freezers. Walk-in coolers and walk-in freezers shall comply with all of the following:

1. Anti-sweat heaters without anti-sweat heater controls shall have a total door rail, glass, and frame heater power draw of less than or equal to 7.1 watts per square foot of door opening for *walk-in freezers*, and 3.0 watts per square foot of door opening for *walk-in coolers*.
2. Anti-sweat heater controls shall reduce the energy use of the anti-sweat heater as a function of the relative humidity in the air outside the door or to the condensation on the inner glass pane.
3. Evaporator fan motors that are less than 1 horsepower and less than 460 volts shall use electronically commutated motors (brushless direct current motors) or 3-phase motors.

4. Condenser fan motors that are less than 1 horsepower shall use electronically commutated motors, permanent split capacitor-type motors or 3-phase motors.

C403.6 Refrigerated warehouse coolers and refrigerated warehouse freezers. Refrigerated warehouse coolers and refrigerated warehouse freezers shall comply with all of the following:

1. Evaporator fan motors that are less than 1 horsepower and less than 460 volts shall use electronically commutated motors (brushless direct current motors) or 3-phase motors.
2. Condenser fan motors that are less than 1 horsepower shall use electronically commutated motors, permanent split capacitor-type motors or 3-phase motors.
3. Evaporator fans 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.
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 (21°C) 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.

C403.7 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:

   1.1. All water drains shall be "no loss" drains.

   1.2. 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:

   2.1. Receiver capacity greater than three gallons per cfm to allow efficient load/unload control;

   2.2. Variable speed drive controlled air compressor; or

   2.3. 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 3-gallon receiver capacity per cfm for the trim air compressor.

C403.8 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.

TABLE C403.4.8
PIPING SYSTEM DESIGN MAXIMUM FLOW RATE IN GPM[1]

	≤ = 2,000 hours/yr		> 2,000 and ≤ 4,400 hours/year		> 4,400 hours/year	
Pipe Size (in)	Other	Variable Flow/ Variable Speed	Other	Variable Flow/ Variable Speed	Other	Variable Flow/ Variable Speed
2 1/2	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	1,100	570	860	440	680
8	1,200	1,800	900	1,400	700	1,100
10	1,800	2,700	1,300	2,000	1,000	1,600
12	2,500	3,800	1,900	2,900	1,500	2,300

For SI: 1 inch = 25.4 mm.

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.

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.

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

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

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

Exceptions:

1. Heat-traced piping systems shall meet the insulation thickness requirements per the manufacturer's installation instructions. Untraced piping within a heat traced system shall be insulated with not less than 1 inch (25 mm) of insulation having a conductivity not exceeding 0.27 Btu per inch/h × ft^2 × °F (1.53 W per 25 mm/m^2 × K).
2. Hot water piping that is part of the final pipe run to the plumbing fixture and is not part of the automatic-circulating hot water recirculation path is not required to meet the minimum insulation requirements of C404.6.

C404.7 Reserved. ((~~**Hot water system controls.** Circulating hot water system pumps or heat trace shall be arranged to be turned off either automatically or manually when there is limited hot water demand. Ready access shall be provided to the operating controls.~~))

C404.8 Shutoff controls. Systems designed to maintain usage temperatures in hot water pipes, such as circulating hot water systems or heat traced pipes, shall be equipped with automatic time switches or other controls to turn off the system during periods of nonuse.

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 Pools and inground permanently installed spas (Mandatory). Pools and inground permanently installed spas shall comply with Sections C404.10.1 through C404.10.4.

C404.10.1 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~~)) AHRI Standard 1160, Performance Rating of Heat Pump Pool Heaters. Other pool heating equipment shall comply with the applicable efficiencies in Section C404.2.3.

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

C404.10.2 Time switches. Time switches or other control method that can automatically turn off and on heaters and pumps according to a preset schedule shall be installed on all heaters and pumps. Heaters, pumps and motors that have built in timers shall be deemed in compliance with this requirement.

Exceptions:

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

C404.10.3 Covers. Heated pools and in-ground permanently installed spas shall be provided with a vapor-retardant cover on or at the water surface. Pools heated to more than 90°F (32°C) shall have a pool cover with a minimum insulation value of R-12, and the sides and bottom of the pool shall also have a minimum insulation value of R-12.

C404.10.4 Heat recovery. Heated indoor swimming pools, spas or hot tubs with water surface area greater than 200 square feet (18.6 m^2) 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 capable of decreasing the exhaust air temperature at design heating conditions [80°F (27°C) indoor] by 36°F (10°C) in Climate Zones 4C and 5B and 48°F (26.7°C) in Climate Zone 6B.

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 providing at least 70 percent of the heating energy required over an operating season.

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

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

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

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

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

C404.11 Conservation of water pumping energy. Pumps for domestic water systems shall comply with Section C403.2.12. 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.
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 connection of ballasts, the maximum lighting power for interior applications, electrical energy consumption, minimum acceptable lighting equipment for exterior applications, and minimum efficiencies for motors and transformers.

Exception: Dwelling units within commercial buildings shall not be required to comply with Sections C405.2 through C405.5 provided that a minimum of 75 percent of the lamps in permanently installed light fixtures shall be high efficacy lamps.

Walk-in coolers and walk-in freezers shall comply with C405.10. Refrigerated warehouse coolers and refrigerated warehouse freezers shall comply with C405.11.

Escalators and moving walks shall comply with Section C405.12. Lighting systems shall be commissioned according to Section C405.13. Receptacles shall be controlled according to Section C405.14.

C405.2 Lighting controls (Mandatory). Lighting systems shall be provided with controls as specified in Sections C405.2.1, C405.2.2, C405.2.3, C405.2.4 and C405.2.5.

Exception: Industrial or manufacturing process areas, as may be required for production and safety.

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

C405.2.1.1 Interior lighting controls. Each area enclosed by walls or floor-to-ceiling partitions shall have at least one manual control for the lighting serving that area. The required controls shall be located within the area served by the controls or be a remote switch that identifies the lights served and indicates their status.

Exceptions:

1. Areas designated as security or emergency areas that need to be continuously lighted.
2. Lighting in stairways or corridors that are elements of the means of egress.
3. Stairwells and parking garages are not permitted to have a wall-mounted manual switch.

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

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

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

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

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

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

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

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

Automatic time switches shall have a minimum 7 day clock and be capable of being set for 7 different day types per week and incorporate an automatic holiday "shutoff" feature, which turns off all loads for at least 24 hours and then resumes normally scheduled operations. Automatic time switches shall also have program back-up capabilities, which prevent the loss

of program and time settings for at least 10 hours, if power is interrupted.

Exceptions:

1. Emergency egress lighting does not need to be controlled by an automatic time switch, except as required by Item 7 of Section C405.2.3.
2. Lighting in spaces controlled by occupancy sensors does not need to be controlled by automatic time switch controls.

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

1. The override switch shall be in a readily accessible location;
2. The override switch shall be located where the lights controlled by the switch are visible; or the switch shall provide a mechanism which announces the area controlled by the switch;
3. The override switch shall permit manual operation;
4. The override switch, when initiated, shall permit the controlled lighting to remain on for a maximum of 2 hours; and
5. Any individual override switch shall control the lighting for a maximum area of ((~~5,000~~)) 2,500 square feet (((~~465~~)) 232 m^2).

Exception: Within malls, arcades, auditoriums, single tenant retail spaces, industrial facilities, pools, gymnasiums, skating rinks and arenas:

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

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

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.

C405.2.2.3 Daylight zone control. Daylight zones shall be designed such that lights in the daylight zone are controlled independently of general area lighting and are controlled in accordance with Section C405.2.2.3.2. Each daylight control zone shall not exceed 2,500 square feet (232 m^2). Contiguous daylight zones adjacent to vertical fenestration are allowed to be controlled by a single controlling device serving no more than 60 lineal feet (18 288 mm) of facade, provided that they do not include zones facing more than two adjacent cardinal orientations (i.e., north, east, south, west). The primary daylight zone shall be controlled separately from the secondary daylight zone. Daylight zones under skylights more than 15 feet (4572 mm) from the perimeter shall be controlled separately from daylight zones adjacent to vertical fenestration. Controls shall:

1. Control only luminaires within the daylit area.
2. Incorporate time-delay circuits to prevent cycling of light level changes of less than three minutes.
3. Be set initially at 30 footcandles (323 lux) or not more than 110 percent of the illuminance level specified on the construction documents.

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

C405.2.2.3.1 Reserved.

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

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

1. Continuous dimming using dimming ballasts and daylight-sensing automatic controls that are capable of reducing the power of general lighting in the daylit zone continuously to less than 20 percent of rated power at maximum light output.
2. Stepped dimming using multi-level switching and daylight-sensing controls that are capable of reducing lighting power automatically. The system shall provide a minimum of two control channels per zone and be installed in a manner such that at least one control step is between 50 percent and 70 percent of design lighting power and another control step is no greater than 35 percent of design power, and the system is capable of automatically turning the system off.

Exception: In restaurant dining areas and retail sales areas, light fixtures located less than 10 feet (3048 mm) horizontally from vertical *fenestration* are not required to be controlled by daylight sensors where the *fenestration* adjoins a sidewalk or other

outdoor pedestrian area, provided that the light fixtures are controlled separately from the general area lighting.

C405.2.2.3.3 Reserved.

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

1. Display and accent light shall be controlled by a dedicated control which is independent of the controls for other lighting within the room or space.
2. Lighting in cases used for display case purposes shall be controlled by a dedicated control which is independent of the controls for other lighting within the room or space.
3. Hotel and motel sleeping units and guest suites shall have a master control device at the main room entry that controls all permanently installed luminaires and switched receptacles. Where a hotel/motel includes more than 50 rooms, controls shall be automatic to ensure all power to the lights and switched outlets are turned off when the occupant is not in the room.
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 the control device is readily accessible.
5. Lighting for nonvisual applications, such as plant growth and food warming, shall be controlled by a dedicated control which is independent of the controls for other lighting within the room or space.
6. Lighting equipment that is for sale or for demonstrations in lighting education shall be controlled by a dedicated control which is independent of the controls for other lighting within the room or space.
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 0.05 watts per square foot (0.0045 W/m^2) 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 30 minutes, and restore lighting to full power when occupants enter the stairway. All portions of stairways shall remain illuminated to at least 1 footcandle (11 lux) at the walking surface 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 (669 m^2). Pedestrian occupancy sensors controlling any lighting zone are permitted to be configured to detect pedestrians no more than 30 feet (9144 mm) outside of that zone. Vehicle occupancy sensors controlling any lighting zone are permitted to be configured to detect vehicles no more than 60 feet (18 288 mm) outside of that zone.

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

Building façade lighting shall be automatically shut off between midnight or business/facility closing, whichever is later, and 6 a.m. or business/facility opening, whichever is earlier. Other lighting, including advertising signage, shall be controlled by a device that automatically reduces the connected lighting power, on a system-wide basis, by at least 30 percent for at least one of the following conditions:

1. From midnight or business/facility closing, whichever is later, and 6 a.m. or business/facility opening, whichever is earlier; or
2. During any period when no activity has been detected on the site for a time of no longer than 15 minutes.

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

C405.2.5 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 square feet (93 m^2).

C405.3 Reserved.

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

C405.5 Interior lighting power requirements (Prescriptive). A building complies with this section if its total con-

nected lighting power calculated under Section C405.5.1 is no greater than the interior lighting power calculated under Section C405.5.2.

C405.5.1 Total connected interior lighting power. The total connected interior lighting power (watts) shall be the sum of the watts of all interior lighting equipment as determined in accordance with Sections C405.5.1.1 through C405.5.1.4. 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 limits of the applicable areas shall be clearly documented on the electrical construction documents.

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 the visually impaired 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.
2. Lighting equipment used for the following shall be exempt provided that it is in addition to general lighting and is controlled by an independent control device:
    2.1. Task lighting for medical and dental purposes.
    2.2. Display lighting for exhibits in galleries, museums and monuments.
3. Lighting for theatrical purposes, including performance, stage, film production and video production.
4. Lighting for photographic processes.
5. Lighting integral to equipment or instrumentation and is installed by the manufacturer.
6. Task lighting for plant growth or maintenance.
7. Advertising signage or directional signage.
8. In restaurant buildings and areas, lighting for food warming or integral to food preparation equipment.
9. Lighting equipment that is for sale.
10. Lighting demonstration equipment in lighting education facilities.
11. Lighting *approved* because of safety or emergency considerations, inclusive of exit lights.
12. Lighting integral to both open and glass-enclosed refrigerator and freezer cases.
13. Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions.
14. Furniture mounted supplemental task lighting that is controlled by automatic shutoff.
15. Lighting used for aircraft painting.

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

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

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

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

1. The specified wattage of the luminaires included in the system with a minimum of 50 W/lin ft. (162 W/lin. m);
2. The wattage limit of the system's circuit breaker; or
3. The wattage limit of other permanent current limiting device(s) on the system.

C405.5.2 Interior lighting power. The total interior lighting power allowance (watts) is determined according to Table C405.5.2(1) using the Building Area Method, or Table C405.5.2(2) using the Space-by-Space Method, for all areas of the building covered in this permit. For the Building Area Method, the interior lighting power allowance is the floor area for each building area type listed in Table C405.5.2(1) times the value from Table C405.5.2(1) for that area. For the purposes of this method, an "area" shall be defined as all contiguous spaces that accommodate or are associated with a single building area type as listed in Table C405.5.2(1). Where this method is used to calculate the total interior lighting power for an entire building, each building area type shall be treated as a separate area. For the Space-by-Space Method, the interior lighting power allowance is determined by multiplying the floor area of each space times the value for the space type in Table C405.5.2(2) that most closely represents the proposed use of the space, and then summing the lighting power allowances for all spaces. Tradeoffs among spaces are permitted, except that tradeoffs with covered parking areas are not permitted. See the *Seattle Building Code*, Section 3016.15, for energy efficiency requirements for lighting in elevators.

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

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

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

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

BUILDING AREA TYPE	LPD (w/ft^2)
Automotive facility	0.82
Convention center	1.08
Court house	1.05
Dining: bar lounge/leisure	0.99
Dining: cafeteria/fast food	0.90
Dining: family	0.89
Dormitory	0.61
Exercise center	0.88
Fire station	0.71
Gymnasium	0.95
Health care clinic	0.87
Hospital	1.20
Hotel	1.00
Library	1.18
Manufacturing facility	1.11
Motel	0.88
Motion picture theater	0.83
Multifamily	0.60
Museum	1.00
Office	0.90
Parking garage	0.20
Penitentiary	0.90
Performing arts theater	1.25
Police station	0.90
Post office	0.87
Religious building	1.05
Retail	1.33
School/university	0.99
Sports arena	0.78
Town hall	0.92
Transportation	0.77
Warehouse	0.50
Workshop	1.20

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

COMMON SPACE-BY-SPACE TYPES	LPD (w/ft^2)
Atrium – First 40 feet in height	0.03 per ft. ht.
Atrium – Above 40 feet in height	0.02 per ft. ht.
Audience/seating area – permanent	
For auditorium	0.79
For performing arts theater	2.43
For motion picture theater	1.14
Classroom/lecture/training	1.24
Conference/meeting/multipurpose	1.23
Corridor/transition	0.66
Dining area	
Bar/lounge/leisure dining	1.31
Family dining area	0.89
Dressing/fitting room performing arts theater	0.40
Electrical/mechanical	0.95
Food preparation	0.99
Laboratory for classrooms	1.28
Laboratory for medical/industrial/research	1.81
Lobby	0.90
Lobby for performing arts theater	2.00
Lobby for motion picture theater	0.52
Locker room	0.75
Lounge recreation	0.73
Office – enclosed	1.11
Office – open plan	0.98
Restroom	0.98
Sales area	1.68[a]
Stairway	0.69
Storage	0.63
Workshop	1.59
BUILDING SPECIFIC SPACE-BY-SPACE TYPES	**LPD (w/ft^2)**
Automotive – service/repair	0.67
Bank/office – banking activity area	1.38
Convention center	
Exhibit space	1.45
Audience/seating area	0.82
Courthouse/police station/penitentiary	
Courtroom	1.72
Confinement cells	1.10
Judge chambers	1.17
Penitentiary audience seating	0.43
Penitentiary classroom	1.34
Penitentiary dining	1.07
Dormitory living quarters	0.38
Fire stations	
Engine rooms	0.56
Sleeping quarters	0.25

(continued)

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

BUILDING SPACE-BY-SPACE TYPES	LPD (w/ft²)
Gymnasium/fitness center	
Fitness area	0.72
Gymnasium audience/seating	0.43
Playing area	1.20
Healthcare clinic/hospital	
Corridors/transition	0.89
Emergency	2.26
Exam/treatment	1.66
Medical supplies	1.27
Nursery	0.88
Nurse station	0.87
Operating room	1.89
Patient room	0.62
Pharmacy	1.14
Physical therapy	0.91
Radiology/imaging	1.32
Recovery	1.15
Hotel	
Dining area	0.82
Guestrooms	1.11
Hotel lobby	1.06
Highway lodging dining	0.88
Highway lodging guestrooms	0.75
Library	
Card file and cataloguing	0.72
Reading area	0.93
Stacks	1.71
Manufacturing	
Corridors/transition	0.41
Detailed manufacturing	1.29
Equipment room	0.95
Extra high bay (> 50-foot floor-ceiling height)	1.05
High bay (25 – 50-foot floor-ceiling height)	1.23
Low bay (< 25-foot floor-ceiling height)	1.19
Museum	
General exhibition	1.05
Restoration	1.02
Parking garage – garage areas	0.19
Post office	
Sorting area	0.94
Religious building	
Audience seating	1.53
Fellowship hall	0.64
Worship pulpit/choir	1.53
Retail	
Dressing/fitting area	0.87
Mall concourse	1.10
Sales area	1.68[a]
Sports arena	
Audience seating	0.43
Court sports area – Class 4	0.72
Court sports area – Class 3	1.20
Court sports area – Class 2	1.92
Court sports area – Class 1	3.01
Ring sports area	2.68

(continued)

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

BUILDING SPECIFIC SPACE-BY-SPACE TYPES	LPD (w/ft²)
Transportation	
Air/train/bus baggage area	0.76
Airport concourse	0.36
Audience seating	0.54
Terminal – ticket counter	1.08
Warehouse	
Fine material storage	0.95
Medium/bulky material	0.58

For SI: 1 foot = 304.8 mm, 1 watt per square foot = 11 W/m².

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

Calculate the additional lighting power as follows:

Additional Interior Lighting Power Allowance = 500 watts + (Retail Area 1 × 0.6 W/ft²) + (Retail Area 2 × 0.6 W/ft²) + (Retail Area 3 × 1.4 W/ft²) + (Retail Area 4 × 2.5 W/ft²).

where:

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

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

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

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

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

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

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

1. Specialized signal, directional and marker lighting associated with transportation;
2. Advertising signage or directional signage;
3. Integral to equipment or instrumentation and is installed by its manufacturer;
4. Theatrical purposes, including performance, stage, film production and video production;

5. Athletic playing areas;
6. Temporary lighting;
7. Industrial production, material handling, transportation sites and associated storage areas;
8. Theme elements in theme/amusement parks; and
9. Used to highlight features of public monuments and registered historic landmark structures or buildings.

TABLE C405.6.2(1)
EXTERIOR LIGHTING ZONES

LIGHTING ZONE	DESCRIPTION
1	Developed areas of national parks, state parks, forest land, and rural areas
2	Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed use areas
3	All other areas
4 (not used)	((~~High activity commercial districts in major metropolitan areas as designated by the local land use planning authority~~))

C405.6.3 Full cutoff luminaires. For open parking and outdoor areas and roadways, luminaires mounted more than 15 feet (4572 mm) above the ground shall be full cutoff luminaires. Full cutoff means a luminaire light distribution where zero candela intensity occurs at an angle of 90 degrees above nadir and all greater angles from nadir.

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

C405.8 Electric motors. All permanently wired polyphase motors of 1 hp (0.75 kW) or more which are not part of an HVAC system shall comply with Section C403.2.13.

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.

C405.9 Transformers. The minimum efficiency of a low voltage dry-type distribution transformer shall be the Class I Efficiency Levels for distribution transformers specified in Table 4-2 of NEMA TP-1.

C405.10 Walk-in coolers and walk-in freezers. *Walk-in coolers* and *walk-in freezers* shall comply with all of the following:

1. Lights shall use light sources with an efficacy of 40 lumens per watt or more, including ballast losses (if any). Light sources with an efficacy of less than 40 lumens per watt, including ballast losses (if any), may be used in conjunction with a timer or device that turns off the lights within 15 minutes of when the *walk-in cooler* or *walk-in freezer* is not occupied by people.

C405.11 Refrigerated warehouse coolers and refrigerated warehouse freezers. *Refrigerated warehouse coolers* and *refrigerated warehouse freezers* shall comply with all of the following:

1. Lights shall use light sources with an efficacy of 40 lumens per watt or more, including ballast losses (if any). Light sources with an efficacy of less than 40 lumens per watt, including ballast losses (if any), may be used in conjunction with a timer or device that turns off the lights within 15 minutes of when the *refrigerated warehouse cooler* or *refrigerated warehouse freezer* is not occupied by people.

C405.12 Escalators and moving walks.

C405.12.1 Variable speed escalators. Where variable speed escalators and moving walks are permitted by the administrative authority, all escalators and moving walks shall reduce their operating speed to no more than 15 feet (4572 mm) per minute when no passengers have been detected for a period of time not exceeding three times the amount of time required to transfer a passenger between landings. Such escalators and moving walks shall comply with the requirements of ANSI/ASME A17.1 for variable speed escalators and moving walks.

Exception: A power factor controller that reduces operating voltage in response to light loading conditions may be provided in place of the variable speed function.

C405.12.2 Regenerative drive. Escalators designed either for one-way down operation only or for reversible operation shall have variable frequency regenerative drives that supply electrical energy to the building electrical system when loaded with more than five passengers.

C405.13 Electrical power and lighting systems commissioning and completion requirements. Electrical power and lighting systems shall be commissioned and completed in accordance with Section C408.

C405.14 Controlled receptacles. At least 50 percent of all 125 volt 15- and 20-ampere receptacles installed in private offices, open offices, or classrooms, including those installed in modular partitions and modular office workstation systems, shall be *controlled receptacles*. In rooms larger than 200 square feet (19 m^2), a controlled receptacle shall be located within 72 inches (1.8 m) of each uncontrolled receptacle. *Controlled receptacles* shall be visibly differentiated from standard receptacles 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 30 minutes, or
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 capable of providing an independent schedule for each portion of the building not to exceed 25,000 square feet (2,323 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

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

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

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

switches for *controlled receptacles* are permitted to control the lighting within the same area.

Exception: 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 inches (1.8 m) of a *controlled receptacle*.

Informative Note: See Section C101.4.3, exceptions 9, 10 and 11, regarding controlled receptacle requirements for alterations to existing buildings.

SECTION C406
ADDITIONAL EFFICIENCY PACKAGE OPTIONS

Sections C406.1 through C406.4 are not adopted.

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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 requires that the criteria of Sections C402.4, C403.2, C404, ((~~and~~)) C405, C408, C409 and C410 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.

C407.3 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 is less than or equal to 93 percent of the annual energy consumption of the *standard reference design*.

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. ((~~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 C402.2.

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.

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: from Table C402.1.2	As proposed
	Solar absorptance: 0.75	As proposed
	Emittance: 0.90	As proposed
Walls, above-grade	Type: Mass wall if proposed wall is mass; otherwise steel-framed wall	As proposed
	Gross area: same as proposed	As proposed
	U-factor: from Table C402.1.2	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: from Table C402.1.2 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: from Table C402.1.2	As proposed
Floors, slab-on-grade	Type: Unheated	As proposed
	F-factor: from Table C402.1.2	As proposed
Doors	Type: Swinging	As proposed
	Area: Same as proposed	As proposed
	U-factor: from Table C402.2	As proposed
Vertical fenestration	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 C402.3 for the same framing material as proposed	As proposed
	SHGC: from Table C402.3 except that for climates with no requirement (NR) SHGC = 0.40 shall be used	As proposed
	External shading and PF: None	As proposed
Skylights	Area 1. The proposed skylight area; where the proposed skylight area is less than ((~~3~~)) 5 percent of gross area of roof assembly. 2. ((~~3~~)) 5 percent of gross area of roof assembly; where the proposed skylight area is ((~~3~~)) 5 percent or more of gross area of roof assembly	As proposed
	U-factor: from Table C402.3	As proposed
	SHGC: from Table C402.3 except that for climates with no requirement (NR) SHGC = 0.40 shall be used.	As proposed
Lighting, interior	The interior lighting power shall be determined in accordance with Section C405.5.2. Where the occupancy of the building is not known, the lighting power density shall be 1.0 Watt per square foot (10.73 W/m^2) based on the categorization of buildings with unknown space classification as offices. 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
Lighting, exterior	The lighting power shall be determined in accordance with Table C405.6.2(2). Areas and dimensions of tradable and nontradable surfaces shall be the same as proposed.	As proposed

(continued)

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

BUILDING COMPONENT CHARACTERISTICS	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
Internal gains	Same as proposed	Receptacle, motor and process loads shall be modeled and estimated based on the space use classification. All end-use load components within and associated with the building shall be modeled to include, but not be limited to, the following: exhaust fans, parking garage ventilation fans, exterior building lighting, swimming pool heaters and pumps, elevators, escalators, refrigeration equipment and cooking equipment.
Schedules	Same as proposed	Operating schedules shall include hourly profiles for daily operation and shall account for variations between weekdays, weekends, holidays and any seasonal operation. Schedules shall model the time-dependent variations in occupancy, illumination, receptacle loads, thermostat settings, mechanical ventilation, HVAC equipment availability, service hot water usage and any process loads. The schedules shall be typical of the proposed building type as determined by the designer and approved by the jurisdiction.
Mechanical ventilation	Same as proposed, except when modeling demand-control ventilation in the proposed design when its use is not required by Section C403.2.5.1 or occupancy sensor ventilation controls when their use is not required by Section C403.2.5.2.	As proposed, in accordance with Section C403.2.5.
Heating systems	Fuel type: same as proposed design	As proposed
	Equipment type[a]: from Tables C407.5.1(2) and C407.5.1(3)	As proposed
	Efficiency: from Tables C403.2.3(2), C403.2.3(3),C403.2.3(4) and C403.2.3(5)	As proposed
	Preheat coils: If the HVAC system in the proposed design has a preheat coil and a preheat coil can be modeled in the *standard reference design*, the *standard reference design* shall be modeled with a preheat coil controlled in the same manner as the proposed design.	
	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.	As proposed
	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.	
Cooling systems	Fuel type: same as proposed design	As proposed
	Equipment type[c]: from Tables C407.5.1(2) and C407.5.1(3)	As proposed
	Efficiency: from Tables C403.2.3(1), C403.2.3(2) and C403.2.3(3)	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 accordance with Section C403.4.1. The high-limit shutoff shall be a dry-bulb switch with a setpoint as determined by Table C403.3.1.1.3(2).	As proposed
Energy recovery	*Standard reference design* systems shall be modeled where required in Section C403.2.6.	As proposed

(continued)

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

BUILDING COMPONENT CHARACTERISTICS	STANDARD REFERENCE DESIGN	PROPOSED DESIGN
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. 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 8 and 10, Pfan = CFMS × 0.3 For all other systems, 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 C403.2.10.1(1) - Option 2 Fan motor = The efficiency from Table C403.2.13 for the efficiency next motor size greater than the bhp using the enclosed motor at 1,800 rpm CFMS = The *standard reference design* system maximum design supply fan airflow rate in cfm	As proposed As proposed
On-site renewable energy	No on-site renewable energy shall be modeled in the *standard reference design*.	As proposed. On-site renewable energy sources energy shall not be considered to be consumed energy and shall not be included in the proposed building performance.
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 Efficiency: from Table C404.2 Capacity: same as proposed Where no service water hot water system exists or is specified in the proposed design, no service hot water heating shall be modeled.	As proposed As proposed Demand: 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 water temperatures shall be estimated based upon the location. 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. As proposed

a. Where no heating system exists or has been specified, the heating system shall be modeled as fossil fuel. The system characteristics shall be identical in both the standard reference design and proposed design.

b. The ratio between the capacities used in the annual simulations and the capacities determined by sizing runs shall be the same for both the standard reference design and proposed design.

c. Where no cooling system exists or no cooling system has been specified, the cooling system shall be modeled as an air-cooled single-zone system, one unit per thermal zone. The system characteristics shall be identical in both the standard reference design and proposed design.

d. Reserved.

TABLE C407.5.1(2)
HVAC SYSTEMS MAP

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

a. Select "water/ground" if the proposed design system condenser is water or evaporatively cooled; select "air/none" if the condenser is air cooled. Closed-circuit dry coolers shall be considered air cooled. Systems utilizing district cooling shall be treated as if the condenser water type were "water." If no mechanical cooling is specified or the mechanical cooling system in the proposed design does not require heat rejection, the system shall be treated as if the condenser water type were "Air." For proposed designs with ground-source or groundwater-source heat pumps, the standard reference design HVAC system shall be water-source heat pump (System 6).

b. Select the path that corresponds to the proposed design heat source: electric resistance, heat pump (including air source and water source), or fuel fired. Systems utilizing district heating (steam or hot water) and systems with no heating capability shall be treated as if the heating system type were "fossil fuel." For systems with mixed fuel heating sources, the system or systems that use the secondary heating source type (the one with the smallest total installed output capacity for the spaces served by the system) shall be modeled identically in the standard reference design and the primary heating source type shall be used to determine *standard* reference design HVAC system type.

c. Select the standard reference design HVAC system category: The system under "single-zone residential system" shall be selected if the HVAC system in the proposed design is a single-zone system and serves a residential space. The system under "single-zone nonresidential system" shall be selected if the HVAC system in the proposed design is a single-zone system and serves other than residential spaces. The system under "all other" shall be selected for all other cases.

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

SYSTEM NO.	SYSTEM TYPE	FAN CONTROL	COOLING TYPE	HEATING TYPE
1	Variable air volume with parallel fan-powered boxes[a]	VAV[d]	Chilled water[e]	Electric resistance
2	Variable air volume with reheat[b]	VAV[d]	Chilled water[e]	Hot water fossil fuel boiler[f]
3	Packaged variable air volume with parallel fan-powered boxes[a]	VAV[d]	Direct expansion[c]	Electric resistance
4	Packaged variable air volume with reheat[b]	VAV[d]	Direct expansion[c]	Hot water fossil fuel boiler[f]
5	Two-pipe fan coil	Constant volume[i]	Chilled water[e]	Electric resistance
6	Water-source heat pump	Constant volume[i]	Direct expansion[c]	Electric heat pump and boiler[g]
7	Four-pipe fan coil	Constant volume[i]	Chilled water[e]	Hot water fossil fuel boiler[f]
8	Packaged terminal heat pump	Constant volume[i]	Direct expansion[c]	Electric heat pump[h]
9	Packaged rooftop heat pump	Constant volume[i]	Direct expansion[c]	Electric heat pump[h]
10	Packaged terminal air conditioner	Constant volume[i]	Direct expansion	Hot water fossil fuel boiler[f]
11	Packaged rooftop air conditioner	Constant volume[i]	Direct expansion	Fossil fuel furnace

For SI: 1 foot = 304.8 mm, 1 cfm/ft^2 = 0.0004719, 1 Btu/h = 0.293/W, °C = [(°F) -32/1.8].

a. **VAV with parallel boxes:** Fans in parallel VAV fan-powered boxes shall be sized for 50 percent of the peak design flow rate and shall be modeled with 0.35 W/cfm fan power. Minimum volume setpoints for fan-powered boxes shall be equal to the minimum rate for the space required for ventilation consistent with Section C403.4.5, Exception 5. Supply air temperature setpoint shall be constant at the design condition.

b. **VAV with reheat:** Minimum volume setpoints for VAV reheat boxes shall be 0.4 cfm/ft^2 of floor area. Supply air temperature shall be reset based on zone demand from the design temperature difference to a 10°F temperature difference under minimum load conditions. Design airflow rates shall be sized for the reset supply air temperature, i.e., a 10°F temperature difference.

c. **Direct expansion:** The fuel type for the cooling system shall match that of the cooling system in the proposed design.

d. **VAV:** When the proposed design system has a supply, return or relief fan motor horsepower (hp) requiring variable flow controls as required by Section C403.2.12, the corresponding fan in the VAV system of the standard reference design shall be modeled assuming a variable speed drive. For smaller fans, a forward-curved centrifugal fan with inlet vanes shall be modeled. If the proposed design's system has a direct digital control system at the zone level, static pressure setpoint reset based on zone requirements in accordance with Section C403.4.2 shall be modeled.

e. **Chilled water:** For systems using purchased chilled water, the chillers are not explicitly modeled. Otherwise, the standard reference design's chiller plant shall be modeled with chillers having the number as indicated in Table C407.5.1(4) as a function of standard reference building chiller plant load and type as indicated in Table C407.5.1(5) as a function of individual chiller load. Where chiller fuel source is mixed, the system in the standard reference design shall have chillers with the same fuel types and with capacities having the same proportional capacity as the proposed design's chillers for each fuel type. Chilled water supply temperature shall be modeled at 44°F design supply temperature and 56°F return temperature. Piping losses shall not be modeled in either building model. Chilled water supply water temperature shall be reset in accordance with Section C403.4.3.4. Pump system power for each pumping system shall be the same as the proposed design; if the proposed design has no chilled water pumps, the standard reference design pump power shall be 22 W/gpm (equal to a pump operating against a 75-foot head, 65-percent combined impeller and motor efficiency). The chilled water system shall be modeled as primary-only variable flow with flow maintained at the design rate through each chiller using a bypass. Chilled water pumps shall be modeled as riding the pump curve or with variable-speed drives when required in Section C403.4.3.4. The heat rejection device shall be an axial fan cooling tower with variable-speed fans if required in Section C403.4.4 or Section C403.2.12. 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 C403.4.3.4. Pump system power for each pumping system shall be the same as the proposed design; if the proposed design has no hot water pumps, the standard reference design pump power shall be 19 W/gpm (equal to a pump operating against a 60-foot head, 60-percent combined impeller and motor efficiency). The hot water system shall be modeled as primary only with continuous variable flow. Hot water pumps shall be modeled as riding the pump curve or with variable speed drives when required by Section C403.4.3.4.

g. **Electric heat pump and boiler:** Water-source heat pumps shall be connected to a common heat pump water loop controlled to maintain temperatures between 60°F and 90°F. Heat rejection from the loop shall be provided by an axial fan closed-circuit evaporative fluid cooler with variable-speed fans if required in Section C403.4.2 or Section C403.2.12. Heat addition to the loop shall be provided by a boiler that uses the same fuel as the proposed design and shall be natural draft. If no boilers exist in the proposed design, the standard reference building boilers shall be fossil fuel. The standard reference design boiler plant shall be modeled with a single boiler if the standard reference design plant load is 600,000 Btu/h or less and with two equally sized boilers for plant capacities exceeding 600,000 Btu/h. Boilers shall be staged as required by the load. Piping losses shall not be modeled in either building model. Pump system power shall be the same as the proposed design; if the proposed design has no pumps, the standard reference design pump power shall be 22 W/gpm, which is equal to a pump operating against a 75-foot head, with a 65-percent combined impeller and motor efficiency. Loop flow shall be variable with flow shutoff at each heat pump when its compressor cycles off as required by Section C403.4.3.3. Loop pumps shall be modeled as riding the pump curve or with variable speed drives when required by Section C403.4.3.4.

h. **Electric heat pump:** Electric air-source heat pumps shall be modeled with electric auxiliary heat. The system shall be controlled with a multistage space thermostat and an outdoor air thermostat wired to energize auxiliary heat only on the last thermostat stage and when outdoor air temperature is less than 40°F. In heating operation the system shall be controlled to operate the heat pump as the first stage of heating, before energizing the electric auxiliary heat, down to a minimum outdoor air temperature of 35°F for System No. 8 or 17°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:** Fans shall be controlled in the same manner as in the proposed design; i.e., fan operation whenever the space is occupied or fan operation cycled on calls for heating and cooling. If the fan is modeled as cycling and the fan energy is included in the energy efficiency rating of the equipment, fan energy shall not be modeled explicitly.

TABLE C407.5.1(4)
NUMBER OF CHILLERS

TOTAL CHILLER PLANT CAPACITY	NUMBER OF CHILLERS
≤ 300 tons	1
> 300 tons, < 600 tons	2, sized equally
≥ 600 tons	2 minimum, with chillers added so that no chiller is larger than 800 tons, all sized equally

For SI: 1 ton = 3517 W.

TABLE C407.5.1(5)
WATER CHILLER TYPES

INDIVIDUAL CHILLER PLANT CAPACITY	ELECTRIC-CHILLER TYPE	FOSSIL FUEL CHILLER TYPE
≤ 100 tons	Reciprocating	Single-effect absorption, direct fired
>100 tons, < 300 tons	Screw	Double-effect absorption, direct fired
≥ 300 tons	Centrifugal	Double-effect absorption, direct fired

For SI: 1 ton = 3517 W.

C407.5.2.2 HVAC zones not designed. Where HVAC *zones* have not yet been designed, thermal blocks shall be defined based on similar internal load densities, occupancy, lighting, thermal and temperature schedules, and in combination with the following guidelines:

1. Separate thermal blocks shall be assumed for interior and perimeter spaces. Interior spaces shall be those located more than 15 feet (4572 mm) from an exterior wall. Perimeter spaces shall be those located closer than 15 feet (4572 mm) from an *exterior wall*.
2. Separate thermal blocks shall be assumed for spaces adjacent to glazed exterior walls: a separate *zone* shall be provided for each orientation, except orientations that differ by no more than 45 degrees (0.79 rad) shall be permitted to be considered to be the same orientation. Each *zone* shall include floor area that is 15 feet (4572 mm) or less from a glazed perimeter wall, except that floor area within 15 feet (4572 mm) of glazed perimeter walls having more than one orientation shall be divided proportionately between *zones*.
3. Separate thermal blocks shall be assumed for spaces having floors that are in contact with the ground or exposed to ambient conditions from *zones* that do not share these features.
4. Separate thermal blocks shall be assumed for spaces having exterior ceiling or roof assemblies from *zones* that do not share these features.

C407.5.2.3 Multifamily residential buildings. Residential spaces shall be modeled using one thermal block per space except that those facing the same orientations are permitted to be combined into one thermal block. Corner units and units with roof or floor loads shall only be combined with units sharing these features.

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 meeting 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. When the *simulation program* does not model a design, material, or device of the *proposed design*, an exceptional calculation method shall be used if approved by the *building official*. If 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. At no time shall the total exceptional savings constitute more than half of the difference between the *baseline building performance* and the *proposed building performance*. All applications for approval of an exceptional method shall include:

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 when 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; and
5. The *performance rating* calculated with and without the exceptional calculation method.

SECTION C408
SYSTEM COMMISSIONING

C408.1 General. This section covers the commissioning of the building mechanical systems in Section C403, service water heating systems in Section C404, electrical power and lighting systems in Section C405 and energy metering in Section C409. Prior to passing the final mechanical and electrical inspections or obtaining a certificate of occupancy, the *registered design professional* or ((~~approved agency~~)) *qualified commissioning authority* shall provide evidence of systems *commissioning* and completion in accordance with the provisions of this section.

Exception: Where commissioning is not required by Sections C408.2 through C408.5, the requirements of Section C408.1 do not apply.

Copies of all documentation shall be given to the owner and made available to the code official upon request in accordance with Sections C408.1.2 and C408.1.3.

C408.1.1 Commissioning plan. A *commissioning plan* shall be developed by a *registered design professional* or *qualified commissioning authority* and shall include the items listed in this section. Items 1–4 shall be included with the construction documents, and Items 5–8 shall be submitted prior to the first mechanical inspection. For projects where no mechanical inspection is required, Items 5–8 shall be submitted prior to the first electrical inspection. ((~~A commissioning plan shall be developed by a registered design professional or approved agency and shall include the following items:~~))

1. A narrative description of the activities that will be accomplished during each phase of commissioning, including the personnel intended to accomplish each of the activities.
2. Roles and responsibilities of the commissioning team, including statement of qualifications of the commissioning authority in accordance with Section C408.1.
3. A schedule of activities including systems testing and balancing, functional testing, and supporting documentation.
4. Where the *qualified commissioning authority* 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 *qualified commissioning authority's* contractual relationship with other team members and provide a conflict management plan demonstrating that the *qualified commissioning authority* is free to identify any issues discovered and report directly to the owner.

((~~4~~))5. A listing of the specific equipment, appliances or systems to be tested and a description of the tests to be performed.

((~~5~~))6. Functions to be tested.

((~~6~~))7. Conditions under which the test will be performed.

((~~7~~))8. Measurable criteria for performance.

((~~**C408.1.2 Preliminary commissioning report.** A preliminary report of commissioning test procedures and results shall be completed and certified by the *registered design professional* or *approved agency* and provided to the building owner. The report shall be identified as "Preliminary Commissioning Report" and shall identify:~~

1. ~~Itemization of deficiencies found during testing required by this section that have not been corrected at the time of report preparation.~~
2. ~~Deferred tests that cannot be performed at the time of report preparation because of climatic conditions, with anticipated date of completion.~~
3. ~~Climatic conditions required for performance of the deferred tests.~~
4. ~~Record of progress and completion of operator training.~~))

C408.1.2((~~.1~~)) Acceptance of ((~~report~~)) Commissioning Report. *Buildings*, or portions thereof, shall not pass the final mechanical and electrical inspections or obtain a certificate of occupancy, until such time as the *code official* has received a letter of transmittal from the *building* owner acknowledging that the building owner has received the ((~~Preliminary~~)) Commissioning Report required by Section C408.1.3.4 and the com-

pleted ((~~.Completion of the~~)) Commissioning Compliance Checklist (Figure C408.1.2.1) ((~~is deemed to satisfy this requirement~~)).

((**~~C408.1.2.2 Copy of report.~~** ~~The *code official* shall be permitted to require that a copy of the Preliminary Commissioning Report be made available for review by the *code official*.~~))

C408.1.3 Documentation requirements. The *construction documents* shall specify that the manuals and system balancing report required by Sections C408.1.3.2 and C408.1.3.3 be provided to the building owner prior to issuance of the certificate of occupancy, the record *documents* required by Section C408.1.3.1 ((~~described in this section~~)) be provided to the building owner within 90 days of the date of receipt of the *certificate of occupancy*, and that the Commissioning Report documents described under Section C408.1.3.4 be provided to the building owner and the *code official* prior to issuance of the certificate of occupancy.

C408.1.3.1 Record documents. Construction documents shall be updated to convey a record of the alterations to the original design. The updates shall be provided to the building owner. Such updates shall include updated mechanical, electrical and control drawings red-lined, or redrawn if specified, that show all changes to size, type and locations of components, equipment and assemblies.

C408.1.3.2 Manuals. An operating and maintenance manual shall be provided and include all of the following:

1. Submittal data stating equipment size and selected options for each piece of equipment requiring maintenance.
2. Manufacturer's operation manuals and maintenance manuals for each piece of equipment requiring maintenance, except equipment not furnished as part of the project. Required routine maintenance actions shall be clearly identified.
3. Name and address of at least one service agency.
4. Controls system maintenance and calibration information, including wiring diagrams, schematics, record documents, and control sequence descriptions. Desired or field-determined setpoints shall be permanently recorded on control drawings at control devices or, for digital control systems, in system programming instructions.
5. A narrative of how each system is intended to operate, including recommended setpoints. Sequence of operation is not acceptable for this requirement.

C408.1.3.3 System balancing report. A written report describing the activities and measurements completed in accordance with Section C408.2.2.

C408.1.3.4 ((~~Final c~~))Commissioning report. A report of test procedures and results identified as "((~~Final~~)) Commissioning Report" shall be delivered to the building owner and *code official* and shall include:

1. Results of functional performance tests.
2. Disposition of deficiencies found during testing, including details of corrective measures used or proposed.
3. Functional performance test procedures used during the commissioning process including measurable criteria for test acceptance((~~, provided herein for repeatability~~)).
4. 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.
5. List and description of any unresolved deficiencies or incomplete tasks, in checklist format.
6. A copy of a Commissioning Permit issued for the completion and resolution of items identified in the lists required by Items 4 and 5 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 4 and 5, the Commissioning Permit is not required. ((~~Deferred tests which cannot be performed at the time of report preparation due to climatic conditions.~~))
7. Completed Commissioning Compliance Checklist (Figure C408.1.2.1).
8. Record of progress and completion of systems operation training.

C408.1.4 Systems operation training. Training of the maintenance staff for equipment included in the manuals required by Section C408.1.3.2 shall include at a minimum:

1. Review of systems documentation.
2. Hands-on demonstration of all normal maintenance procedures, normal operating modes, and all emergency shutdown and startup procedures.
3. Training completion report.

C408.2 Mechanical systems commissioning and completion requirements. Mechanical equipment and controls shall comply with Section C408.2.

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.

Exception: Systems which (a) qualify as simple systems using the criteria in Section C403.3, (b) are not required to have an economizer per Section C403.3.1, and (c) where the building total mechanical equipment capacity is less than 480,000 Btu/h (140,690 W) cooling capacity and 600,000 Btu/h (175,860 W) heating capacity.

FIGURE C408.1.2.1
COMMISSIONING COMPLIANCE CHECKLIST

Project Information	**Project Name:**
	Project Address:
	Commissioning Authority:
Qualifications (Section C408.1)	Statement of commissioning authority's formal training, experience and certification.
Commissioning Plan (Section C408.1.1)	❑ **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. • In-House Commissioning Disclosure and Conflict Management Plan, where applicable.
Systems Balancing (Section C408.2.2)	❑ **Systems Balancing has been completed** • Air and Hydronic systems are proportionately balanced in a manner to first minimize throttling losses. • Test ports are provided on each pump for measuring pressure across the pump.
Functional Testing (Sections C408.2.3, C408.3.1, C408.4.1 and C408.5.1)	❑ **HVAC Equipment Functional Testing has been completed (Section C408.2.3.1)** HVAC equipment has been tested to demonstrate the installation and operation of components, systems and system-to-system interfacing relationships in accordance with approved plans and specifications.
	❑ **HVAC Controls Functional Testing has been completed (Section C408.2.3.2)** HVAC controls have been tested to ensure that control devices are calibrated, adjusted and operate properly. Sequences of operation have been functionally tested to ensure they operate in accordance with approved plans and specifications.
	❑ **Economizers Functional Testing has been completed (Section C408.2.3.3)** Economizers operate in accordance with manufacturer's specifications
	❑ **Lighting Controls Functional Testing has been completed (Section C408.3.1)** Lighting controls have been tested to ensure that control devices, components, equipment, and systems are calibrated, adjusted and operate in accordance with approved plans and specifications.
	❑ **Service Water Heating System Functional Testing has been completed (Section C408.4.1)** Service water heating equipment has been tested to ensure that control devices, components, equipment, and systems are calibrated, adjusted and operate in accordance with approved plans and specifications.
	❑ **Pool and Spa Functional Testing has been completed (Section C408.4.1.3)** Pools and spas have been tested to ensure service water heating equipment, time switches and heat recovery equipment are calibrated, adjusted and operate in accordance with approved plans and specifications.
	❑ **Metering System Functional Testing has been completed (Section C408.5.1)** Energy source meters, energy end-use meters, the energy metering data acquisition system and required display are calibrated, adjusted and operate in accordance with approved plans and specifications.
Supporting Documents (Section C408.1.3.2)	❑ **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: _____
((**~~Commissioning Report~~** (~~Section C408.1.2~~)))	((❑ ~~**Preliminary Commissioning Report submitted to Owner and includes items below**~~ • ~~Deficiencies found during testing required by this section which have not been corrected at the time of report preparation.~~ • ~~Deferred tests, which cannot be performed at the time of report preparation due to climatic conditions.~~))

(continued)

FIGURE C408.1.2.1—continued
COMMISSIONING COMPLIANCE CHECKLIST

Commissioning Report (Section C408.1.3.4)	❑	**Commissioning Report submitted to Owner and includes items below** 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. 4. List and description of any deferred tests that cannot be completed at the time of report preparation, including timeframe for completion and parties to be involved. 5. List and description of any unresolved deficiencies or incomplete tasks noted in the Commissioning Report. 6. A copy of a Commissioning Permit issued for the completion and resolution of items identified in the lists required by Items 4 and 5 above. 7. Completed Commissioning Compliance Checklist (Figure C408.1.2.1). 8. Record of progress and completion of systems operation training.
Certification	❑	I hereby certify that all requirements for Commissioning have been completed in accordance with the ((~~Washington State~~)) Seattle Energy Code, including all items above. --- Building Owner or Owner's Representative Date

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 product specifications. Test and balance activities shall include air system and hydronic system balancing.

C408.2.2.1 Air systems balancing. Each supply air outlet and *zone* terminal device shall be equipped with means for air balancing in accordance with the requirements of Chapter 6 of the *International Mechanical Code*. Discharge dampers are prohibited on constant volume fans and variable volume fans with motors 10 hp (18.6 kW) and larger. Air systems shall be balanced in a manner to first minimize throttling losses then, for fans with system power of greater than 1 hp (0.74 kW), fan speed shall be adjusted to meet design flow conditions.

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

C408.2.2.2 Hydronic systems balancing. Individual hydronic heating and cooling coils shall be equipped with means for balancing and measuring flow. Hydronic systems shall be proportionately balanced in a manner to first minimize throttling losses, then the pump impeller shall be trimmed or pump speed shall be adjusted to meet design flow conditions. Each hydronic system shall have either the capability to measure pressure across the pump, or test ports at each side of each pump.

Exceptions:

1. Pumps with pump motors of 5 hp (3.7 kW) or less.
2. Where throttling results in no greater than five percent of the nameplate horsepower draw above that required if the impeller were trimmed.

C408.2.3 Functional performance testing. Functional performance testing specified in Sections C408.2.3.1 through C408.2.3.3 shall be conducted. Written procedures that 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. At a minimum, 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 *sequence of operation*, including under full-load, part-load and the following emergency conditions:

1. All modes as described in the *sequence* of *operation*;
2. Redundant or *automatic* back-up mode;
3. Performance of alarms; and
4. Mode of operation upon a loss of power and restoration of power.

Exception: Unitary or packaged HVAC equipment listed in Tables C403.2.3(1) through C403.2.3(3) that do not require supply air economizers.

C408.2.3.2 Controls. HVAC control systems shall be tested to document that control devices, components, equipment, and systems are calibrated, adjusted and operate in accordance with approved plans and specifications. Sequences of operation shall be functionally tested to document they operate in accordance with *approved* plans and specifications.

C408.2.3.3 Economizers. Air economizers shall undergo a functional test to determine that they operate in accordance with manufacturer's specifications.

C408.3 Lighting system functional testing. Controls for automatic lighting systems shall comply with Section C408.3.1.

Exception: Lighting systems are exempt from the functional testing requirements in buildings where the total installed lighting load is less than 20 kW and less than 10 kW of lighting load is controlled by occupancy sensors or automatic daylighting controls.

C408.3.1 Functional testing. Testing shall ensure that control hardware and software are calibrated, adjusted, programmed and in proper working condition in accordance with the construction documents and manufacturer's installation instructions. Written procedures that 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. At a minimum, testing shall affirm operation during normally occupied daylight conditions. The construction documents shall state the party who will conduct the required functional testing.

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

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

C408.4 Service water heating systems commissioning and completion requirements. Service water heating equipment and controls shall comply with Section C408.4. 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.

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

1. Service water heating systems 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 in-ground permanently installed 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 that 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. At a minimum, 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* backup 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 in-ground permanently installed spas shall undergo a functional test to determine that they operate in accordance with manufacturer's specifications.

C408.5 Metering system commissioning. Energy metering systems required by Section C409 shall comply with Section C408.5 and be included in the commissioning process required by Section C408.1. Construction documents shall clearly indicate provisions for *commissioning* in accordance with Section C408 and are permitted to refer to specifications for further requirements.

C408.5.1 Functional testing. Functional testing shall be conducted by following written procedures that 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. Buildings with a gross conditioned floor area over ((~~50,000~~)) 20,000 square feet (((~~4645~~)) 1860 m^2) 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 multifamily buildings, the floor area of dwelling units shall be excluded from the total conditioned floor area. Alterations and additions to existing buildings shall conform to Section C409.5.

Exceptions:

1. Tenant spaces 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 (((~~2323~~)) 929 m^2), 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~~)).

C409.2 Energy source metering. Buildings shall have a meter at each energy source. For each energy supply source listed in Sections 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 exceptions to Section C409.1. Not more than 10 percent of the total connected load of any of the end-use metering categories in Sections 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 in Sections 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 sub-metering data shall be provided to the tenant in accordance with Section C409.3.5, 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 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 (232 m^2) 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 sub-metering 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 sub-metering 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 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:

1. All 120 volt equipment.
2. 208/120 volt equipment in a building where the main service is 480/277 volt power.
3. 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 Section 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. Meters shall collect data for energy used by any nonbuilding process load, including but not limited to nonresidential refrigeration and cooking equipment, laundry equipment, industrial equipment and stage lighting.

Exception: Process load energy use less than 50 kVA does not require end-use metering.

C409.3.6 Full-floor tenant space electrical sub-metering. In a multitenant 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 submetering. 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 percent. 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 Sections C409.2 and C409.3, it shall provide real-time energy consumption data and logged data for any hour, day, month or year.

C409.4.3 Energy display. For each building subject to Sections 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 and peak values for any day, week or year.

C409.4.4 Commissioning. The entire system shall be commissioned in accordance with Section C408.5. 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 Metering for existing buildings.

C409.5.1 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.

C409.5.1.1 Small existing buildings. For existing buildings that were constructed subject to the requirements of this code, but were exempt from the requirements of Section C409 due to being smaller than the thresholds set forth in Section C409.1, ((~~M~~))metering and data acquisition systems shall be provided for additions over ((~~25,000~~)) 10,000 square feet (((~~2323~~)) 929 m^2) in accordance with the requirements of Sections C409.2, ((~~and~~)) C409.3 and C409.4.

C409.5.2 Metering for HVAC equipment replacement. Where permits are issued for new or replacement HVAC equipment that has a total heating and cooling capacity greater than 1,200 kBtu/hour and greater than 50 percent of the building's existing HVAC heating and cooling capacity, within any 12-month period, the following shall be provided for the building:

1. Energy source metering required by Section C409.2.
2. HVAC system end-use metering required by Section C409.3.1.
3. Data acquisition and display system per the requirements of Section C409.4.

Each of the building's existing HVAC chillers, boilers, cooling towers, air handlers, packaged units and heat pumps that has a capacity larger than 5 tons or that represents more than 10 percent of the total heating and cooling capacity of the building shall be included in the calculation of the existing heating and cooling capacity of the building. Where heat pumps are configured to deliver both heating and cooling, the heating and cooling capacities shall both be included in the calculation of the total capacity.

Each of the building's existing and new HVAC chillers, boilers, cooling towers, air handlers, packaged units and heat pumps that has a heating or cooling capacity larger than 5 tons or that represents more than 10 percent of the total heating and cooling capacity of the building shall be included in the HVAC system end-use metering.

Construction documents for new or replacement heating and cooling equipment projects shall indicate the total heating and cooling capacity of the building's existing HVAC equipment and the total heating and cooling capacity of the new or replacement equipment. Where permits have been issued for new or replacement heating and cooling equipment within the 12-month period prior to the permit application date, the heating and cooling capacity of that equipment shall also be indicated. For the purpose of this tabulation, heating and cooling capacities of all equipment shall be expressed in kBtu/hour.

C409.5.3 Tenant space electrical sub-metering for existing buildings. For tenant improvements in which a single tenant will occupy a full floor of a building, the electrical consumption for the tenant space on that floor shall be separately metered, and the metering data provided to the tenant with a display system per the requirements of Section C409.4.3. For the purposes of this section, separate end-use categories need not be segregated.

Exception: Where an existing branch circuit electrical panel serves tenant spaces on multiple full floors of a building, the floors served by that panel are not required to comply with this section.

C409.5.4 Metering for complete electrical system replacement. If all, or substantially all, of the existing electrical system is replaced under a single electrical permit or within a 12-month period, all of the provisions of Section C409 shall be met.

SECTION C410
RENEWABLE ENERGY AND SOLAR READINESS

C410.1 On-site renewable energy systems. Each new building or addition larger than 5,000 square feet (465 m^2) of gross conditioned floor area shall include a renewable energy generation system consisting of at least 70 Watts rated peak PV (photovoltaic) energy production, or 240 kBtu of annual SWH (solar water heating) energy production, per 1,000 square feet (92.9 m^2) of conditioned space or fraction thereof. For buildings over five stories in height, the conditioned area for this calculation shall be based on the conditioned area of the largest five above-grade stories in the building. This system is permitted to be mounted either within the allocated *solar zone* required by Section C410.2.3, 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(8). The minimum efficiency for this exception shall be in excess of that required elsewhere in the *Seattle Energy Code*, including Section C403.4.1 (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.

C410.2 Solar readiness.

C410.2.1 General. In addition to the requirements of Section C410.1, a *solar zone* shall be provided on nonresidential buildings of any size that are five stories or less in height above grade plane, and 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 C410.2.2 through C410.2.8 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 unobstructed area, as defined in Section C410.2.3, in the same location, as measured by one of the following:

1. Incident solar radiation expressed in kWh/ft^2-yr using typical meteorological year (TMY) data;
2. Annual sunlight exposure expressed in cumulative hours per year using TMY data;
3. Shadow studies indicating that the roof area is more than 25 percent in shadow, on September 21 at 10 am, 11 am, 12 pm, 1 pm, and 2 pm solar time.

C410.2.2 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 shall be 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 PV 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 C410.2.2 to the maximum practicable area.

Example: A building with a 10,000 ft^2 total roof area, 1,000 ft^2 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 ft^2 roof area – 1,000 ft^2 skylights)] = 3,600 ft^2; or
2. [400 amp x 240 volts x 20% / 10 watts per ft^2] = 1,920 ft^2

Therefore, a *solar zone* of 1,920 square feet is required.

C410.2.3 Obstructions. The *solar zone* shall be free of pipes, vents, ducts, HVAC equipment, skylights and other obstructions, except those serving PV or SWH systems within the *solar zone*. PV or SHW 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 *Seattle Land Use Code.*

C410.2.4 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 degrees of true north.

C410.2.5 Contiguous area. The *solar zone* is permitted to be comprised of smaller separated sub-zones. Each subzone shall be at least 5 feet (1524 mm) wide in the narrowest dimension.

C410.2.6 Access. Areas contiguous to the *solar zone* shall provide access pathways and provisions for emergency smoke ventilation as required by the *International Fire Code.*

C410.2.7 Structural integrity. If the *solar zone* is on the roof of the building or another structure on the site, the as-designed dead load and live load for the *solar zone* shall be clearly marked on the record drawings, and shall accommodate future PV or SHW arrays at an assumed dead load of 5 pounds per square foot in addition to other required live and dead loads. For PV systems, a location for future inverters shall be designated either within or adjacent to the *solar zone*, with a minimum area of 2 square feet (0.186 m^2) for each 1,000 square feet (92.9 m^2) of *solar zone* area, and shall accommodate an assumed dead load of 175 pounds per square foot. Where PV or SWH systems are installed in the solar zone, structural analysis shall be based upon calculated loads, not upon these assumed loads.

C410.2.8 PV or SWH interconnection provisions. Buildings shall provide for the future interconnection of either a PV system in accordance with Section C410.2.8.1 or an SWH system in accordance with Section C410.2.8.2.

C410.2.8.1 PV interconnection. A capped roof penetration sleeve shall be provided in the vicinity of the future inverter, sized to accommodate the future PV system conduit. Interconnection of the future PV 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:

1. 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.
2. 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:

1. *Solar zone* boundaries and access pathways;
2. Location for future inverters and metering equipment; and
3. Route for future wiring between the PV panels and the inverter, and between the inverter and the main service panel.

C410.2.8.2 SWH interconnection. Two capped pipe tees shall be provided upstream of the domestic water heating equipment to provide plumbing interconnections between a future SWH 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 SWH system.

The plumbing construction documents shall indicate the following:

1. *Solar zone* boundaries and access pathways;
2. Location for future hot water storage tanks; and
3. Route for future piping between the *solar zone* and the plumbing interconnection point, following the shortest feasible pathway.