

CHAPTER 4 [CE]

COMMERCIAL ENERGY EFFICIENCY

SECTION C401 GENERAL

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

C401.2 Application. Commercial buildings shall comply with the fossil fuel compliance path according to Section C401.3, or with one of the following:

1. Prescriptive (~~(compliance)~~) path. The prescriptive compliance option requires compliance with (~~(Sections C402 through C406, and Sections C408, C409, C410, C411, and C412)~~) all of Chapter 4, other than Sections C401.3, C401.5, and C407.
2. Total building performance path. The total building performance option requires compliance with Section C407.
3. ~~Appendix F is not adopted by The City of Seattle. ((adopted by the local jurisdiction, the requirements of Appendix F, Outcome Based Energy Budget, Sections C408, C409, C410, C411, C412 and any specific sections in Table C407.2 as determined by the local jurisdiction. The Proposed Total UA of the proposed building shall be no more than 20 percent higher than the Allowed Total UA as defined in Section C402.1.5.))~~
4. Target Performance Path. The requirements of Section C401.5.

C401.2.1 Application to existing buildings. Additions, alterations, repairs, and changes of space conditioning, occupancy, or use to existing buildings shall comply with Chapter 5.

C401.2.2 Application to process equipment. Energy using equipment used by a manufacturing, industrial, or commercial process other than for conditioning spaces or maintaining comfort and amenities for the occupants shall comply with Section C401.3 Item 2, C403.3.2, Tables C403.3.2(1) through (16) inclusive, Sections C403.3.4.1 through C403.3.4.3, C403.7.7, C403.9.2.1, C403.10.3, C403.11.2, C403.11.3, ~~((Table C404.2, and Sections))~~ C404.2, C404.6, C404.13, C405.8, C410, and C412.

C401.3 Fossil fuel compliance path. Buildings complying with the fossil fuel compliance path shall comply with the prescriptive compliance path of this code as defined in Item 1 of Section C401.2, and as modified by this Section C401.3.

C401.3.1 Modification of code requirements. For use of this compliance path only, the following changes shall be made to this code:

1. Section C403.1.4 – Space heating. Strike the phrase “...or fossil fuel combustion...” from the first sentence of Section C403.1.4.
2. Section C404.2.1 – Service water heating. Revise the first sentence of Section C404.2.1 to read: “Service hot water shall be provided by fossil fuel water heating equipment, electric air-source heat pump water heating equipment, electric resistance water heating equipment, or a combination of these equipment types meeting the requirements of this section.”
3. ~~((Section C406.2.5 – Renewable energy. When determining renewable energy credits in Equation 4-17 of Section C406.2.5, strike the phrase “...limited to 50 percent of the required credits in Section C406.1” in the definition of the factor AEC_{RRa}))~~ Reserved.
4. Table C406.2(1) – Efficiency measure credits. Use Table C406.2(2) credit values in place of Table C406.2(1) credit values.

C401.3.2 Fossil fuel equipment. Fossil fuel combustion appliances are permitted for HVAC heating, and shall comply with the applicable efficiency standards referenced in Section C403.3.3.2. Fossil fuel combustion appliances are permitted for service water heating, and shall comply with applicable efficiency standards referenced in Table C404.2.

C401.3.3 Additional efficiency credits. The number of additional efficiency credits required by Table C406.1 shall be increased by the number required in Table C401.3.3, modified as permitted in this section, and is in addition to the energy efficiency credits and load management credits required by Section C406.

EXCEPTION: The required number of space heating additional efficiency credits are permitted to be reduced in the following instances:

1. Low energy spaces in accordance with Section C402.1.1.1 and equipment buildings in accordance with Section C402.1.2 that are served by space heating systems shall comply with sufficient measures from Table C406.2(1) or Table C406.2(2) to achieve a minimum of 50 percent of the efficiency credits required for new construction by Table C401.3.3, modified as permitted in this section.

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2. Building additions that have less than 1,000 square feet of conditioned floor area and that comply with sufficient measures from Table C406.2(1) or Table C406.2(2) to achieve a minimum of 50 percent of the additional efficiency credits required for additions by Table C401.3.3, modified as permitted in this section.
3. Semi-heated spaces in accordance with Section C402.1.1.2 that comply with sufficient measures from Table C406.2(1) or Table C406.2(2) to achieve a minimum of 50 percent of the ((space heating)) additional efficiency credits required by Table C401.3.3, modified as permitted in this section.
4. Unconditioned spaces, open parking garages and ((unheated)) unconditioned enclosed parking garages are not required to achieve the additional efficiency credits for space heating required by Table C401.3.3.

**TABLE C401.3.3
ADDITIONAL CREDITS REQUIRED**

Measure Title	Applicable Section	R-1	R-2	B	E	M	All other
New building – Additional efficiency credits required for space heating systems using the fossil fuel pathway	C401.3.3.1	7	24	101	38	111	56
New building – Additional efficiency credits required for service water heating systems using the fossil fuel pathway	C401.3.3.2	198	212	27	17	79	107
Building additions – Additional efficiency credits required for space heating systems using the fossil fuel pathway	C401.3.3.1	4	12	51	19	56	28
Building additions – Additional efficiency credits required for service water heating systems using the fossil fuel pathway	C401.3.3.1	99	106	14	9	40	54

C401.3.3.1 HVAC credit modification. The number of HVAC heating energy efficiency credits required by Table C401.3.3 is permitted to be decreased according to the following equation:

$$((CR = A \times (B - C) / D)) \quad CR = A \times (C - B) / D$$

Where:

- CR = additional credits required, rounded to the nearest whole number
- A = baseline HVAC heating credits from Table C401.3.3
- B = installed ((fossil fuel)) space heating capacity in kBTU/h of space heating appliances that comply with any of the exceptions to Section C403.1.4
- C = total installed fossil fuel or electric resistance space heating capacity in kBTU/h of all HVAC heating appliances
- D = total capacity in kBTU/h of all types of space heating appliances

C401.3.3.2 Service water heating credit modification. The number of service water heating energy efficiency credits required by Table C401.3.3 is permitted to be decreased according to the following equation:

$$((CR = A \times (B - C) / D)) \quad CR = A \times (C - B) / D$$

Where:

- CR = additional credits required, rounded to the nearest whole number
- A = baseline service water heating credits from Table C401.3.3
- B = installed service water heating appliances capacity in kBTU/h of service water heating appliances that comply with any of the exceptions to Section C404.2.1
- C = total installed fossil fuel or electric resistance service water heating capacity in kBTU/h of all service water heating appliances
- D = total capacity in kBTU/h of all types of service water heating appliances

C401.3.4 Renewable energy credit limit. No more than 80 percent of the efficiency credits required by Sections C401.3.3.1 and C401.3.3.2 are permitted to be Renewable Energy credits defined in Section C406.2.5.

C401.3.5 Discrete area-weighted project compliance. In addition to the area-weighted credit requirements in Section C406.1.2, where a building includes multiple occupancies, the additional required credits per Table C401.3.3 shall be determined separately for each occupancy group. Additional required credits shall be prorated on an area-weighted basis for each occupancy group in the same manner as required project credits per Section C406.1.

1. Where a single space heating or service water heating system serves multiple occupancies, the number of additional required credits shall be prorated on an area-weighted basis for each occupancy served.

2. Additional required credits for envelope systems shall be prorated on an area-weighted basis for all occupancies.
3. Occupancies are permitted to be subdivided into discrete areas, with required and achieved credits for each area prorated on an area-weighted basis as required for the occupancy group.

C401.3.6 Electrification readiness. Additionally, the following provisions shall be required for new construction for each fossil fuel space heating or service water heating appliance installed:

1. Provide a spare electrical branch circuit conduit to the location of a future replacement heat pump appliance to support an equivalent heating capacity.
2. Provide spare electrical service entrance conduits for the purpose of upgrading the main electrical service to support all heat pump appliances throughout the building.
3. The main electrical room has sufficient space to accommodate increasing the main electrical service's size to support all heat pump appliances throughout the building.
4. Additional accommodations for the equipment comprised of transformer(s) and other equipment necessary to support an electrical service upgrade. These accommodations shall include adequate space on the site. If the equipment is located in a transformer vault, that vault must include not only the space to support electrical service upgrade but also include accommodations for additional cooling for larger transformer(s).

C401.4 Thermal envelope certificate. A permanent thermal envelope certificate shall be completed by an *approved* party. Such certificate shall be posted on a wall in the space where the space conditioning equipment is located, a utility room or other *approved* location. If located on an electrical panel, the certificate shall not cover or obstruct the visibility of the circuit directory label, service disconnect label, or other required labels. A copy of the certificate shall also be included in the construction files for the project. The certificate shall include:

1. R-values of insulation installed in or on ceilings, roofs, walls, foundations and slabs, crawlspace walls and floors, and ducts outside *conditioned spaces*.
2. U-factors and *solar heat gain coefficients* (SHGC) of fenestration.
3. Results from any building envelope air leakage testing performed on the building.

Where there is more than one value for any component of the building envelope, the certificate shall indicate the area-weighted average value where available. If the area-weighted average is not available, the certificate shall list each value that applies to 10 percent or more of the total component area.

C401.5 Target Performance Path.

C401.5.1 Scope. Buildings of the following occupancy types, including their initial tenant improvements, are permitted to conform to the Target Performance Path as described in this section and are not required to comply with Seattle Energy Code requirements other than the mandatory measures listed in Section C401.5.3.

1. Group B office.
2. Group B medical office.
3. Group R-2 multi-family over three stories.
4. Group S-1 & S-2 warehouse (non-refrigerated).
5. Group E school.
6. Group M retail.
7. Group I-2 hospital.
8. Other occupancy type, where specific permission is granted by the code official. Any such permission, if granted, shall be made 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, adjusted to recognize the additional stringency of the current energy code.
9. Mixed use: A mixed use building is any building containing more than one of the occupancies listed in 1 through 8 above.

C401.5.1.1 Increased building performance factor. Each building conforming to this section is permitted to utilize a building performance factor (BPF) 1.12 times the BPF in Table C407.3(2).

C401.5.1.2 Site Energy Performance Target. Each building conforming to this section must demonstrate compliance with the Site energy performance factor per Table C407.3(3) as part of the permit review. Documentation of compliance with Site Energy Performance Target during the performance period is not required.

C401.5.1.3 Conversion of energy use to carbon emissions. Energy use in Target Performance Path calculations shall be converted to carbon emissions according to Table C407.3(1).

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C401.5.2.1 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 the code official showing daily, monthly and annual totals during the operational energy use demonstration period set forth in Section C401.5.6. Actual *IT energy* shall be adjusted in accordance with Section C401.5.7.

C401.5.3 Mandatory measures. Buildings using the Target Performance Path shall:

1. Not exceed the building performance factor (BPF) permitted by Section C401.5.1.1;
2. Not use fossil fuel combustion or electric resistance appliances for purposes of space heating or domestic water heating, except as permitted by the exceptions to Section C403.1.4;
3. Have a building envelope with a Proposed Total UA no greater than the Allowable Total UA as determined by Section C407.3.1; and
4. Comply with the mandatory measures listed in Table C407.2.

C401.5.4 Energy modeling methodology. Energy use shall be modeled according to the requirements of Section C407. Total Building Performance:

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

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

In addition to documenting modeling assumptions, the application documentation required by Section G1.3.2 of ASHRAE 90.1, Appendix G, shall include the following:

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

Table C401.5.4
Example of Sensitivity Analysis Report Format

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

C401.5.5 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 qual-

ified by training and experience to perform energy modeling or by an individual with an active certification from ASHRAE as a Building Energy Modeling Professional (BEMP).

C401.5.6 Demonstration of operating energy use. Metered energy data shall be supplied directly via automated reporting from utilities to the *code official* using Portfolio Manager, and adjusted for the percentage of the *conditioned floor area* intended for occupancy that is occupied during the recording period. While more than 95 percent occupied, the building shall be considered fully occupied. While no less than 85 percent occupied, the building shall operate at or below its assigned building performance factor established in Section C401.5.2 or Item 8 of Section C401.5.1 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 C401.5. The owner shall notify the *code official* when this 12-month period has been success- fully completed.

SDCI Informative Note: Documentation of compliance with the site energy reduction target in Section C407.3 is not required.

C401.5.6.1 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 C401.5.6 based on the most recent one-year period and adjusted for the actual occupancy rate during that period.

C401.5.7 Adjustment for data center energy usage. Where *data center IT energy* usage during the demonstration period, multiplied by a factor of 1.45, is higher than the total *data center* energy use as calculated according to Section C401.5.2.1, 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 C401.5.2.1, that shortfall shall be subtracted from the total allowable energy use.

C401.5.8 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 C401.5.2, 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.

C401.5.9 Adjustment for unusually cold years. If the heating degree days (HDD) recorded by the National Weather Service for the Seattle-Tacoma International Airport exceeds 4,885 HDD for the 12-month demonstration period (4 percent above the average 4,697 HDD at 65°F base), the assigned energy performance target is permitted to be increased by 1 percent for that period.

C401.5.10 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.

C401.5.11 Adjustment for commercial kitchens and other large process loads. Where the building includes a commercial kitchen, commercial laundry, hospital central sterile processing facility, or similar large process load, and where *approved* by the *code official*, the energy use of the process equipment and exhaust fans and relief air fans and air tempering associated with the use of that equipment is permitted to be separately sub-metered and subtracted from the overall building energy usage. Energy use of typical HVAC, lighting, and miscellaneous electrical loads within such spaces shall not be included in this adjustment. An *approved* plan shall be submitted with the permit documents detailing how the sub-metered process load energy will be automatically deducted from the total building energy use and the adjusted total reported to the *code official*.

C401.5.12 Financial security. The applicant shall provide a financial security to be used as a penalty for failing to achieve an operating energy use lower than the building's energy use target according to Section C401.5.6. The penalty shall be administered as provided in Section C110, except that the amount of the penalty shall be determined using Table C401.5.13 and not Section C107. The financial security shall be submitted to and *approved* by the *code official* prior to issuance of the building's Certificate of Occupancy. The financial security requirement shall be fulfilled by one of the following methods:

1. An irrevocable letter of credit from a financial institution authorized to do business in Seattle, in an amount equal to \$4.00 per square foot of gross *conditioned 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 *conditioned floor area*.
3. A binding pledge that within 3 years of receipt of the Certificate of Occupancy, adjusted as allowed under Section C401.5.6.1, the applicant will comply with the requirements of this section.

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3.1. A binding pledge pursuant to item 3 of this subsection shall be recorded as a covenant in the land records of King County between the applicant and The City of Seattle in a form that is satisfactory to the Seattle City Attorney. The covenant shall bind the applicant and any successors in title to pay any fines levied pursuant to this section. A lien will be placed on the property in cases of non-payment.

If the owner provides evidence that the building has operated at or below its target energy performance level as provided in Section C401.5.6, 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.

C401.5.13 Procedure for non-compliance. If the owner fails to provide evidence that the building has operated as required under Section C401.5.6, 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 C401.5.12(3). The fine shall be issued as a civil penalty.

The amount of the fine levied or the amount drawn down from a financial security shall be determined according to Table C401.5.13.

**Table C401.5.13
Financial Security and Energy Efficiency Reimbursements**

<u>Energy use exceeding target</u>	<u>Amount of fine or draw-down from financial security, per square foot of gross conditioned floor area</u>	<u>Maximum reimbursement per square foot of gross conditioned floor area for work approved under Section C401.5.12</u>
<u>Less than 10%</u>	<u>\$1.00</u>	<u>\$0.50</u>
<u>10% to less than 20%</u>	<u>\$2.00</u>	<u>\$1.00</u>
<u>20% to less than 30%</u>	<u>\$3.00</u>	<u>\$1.50</u>
<u>30% or greater</u>	<u>\$4.00</u>	<u>\$2.00</u>

C401.5.14 Reimbursements. Where a financial security has been drawn down pursuant to item 1 in Section C401.5.13, or a fine has been levied pursuant to item 2 in Section C401.5.13, the code official shall reimburse the owner for documented expenses incurred to lower the operating energy use of the building, including commissioning, repairs or improvements to the existing energy-consuming systems, or provision of additional energy efficiency measures, up to the maximum reimbursement amounts listed in Table C401.5.13. Such expenditures shall be approved in advance by the code official, and the work shall be fully completed within one year of the date when a financial security has been drawn down pursuant to item 1 in Section C401.5.13, or a fine has been levied pursuant to item 2 in Section C401.5.13.

**SECTION C402
BUILDING ENVELOPE REQUIREMENTS**

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

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

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

C402.1.1 Low energy buildings, semi-heated buildings and greenhouses. Low energy buildings shall comply with Section C402.1.1.1. Semi-heated buildings and spaces shall comply with Section C402.1.1.2. Greenhouses shall comply with Section C402.1.1.3.

C402.1.1.1 Low energy buildings. The following buildings, or enclosed portions thereof, separated from the remainder of the building by *building thermal envelope* assemblies complying with this code shall be exempt from all thermal envelope provision of this code:

1. Those that are heated and/or cooled with a peak design rate of energy usage less than 3.4 Btu/h × ft² (10.7 W/m²) or 1.0 watt/ft² (10.7 W/m²) of floor area for space conditioning purposes.

2. Those that do not contain *conditioned space*.
3. Unstaffed equipment shelters or cabinets used solely for personal wireless service facilities.

C402.1.1.2 Semi-heated buildings and spaces. The building envelope of *semi-heated* buildings, or portions thereof, shall comply with the same requirements as that for conditioned spaces in Section C402, except as modified by this section. The total installed output capacity of mechanical space conditioning systems serving a *semi-heated* building or space shall comply with Section C202, except as modified by this section. Building envelope assemblies separating conditioned space from *semi-heated space* shall comply with exterior envelope insulation requirements. *Semi-heated spaces* are not required to comply with the opaque wall insulation provisions of Section ((~~C402.2.3~~)) C402.2.2 for walls that separate *semi-heated* spaces from the exterior or low energy spaces. Fenestration that forms part of the *building thermal envelope* enclosing semi-heated spaces shall comply with Section C402.4. *Semi-heated spaces* shall be calculated separately from other conditioned spaces for compliance purposes.

Opaque walls in *semi-heated* spaces shall be calculated as fully code compliant opaque walls for both the target and proposed for the Target UA calculations for Component Performance compliance per Section C402.1.5, and for the Baseline Building Design for Total Building Performance compliance per Section C407. The capacity of heat trace temperature maintenance systems complying with Section C404.7.2 that are provided for freeze protection of piping and equipment only shall not be included in the total installed output capacity of mechanical space conditioning systems.

EXCEPTION: Provided the total installed heating output capacity of mechanical space conditioning does not exceed the criteria for semi-heated space as defined in Section C202, a semi-heated building or space is permitted to comply with this section when served by heat pumps without electric resistance back up and connected to a heating only thermostat.

SDCI Informative Note: There is no separate “freeze protection” space conditioning category for unoccupied utility buildings. Spaces with no cooling and less than 3.4 BTU/h-ft² heating capacity are not required to be insulated. The opaque walls of spaces that meet the definition of “semiheated” in Chapter 2 are not required to be insulated, but other- wise the thermal envelope of semiheated spaces must meet all requirements for *conditioned space*. Spaces with any mechanical cooling or with more than 8 BTU/h-ft² heating capacity must meet all the *building thermal envelope* requirements for *conditioned space*.

C402.1.1.3 Greenhouses. *Greenhouse* structures or areas that comply with all of the following shall be exempt from the building envelope requirements of this code:

1. Exterior opaque envelope assemblies complying with Sections C402.2 and C402.4.4.
 - EXCEPTION:** Low energy greenhouses that comply with Section C402.1.1.1.
2. Interior partition building thermal envelope assemblies that separate the *greenhouse* from conditioned space complying with Sections C402.2, C402.4.3 and C402.4.4.
3. Fenestration assemblies complying with the thermal envelope requirements in Table C402.1.1.3. The *U*-factor for the skylight shall be for the roof assembly or a roof that includes the assembly and an internal curtain system.
 - EXCEPTION:** Unheated *greenhouses*.
4. No mechanical cooling is provided.
5. For heated greenhouses, heating is provided by a radiant heating system, a condensing natural gas-fired or condensing propane-fired heating system, or a heat pump with cooling capacity permanently disabled as pre-approved by the jurisdiction.

**Table C402.1.1.3
Fenestration Thermal Envelope Maximum Requirements**

Component	<i>U</i> -Factor BTU/h-ft ² -°F
Skylights	0.5
Vertical fenestration	0.6

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

1. Are separate buildings with floor area no more than 500 square feet (50 m²).
2. Are intended to house electric equipment with installed equipment power totaling at least 7 watts per square foot (75 W/m²) and not intended for human occupancy.
3. Are served by mechanical cooling and heating systems sized in accordance with Sections C403.1.2 and C403.3.1.
4. Have a heating system capacity not greater than 17,000 Btu/hr (5 kW) and a heating thermostat set point that is restricted to not more than 50°F (10°C).

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5. Have an average wall and roof *U*-factor less than 0.200.

EXCEPTION: Where the cooling and heating system is a heat pump, the heating capacity is allowed to exceed 17,000 Btu/h provided the heat pump cooling efficiency is at least 15 percent better than the requirements in Tables C403.3.2(2) and C403.3.2(14).

C402.1.2.1 Standalone elevator hoistways. Elevator hoistways that comply with all of the following shall be exempt from the building thermal envelope and envelope air barrier provisions of this code:

1. Are separate from any other conditioned spaces in the building (do not serve or open into any conditioned, semi-heated or indirectly conditioned space).
2. Have heating and/or cooling equipment sized only to serve the expected elevator loads with thermostat setpoints restricted to heating to no higher than 40°F and cooling to no lower than 95°F.
3. Have an area weighted average wall, roof and floor (where applicable) *U*-factor of less than or equal to 0.20. Calculations must include any floor-slab-edges that penetrate the hoistway and thus are considered part of the above-grade walls.

**Table C402.1.3
Opaque Thermal Envelope Insulation Component
Minimum Requirements, *R*-value Method^{a, (b)} †**

CLIMATE ZONE	5 AND MARINE 4	
	All Other	Group R
	Roofs	
Insulation entirely above deck	R-38ci	R-38ci
Metal buildings ^b	R-25 + R-22 LS	R-25 + R-22 LS
Attic and other	R-49	R-49
	Walls, Above Gradeⁱ	
Mass ^b	((R-9.5ei)) <u>Exterior: R-16 c.i.</u> <u>Interior:</u> <u>R-13 + R-6 ci wood stud, or</u> <u>R-13 + R-10 ci metal stud</u>	((R-13.3ei)) <u>Exterior: R-16 c.i.</u> <u>Interior:</u> <u>R-13 + R-6 ci wood stud, or</u> <u>R-13 + R-10 ci metal stud</u>
Interior:		
R-13 + R-6 ci wood stud, or		
R-13 + R-10 ci metal stud	Exterior: R-16 c.i.	
Interior:		
R-13 + R-6 ci wood stud, or		
R-13 + R-10 ci metal stud		
Mass transfer deck slab edge	N/R	N/R
Metal buildings	R-13 + R-14ci	R-13 + R-14ci
Steel framed	R-13 + R-10ci	R-19 + R-8.5ci
Wood framed and other	R-13 + R-7.5ci std or R-20 + R-3.8ci std <u>or R-25</u> std	R-13 + R-7.5ci std or R-20 + R-3.8ci std or R-25 std
	Walls, Below Grade	
Below-grade wall ^{d,h}	((Same as above grade)) <u>Exterior: R-10 ci</u> <u>Interior:</u> <u>R-19 wood stud, or</u> <u>R-13 + R-6 ci metal stud</u>	((Same as above grade)) <u>Exterior: R-10 ci</u> <u>Interior:</u> <u>R-19 wood stud, or</u> <u>R-13 + R-6 ci metal stud</u>
	Floors	
Mass ^f	R-30ci	R-30ci
Joist/framing	Steel frame: R-38 +R-10 ci Wood frame: R-38	Steel frame: R-38 +R-10 ci Wood frame: R-38
	Slab-on-Grade Floors	
Unheated slabs	R-10 for 24" below	R-10 for 24" below
Heated slabs	R-10 perimeter & under entire slab	R-10 perimeter & under entire slab

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.
- a Assembly descriptions can be found in Chapter 2 and Appendix A.
 - b Where using *R*-value compliance method, a thermal spacer block with minimum thickness of 1/2-inch and minimum *R*-value of R-3.5 shall be provided, otherwise use the *U*-factor compliance method in Table C402.1.4.
 - c (Reserved) (~~Exception: Integral insulated concrete block walls complying with ASTM C90 with all cores filled and meeting both of the following: At least 50 percent of cores must be filled with vermiculite or equivalent fill insulation; and The building thermal envelope encloses one or more of the following uses: Warehouse (storage and retail), gymnasium, auditorium, church chapel, arena, kennel, manufacturing plant, indoor swimming pool, pump station, water and waste water treatment facility, storage facility, storage area, motor vehicle service facility. Where additional uses not listed (such as office, retail, etc.) are contained within the building, the exterior walls that enclose these areas may not utilize this exception and must comply with the appropriate mass wall *R*-value from Table C402.1.3/*U*-factor from Table C402.1.4.~~)
 - d Where heated slabs are below grade, they shall comply with the insulation requirements for heated slabs.
 - e (Reserved)
 - f “Mass floors” shall include floors weighing not less than:
 - 1. 35 pounds per square foot of floor surface area; or
 - 2. 25 pounds per square foot of floor surface area where the material weight is not more than 120 pounds per cubic foot.
 - g Component performance in accordance with Section C402.1.5 shall be required for buildings with a mass transfer deck slab.
 - h Peripheral edges of intermediate concrete floors are included in the above-grade mass wall category and therefore must be insulated as above-grade mass walls unless they meet the definition of Mass Transfer Deck Slab Edge. The area of the peripheral edges of concrete floors shall be defined as the thickness of the slab multiplied by the perimeter length of the edge condition. See Table A103.3.7.2 for typical default *U*-factors for above-grade slab edges and footnote c for typical conditions of above-grade slab edges.
 - i Where the total area of through-wall mechanical equipment is greater than 1 percent of the opaque *above-grade wall area*, use of the *R*-value method is not permitted. See Section C402.1.4.3.
 - j For roof, wall or floor assemblies where the proposed assembly would not be *continuous insulation*, alternate nominal *R*-value compliance options for assemblies with isolated metal fasteners that penetrate otherwise *continuous insulation* are as shown in columns B and C of Table C402.1.3(i):

Table C402.1.3(i)
Continuous Insulation Equivalents

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

Notes for Table C402.1.3(i)

These alternate nominal *R*-value compliance options are allowed for projects complying with all of the following:

- 1a. The ratio of the cross-sectional area, as measured in the plane of the surface, of metal penetrations of otherwise continuous insulation to the opaque surface area of the assembly is greater than 0.0004 (0.04%), but less than 0.0008 (0.08%), for use of Column B equivalents, and greater than or equal to 0.008 (0.08%), but less than 0.012 (0.12%), for use of Column C equivalents.
- 1b. Where all metal penetrations are stainless steel, Column B is permitted to be used for penetrations greater than 0.12%, but less than 0.24% of opaque surface area, and Column C is permitted to be used for penetrations greater than or equal to 0.24%, but less than 0.48% of opaque surface area.
- 2. The metal penetrations of otherwise continuous insulation are isolated or discontinuous (e.g., brick ties or other discontinuous metal attachments, offset brackets supporting shelf angles that allow insulation to go between the shelf angle and the primary portions of the wall structure). No continuous metal elements (e.g., metal studs, z-girts, z-channels, shelf angles) penetrate the otherwise continuous portion of the insulation.
- 3. Building permit drawings shall contain details showing the locations and dimensions of all the metal penetrations (e.g., brick ties or other discontinuous metal attachments, offset brackets, etc.) of otherwise continuous insulation. In addition, calculations shall be provided showing the ratio of the cross-sectional area of metal penetrations of otherwise continuous insulation to the overall opaque wall area.
For other cases where the proposed assembly is not continuous insulation, see Section C402.1.4 for determination of *U*-factors for assemblies that include metal other than screws and nails.

GENERAL REQUIREMENTS

C402.1.3 Insulation component *R*-value-based method. *Building thermal envelope* opaque assemblies shall comply with the requirements of Section C402.2 based on the climate zone specified in Chapter 3. For opaque portions of the *building thermal envelope* intended to comply on an insulation component *R*-value basis, the *R*-values for cavity insulation and continuous insulation shall not be less than that specified in Table C402.1.3. Where cavity insulation is installed in multiple layers, the cavity insulation *R*-values shall be summed to determine compliance with the cavity insulation *R*-value requirements. Where continuous insulation is installed in multiple layers, the continuous insulation *R*-values shall be summed to determine compliance with the continuous insulation *R*-value requirements. Cavity insulation *R*-values shall not be used to determine compliance with the continuous insulation *R*-value requirements in Table C402.1.3. Commercial buildings or portions of commercial buildings enclosing Group R occupancies shall use the *R*-values from the “Group R” column of Table C402.1.3. Commercial buildings or portions of commercial buildings enclosing occupancies other than Group R shall use the *R*-values from the “All other” column of Table C402.1.3.

EXCEPTION: For stair and elevator shafts that do not comply with Section C402.1.2.1 and that are located within enclosed garages or other enclosed non-conditioned spaces and without conditioned supply air or cooling or heating appliances rated higher than 2 kW in any shaft, walls enclosing the shafts are permitted to be:

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

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

C402.1.4 Assembly *U*-factor, *C*-factor, or *F*-factor-based method. Building thermal envelope opaque assemblies shall meet the requirements of Section C402.2 based on the climate zone specified in Chapter 3. Building thermal envelope opaque assemblies intended to comply on an assembly *U*-, *C*-, or *F*-factor basis shall have a *U*-, *C*-, or *F*-factor not greater than that specified in Table C402.1.4. Commercial buildings or portions of commercial buildings enclosing Group R occupancies shall use the *U*-, *C*-, or *F*-factor from the “Group R” column of Table C402.1.4. Commercial buildings or portions of commercial buildings enclosing occupancies other than Group R shall use the *U*-, *C*-, or *F*-factor from the “All other” column of Table C402.1.4. The *U*-factors for typical construction assemblies are included in Appendix A. These values shall be used for all calculations. Where proposed construction assemblies are not represented in Appendix A, values shall be calculated in accordance with the ASHRAE *Handbook—Fundamentals* using the framing factors listed in Appendix A where applicable and shall include the thermal bridging effects of framing materials.

C402.1.4.1 Roof/ceiling assembly. The maximum roof/ceiling assembly *U*-factor shall not exceed that specified in Table C402.1.4 based on construction materials used in the roof/ceiling assembly.

C402.1.4.1.1 Suspended ceilings. Insulation installed on suspended ceilings having removable ceiling tiles shall not be considered part of the assembly *U*-factor of the roof/ceiling construction.

C402.1.4.1.2 Joints staggered. Continuous insulation board shall be installed not less than two layers, and the edge joints between each layer of insulation shall be staggered, except where insulation tapers to the roof deck at a gutter edge, roof drain, or scupper.

C402.1.4.2 Thermal resistance of cold-formed steel stud walls. *U*-factors of walls with cold-formed steel studs shall be permitted to be determined either by using the values in Table C402.1.4.2, or in accordance with Equation 4-1:

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

Where:

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

ER = The effective *R*-value of the cavity insulation with steel studs as specified in Table C402.1.4.2.

C402.1.4.3 Thermal resistance of mechanical equipment penetrations. When the total area of penetrations from through-wall mechanical equipment or equipment listed in Table C403.3.2(4) exceeds 1 percent of the opaque *above-grade wall* area, the mechanical equipment penetration area shall be calculated as a separate wall assembly with a default *U*-factor of 0.5. Mechanical system ducts and louvers, including those for supply, exhaust and relief, and for condenser air intake and outlet, are not considered to be mechanical equipment for the purposes of this section.

EXCEPTION: Where mechanical equipment has been tested in accordance with *approved* testing standards, the mechanical equipment penetration area is permitted to be calculated as a separate wall assembly using the *U*-factor determined by such test.

Table C402.1.4
Opaque Thermal Envelope Requirements^{a,f}

CLIMATE ZONE	5 AND MARINE 4	
	All Other	Group R
Roofs		
Insulation entirely above deck	U-0.027	U-0.027
Metal buildings	((U-0.031)) <u>U-0.027</u>	((U-0.031)) <u>U-0.027</u>
Attic and other	U-0.021	U-0.021
Joist or single rafter	U-0.027	U-0.027
Walls, Above Grade^k		
Mass ^g	((U-0.104^d)) <u>U-0.057</u>	((U-0.078)) <u>U-0.057</u>
Mass transfer deck slab ⁱ	U-0.20	U-0.20
<u>Slab penetrating thermal envelope wall^h</u>	<u>U-0.10</u>	<u>U-0.10</u>
Metal building	U-0.050	U-0.050
Steel framed	U-0.055	U-0.055
Wood framed and other	U-0.051	U-0.051
Walls, Below Grade		
Below-grade wall ^{b, g}	((Same as above grade)) <u>U-0.070</u>	((Same as above grade)) <u>U-0.070</u>
Floors		
Mass ^e	U-0.031	U-0.031
Joist/framing	((U-0.029)) <u>U-0.029 steel joist</u> <u>U-0.025 wood joist</u>	((U-0.029)) <u>U-0.029 steel joist</u> <u>U-0.025 wood joist</u>
<u>Concrete column or concrete wall penetrating thermal envelope floor^l</u>	<u>U-0.55</u>	<u>U-0.55</u>
<u>Concrete slab floor directly above an electrical utility vault</u>	<u>N.R.</u>	<u>N.R.</u>
Slab-on-Grade Floors		
Unheated slabs	F-0.54	F-0.54
Heated slabs ^c	F-0.55	F-0.55
Opaque Doors		
Nonswinging door	U-0.31	U-0.31
Swinging door ^h	U-0.37	U-0.37
Garage door <14% glazing	U-0.31	U-0.31
Garage door ≥14% and <50% glazing ⁱ	U-0.34	U-0.34

- a Use of opaque assembly *U*-factors, *C*-factors, and *F*-factors from Appendix A is required unless otherwise allowed by Section C402.1.4.
- b ~~(Reserved)~~ ~~((Where heated slabs are below grade, they shall comply with the *F* factor requirements for heated slabs.))~~
- c Heated slab *F*-factors shall be determined specifically for heated slabs. Unheated slab factors shall not be used.
- d ~~(Reserved)~~ ~~((**Exception:** Integral insulated concrete block walls complying with ASTM C90 with all cores filled and meeting both of the following: At least 50 percent of cores must be filled with vermiculite or equivalent fill insulation; and The building thermal envelope encloses one or more of the following uses: Warehouse (storage and retail), gymnasium, auditorium, church chapel, arena, kennel, manufacturing plant, indoor swimming pool, pump station, water and waste water treatment facility, storage facility, storage area, motor vehicle service facility. Where additional uses not listed (such as office, retail, etc.) are contained within the building, the exterior walls that enclose these areas may not utilize this exception and must comply with the appropriate mass wall *R*-value from Table C402.1.3/U-factor from Table C402.1.4.))~~
- e "Mass floors" shall include floors weighing not less than:
- 35 pounds per square foot of floor surface area; or
 - 25 pounds per square foot of floor surface area where the material weight is not more than 120 pounds per cubic foot.
- f Opaque assembly *U*-factors based on designs tested in accordance with ASTM C1363 shall be permitted. The *R*-value of continuous insulation shall be permitted to be added or subtracted from the original test design.
- g Peripheral edges of intermediate concrete floors are included in the above-grade mass wall category and therefore must be insulated as above-grade mass walls unless they meet the definition of *Mass Transfer Deck Slab*. The area of the peripheral edges of concrete floors shall be defined as the thickness of the slab multiplied by the perimeter length of the edge condition. See Table A103.3.7.2 for typical default *U*-factors for above-grade slab edges and footnote c for typical conditions of above-grade slab edges.
- h Swinging door *U*-factors shall be determined in accordance with NFRC-100.

GENERAL REQUIREMENTS

- i Garage doors having a single row of fenestration shall have an assembly *U*-factor less than or equal to 0.44, provided that the fenestration area is not less than 14 percent and not more than 25 percent of the total door area.
 - j Component performance in accordance with Section C402.1.5 shall be required for buildings with a mass transfer deck slab. A mass transfer deck, due to its configuration, is not insulated. The table value (U-0.20) shall be used as the baseline value for component performance or total building performance path calculations. For the proposed value, the appropriate value from Table ((A-104.3.7.2)) A103.3.7.2 shall be used.
 - k Through-wall mechanical equipment subject to Section C402.1.4.3 shall be calculated at the *U*-factor defined in Section C402.1.4.3. The area-weighted *U*-factor of the wall, including through-wall mechanical equipment, shall not exceed the value in the table.
- 1 Value applies to concrete columns and concrete walls that interrupt mass floor insulation, but not to perimeter walls or columns separating interior conditioned space from exterior space.

**Table C402.1.4.2
Effective R-values For Steel Stud Wall Assemblies**

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

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

For buildings with more than one *space conditioning category*, component performance compliance shall be demonstrated separately for each space conditioning category. Interior partition ceilings, walls, fenestration and floors that separate space conditioning areas shall be applied to the component performance calculations for the space conditioning category with the highest level of space conditioning.

$$\text{Proposed Total UA} \leq \text{Allowable Total UA} \quad \text{(Equation 4-2)}$$

Where:

- Proposed Total UA = UA-glaz-prop + UA sky-prop + UA-opaque-prop + FL-slab-prop
- Allowable Total UA = UA-glaz-allow + UA-glaz-excess + UA sky-allow + UA-sky-excess + UA-opaque-allow + FL-slab-allow
- UA-glaz-prop = Sum of (proposed *U*-value × proposed area) for each distinct vertical fenestration type, up to code maximum area
- UA-sky-prop = Sum of (proposed *U*-value × proposed area) for each distinct skylight type, up to the code maximum area
- UA-opaque-prop = Sum of (proposed *U*-value × proposed area) for each distinct opaque thermal envelope type
- FL-slab-prop = Sum of (proposed *F*-value × proposed length) for each distinct slab on grade perimeter assembly
- UA-glaz-allow = Sum of (code maximum vertical fenestration *U*-value from Table C402.4, or Section C402.4.1.1.2 if applicable, × proposed area) for each distinct vertical fenestration type, not to exceed the code maximum area¹
- UA-glaz-excess = *U*-value for the proposed wall type from Table C402.4² × vertical fenestration area in excess of the code maximum area
- UA-sky-allow = Sum of (code maximum skylight *U*-value from Table C402.4 × proposed area) for each distinct skylight type proposed, not to exceed the code maximum area
- UA-sky-excess = *U*-value for the proposed roof type from Table C402.4³ × skylight area in excess of the code maximum area
- UA-opaque-allow = Code maximum opaque envelope *U*-value from Table C402.1.4 for each *opaque door*, wall, roof, and floor assembly × proposed area
- FL-slab-allow = Code maximum *F*-value for each slab-on-grade perimeter assembly × proposed length

Notes:

- 1 Where multiple vertical fenestration types are proposed and the code maximum area is exceeded, the *U*-value shall be the average Table C402.1.4 *U*-value weighted by the proposed vertical fenestration area of each type.
- 2 Where multiple wall types are proposed the *U*-value shall be the average Table C402.1.4 *U*-value weighted by the proposed above grade wall area of each type.

3 Where multiple roof types are proposed the *U*-value shall be the average Table C402.1.4 *U*-value weighted by the proposed roof area of each type.

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

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

1. Results of laboratory measurements according to acceptable methods of test.
2. ASHRAE *Handbook—Fundamentals* where the metal framing is bonded on one or both sides to a metal skin or covering.
3. The zone method as provided in ASHRAE *Handbook—Fundamentals*.
4. Effective framing/cavity *R*-values as provided in Appendix A.

When return air ceiling plenums are employed, the roof/ceiling assembly shall:

- a. For thermal transmittance purposes, not include the ceiling proper nor the plenum space as part of the assembly; and
 - b. For gross area purposes, be based upon the interior face of the upper plenum surface.
5. Tables in ASHRAE 90.1 Normative Appendix A.
 6. Calculation method for steel-framed walls in accordance with Section ((~~C402.1.4.1~~)) C402.1.4.2 and Table ((~~C402.1.4.1~~)) C402.1.4.2.

C402.1.5.2 SHGC rate calculations. Fenestration SHGC values for individual components and/or fenestration are permitted to exceed the SHGC values in Table C402.4 and/or the maximum allowable fenestration areas in Section C402.4.1 where the proposed total SHGCxA less than the allowable total SHGCxA as determined by Equation 4-3.

$$\text{Proposed Total SHGCxA} \leq \text{Allowable Total SHGCxA} \quad \text{(Equation 4-3)}$$

Where:

Proposed Total SHGCxA	=	SHGCxA-glaz-prop + SHGCxA-sky-prop
Allowable Total SHGCxA	=	SHGCxA-glaz-allow + SHGCxA-sky-allow
SHGCxA-glaz-prop	=	Sum of (proposed SHGCx proposed area) for each distinct vertical fenestration type
SHGCxA-sky-prop	=	Sum of (proposed SHGCx proposed area) for each distinct skylight type
SHGCxA-glaz-allow	=	Sum of (code maximum vertical fenestration SHGC from Table C402.4, or Section C402.4.1.3 if applicable, × proposed area) for each distinct vertical fenestration type, not to exceed the code maximum area
SHGCxA-sky-allow	=	Sum of (code maximum skylight SHGC from Table C402.4 × proposed area) for each distinct skylight type, not to exceed the code maximum area

If the proposed vertical fenestration area does not exceed the Vertical Fenestration Area allowed, the target area for each vertical fenestration type shall equal the proposed area. If the proposed vertical fenestration area exceeds the Vertical Fenestration Area allowed, the target 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 Vertical Fenestration Area allowed.

If the proposed skylight area does not exceed the Allowable Skylight Area from Section C402.4.1, the target area shall equal the proposed area. If the proposed skylight area exceeds the Allowable Skylight Area from Section C402.4.1, 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.

C402.2 Specific building thermal envelope insulation requirements. Insulation in building thermal envelope opaque assemblies shall comply with Sections C402.2.1 through ((~~C402.2.8~~)) C402.2.9 and Table C402.1.3.

Where this section refers to installing insulation levels as specified in Section C402.1.3, assemblies complying prescriptively with Section C402.1.4 and buildings complying with Section C402.1.5 are allowed to install alternate levels of insulation so long as the *U*-factor of the insulated assembly is less than or equal to the *U*-factor required by the respective path.

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 C402.1.3, based on construction materials used in the roof assembly.

GENERAL REQUIREMENTS

EXCEPTIONS:

1. Where tapered insulation is used with insulation entirely above deck, those roof assemblies shall show compliance on a U -factor basis per Section C402.1.4. The effective U -factor shall be determined through the use of Tables A102.2.6(1), A102.2.6(2) and A102.2.6(3).
2. Two layers of insulation are not required where insulation tapers to the roof deck, such as at roof drains. At roof drains, the immediate 24 inch by 24 inch plan area around each roof drain has a minimum insulation requirement of R-13, but otherwise is permitted to be excluded from the roof insulation area-weighted calculations.

C402.2.1.1 Minimum thickness, lowest point. The minimum thickness of above-deck roof insulation at its lowest point, gutter edge, roof drain or scupper, shall be not less than 1 inch (25 mm).

C402.2.1.2 Suspended ceilings. Insulation installed on suspended ceilings having removable ceiling tiles shall not be considered part of the minimum thermal resistance (R -value) of roof insulation in roof/ceiling construction.

C402.2.1.3 Skylight curbs. Skylight curbs shall be insulated to the level of roofs with insulation entirely above deck or R-5, whichever is less.

EXCEPTION: Unit skylight curbs included as a component of a skylight listed and labeled in accordance with NFRC 100 shall not be required to be insulated.

C402.2.1.4 Rooftop HVAC equipment curbs. Structural curbs installed to support rooftop HVAC equipment are allowed to interrupt the above roof insulation. The area under the HVAC equipment inside of the equipment curb shall be insulated to a minimum of R-13 in all locations where there are not roof openings for ductwork. The annular space between the roof opening and the ductwork shall be sealed to maintain the building air barrier. The plan-view area of the HVAC equipment curb shall be excluded from the prescriptive roof insulation requirements or the area-weighted component performance calculations.

C402.2.2 Above-grade walls. The minimum thermal resistance (R -value) of materials installed in the wall cavity between the framing members and continuously on the walls shall be as specified in Table C402.1.3, based on framing type and construction materials used in the wall assembly. The R -value of integral insulation installed in concrete masonry units (CMU) shall not be used in determining compliance with Table C402.1.3 except as otherwise noted in the table. In determining compliance with Table C402.1.4, the use of the U -factor of concrete masonry units with integral insulation shall be permitted.

“Mass walls” where used as a component in the thermal envelope of a building shall comply with one of the following:

1. Weigh not less than 35 psf (170 kg/m²) of wall surface area.
2. Weigh not less than 25 psf (120 kg/m²) of wall surface area where the material weight is not more than 120 pounds per cubic foot (pcf) (1,900 kg/m³).
3. Have a heat capacity exceeding 7 Btu/ft² × °F (144 kJ/m² × K).
4. Have a heat capacity exceeding 5 Btu/ft² × °F (103 kJ/m² × K) where the material weight is not more than 120 pcf (1900 kg/m³).

C402.2.3 Floors. The thermal properties (component R -values or assembly U - or F -factors) of floor assemblies over outdoor air or unconditioned space shall be as specified in Table C402.1.3 or C402.1.4 based on the construction materials used in the floor assembly. Floor framing cavity insulation or structural slab insulation shall be installed to maintain permanent contact with the underside of the subfloor decking or structural slabs.

“Mass floors” where used as a component of the thermal envelope of a building shall provide one of the following weights:

1. Thirty-five pounds per square foot of floor surface area;
2. Twenty-five pounds per square foot of floor surface area where the material weight is not more than 120 pounds per cubic foot.

EXCEPTIONS:

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

C402.2.4 Slabs-on-grade. The minimum thermal resistance (R -value) of the insulation for unheated or heated slab-on-grade floors designed in accordance with the R -value method of Section C402.1.3 shall be as specified in Table C402.1.3.

C402.2.4.1 Insulation installation. Where installed, the perimeter insulation shall be placed on the outside of the foundation or on the inside of the foundation wall. The perimeter 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 not less than 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. Where installed, full slab insulation shall be continuous under the entire area of the slab-on-grade floor, except at structural column locations and service penetrations. Insulation required at the heated slab perimeter shall not be required to extend below the bottom of the heated slab and shall be continuous with the full slab insulation.

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

C402.2.5 Below-grade walls. The R -value of the insulating material installed in, or continuously on, the below-grade walls shall be in accordance with Table C402.1.3. The U -factor or R -value required shall extend to the level of the lowest floor of the conditioned space enclosed by the below-grade wall.

C402.2.6 Insulation of radiant heating systems. *Radiant heating system* panels, and their associated components that are installed in interior or exterior assemblies shall be insulated to an R -value of not less than R -3.5 on all surfaces not facing the space being heated. *Radiant heating system* panels that are installed in the *building thermal envelope* shall be separated from the exterior of the building or unconditioned or exempt spaces by not less than the R -value of insulation installed in the opaque assembly in which they are installed or the assembly shall comply with Section C402.1.4.

EXCEPTION: Heated slabs on grade insulated in accordance with Section C402.2.4.

C402.2.7 Airspaces. Where the R -value of an airspace is used for compliance in accordance with Section C401.2, the airspace shall be enclosed in an unventilated cavity constructed to minimize airflow into and out of the enclosed airspace. Airflow shall be deemed minimized where the enclosed airspace is located on the interior side of the continuous air barrier and is bounded on all sides by building components.

EXCEPTION: The thermal resistance of airspaces located on the exterior side of the continuous air barrier and adjacent to and behind the exterior wall covering material shall be determined in accordance with ASTM C1363 modified with an airflow entering the bottom and exiting the top of the airspace at a minimum air movement rate of not less than 70 mm/sec.

C402.2.8 Above-grade exterior concrete slabs. Above-grade concrete slabs that penetrate the *building thermal envelope* including, but not limited to, decks and balconies, shall each include a minimum R -10 thermal break, aligned with the primary insulating layer in the adjoining wall assemblies. Stainless steel (but not carbon steel) reinforcing bars are permitted to penetrate the thermal break. If the total building performance path or the component performance alternative in Section C402.1.5 is utilized and the thermal break required by this section is not provided where concrete slabs penetrate the *building thermal envelope*, the sectional area of the penetration shall be assigned the default U -factors from the “exposed concrete” row of Table A103.3.7.2.

EXCEPTION: *Mass transfer deck slabs.*

C402.2.9 Vertical fenestration intersection with opaque walls. *Vertical fenestration* shall comply with Items 1, 2, and 3, as applicable.

1. Where wall assemblies include *continuous insulation*, the exterior glazing layer of *vertical fenestration* and any required thermal break in the frame shall each be aligned within 2 inches laterally of either face of the *continuous insulation* layer.
2. Where wall assemblies do not include *continuous insulation*, the exterior glazing layer of *vertical fenestration* and any required thermal break in the frame shall each be aligned within the thickness of the *wall* insulation layer and not more than 2 inches laterally from the exterior face of the outermost insulation layer.
3. Where the exterior face of the *vertical fenestration* frame does not extend to the exterior face of the opaque wall rough opening, the exposed exterior portion of the rough opening shall be covered with either a material having an R -value not less than R -3, or with minimum 1.5-inch thickness wood.

C402.3 Reserved.

C402.4 Fenestration. Fenestration shall comply with Sections C402.4 through C402.4.4 and Table C402.4. Daylight responsive controls shall comply with this section and Section C405.2.5.

EXCEPTION:

1. For prescriptive envelope compliance, single-pane glazing is permitted for security purposes and for revolving doors, not to exceed 1 percent of the gross exterior wall area. Where Section C402.1.5, component performance

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alternative, is used, the single glazing shall be included in the percentage of the total glazing area, U-factor and SHGC requirements.

**Table C402.4
Building Envelope Fenestration Maximum U-factor and SHGC Requirements^f**

CLIMATE ZONE	5 AND MARINE 4	
	<i>U-factor for Class AW windows rated in accordance with AAMA/CSA101/I.S.2/A440, vertical curtain walls and site-built fenestration products^a</i>	
Fixed ^b U-factor	U-0.34	
Operable ^c U-factor	U-0.36	
Entrance doors^d		
U-factor	U-0.60	
	<u>U-factor for all other vertical fenestration</u>	
Fixed U-factor	U-0.26	
Operable or mulled windows with fixed and operable sections U-factor	U-0.28	
SHGC for all vertical fenestration		
	Fixed	Operable
PF < 0.2	0.38	0.33
0.2 ≤ PF < 0.5	0.46	0.40
PF ≥ 0.5	0.61	0.53
Skylights		
U-factor	((U-0.50)) <u>U-0.45</u>	
SHGC	((0.35)) <u>0.32</u>	

a U-factor and SHGC shall be rated in accordance with NFRC 100.

b “Fixed” includes curtain wall, storefront, picture windows, and other fixed windows.

c “Operable” includes openable fenestration products other than “entrance doors,” and includes only the operable portions of multi-pane assemblies.

d “Entrance door” includes glazed *swinging* entrance doors and automatic glazed sliding entrance doors. Other doors which are not entrance doors, including manually operated sliding glass doors, are considered “operable.”

e Reserved.

f Fenestration that is entirely within the conditioned space or is between conditioned and other enclosed space is exempt from solar heat gain coefficient requirements and not included in the SHGC calculation.

SDCI Informative Note: The category at the top of Table C402.4, labeled “*U-factor for Class AW windows rated in accordance with AAMA/CSA101/I.S.2/A440, vertical curtain walls and site-built fenestration products,*” includes *curtain wall, storefront, ribbon wall, window wall, and similar site-assembled systems, but does not include typical punched-opening manufactured windows except for “Class AW” windows. Class AW is the AAMA designation for windows typically used in mid-rise and high-rise buildings to resist high wind and water intrusion loads.*

C402.4.1 Maximum area. The total building vertical fenestration area (not including *opaque doors* and opaque spandrel panels) shall not exceed 30 percent of the total building gross above-grade wall area. The skylight area shall not exceed 5 percent of the total building gross roof area (skylight-to-roof ratio).

For buildings with more than one *space conditioning category*, compliance with the maximum allowed window-to-wall ratio and skylight-to-roof ratio shall be demonstrated separately for each *space conditioning category*. Interior partition ceiling, wall, fenestration and floor areas that separate space conditioning areas shall not be applied to the window-to-wall ratio and skylight-to-roof ratio calculations.

EXCEPTIONS:

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

2. Accessory occupancy areas that comprise less than 10 percent of the conditioned floor area of any floor are permitted to be included in the primary occupancy of that floor for determination of the allowable fenestration area for that floor.

C402.4.1.1 Vertical fenestration maximum area with high performance alternates. For buildings that comply with Section C402.4.1.1.1 or C402.4.1.1.2, the total building vertical fenestration area is permitted to exceed 30 percent but shall not exceed 40 percent of the total building gross above grade wall area for the purpose of prescriptive compliance with Section C402.1.4.

When determining compliance using the component performance alternative in accordance with Section C402.1.5, the total building vertical fenestration area allowed in Equation 4-2 (UA-glaz-allow) is 40 percent of the above grade wall area for buildings that comply with the vertical fenestration alternates described in this section.

C402.4.1.1.1 Optimized daylighting. All of the following requirements shall be met:

1. Not less than 50 percent of the total conditioned floor area in the building is within a *daylight zone* that includes *daylight responsive controls* complying with Section C405.2.5.1.
2. Visible transmittance (VT) of all *vertical fenestration* in the building is greater than or equal to 1.1 times the required solar heat gain coefficient (SHGC) in accordance with Section C402.4, or 0.50, whichever is greater. It shall be permitted to demonstrate compliance based on the area weighted average *VT* being greater than or equal to the area weighted average of the minimum *VT* requirements.

EXCEPTION: Fenestration that is outside the scope of NFRC 200 is not required to comply with Item 2.

C402.4.1.1.2 High-performance fenestration. All of the following requirements shall be met:

1. All *vertical fenestration* in the building shall comply with the following *U*-factors:
 - 1.1. *U*-factor for Class AW windows rated in accordance with AAMA/CSA101/I.S.2/A440, vertical curtain walls and site-built fenestration products (fixed) = 0.31
 - 1.2. *U*-factor for Class AW windows rated in accordance with AAMA/CSA101/I.S.2/A440, vertical curtain walls and site-built fenestration products (operable) = 0.36
 - 1.3. Entrance doors = 0.60
 - 1.4. *U*-factor for all other vertical fenestration, fixed = 0.23
 - 1.5. *U*-factor for all other vertical fenestration, operable, or muller windows with fixed and operable sections = 0.24
2. The SHGC of the vertical fenestration shall be no more than 0.9 times the maximum SHGC values listed in Table C402.4.

An area-weighted average shall be permitted to satisfy the *U*-factor requirement for each fenestration product category listed in Item 1 of this section. Individual fenestration products from different fenestration product categories shall not be combined in calculating the area-weighted average *U*-factor, except that fenestration from lines ((a)) 1.1 and ((b-)) 1.2 are permitted to be combined, and the fenestration in lines 1.4 and 1.5 are permitted to be combined. Maximum U-factors for skylights, and maximum SHGC values for all fenestration, shall comply with Section C402.4.

C402.4.2 Minimum skylight fenestration area. Skylights shall be provided in enclosed spaces that meet all the following criteria:

1. Floor area of enclosed spaces is greater than 2,500 square feet (232 m²).
2. Space is located directly under a roof and have a ceiling height greater than 15 feet (4572 mm) for no less than 75 percent of the ceiling area.
3. Space type is one of the following: Office, lobby, atrium, concourse, corridor, gymnasium/exercise center, convention center, automotive service, manufacturing, nonrefrigerated warehouse, retail store, distribution/sorting area, transportation, and workshop.

Skylights in these spaces are required to provide a total toplight daylight zone area not less than 50 percent of the floor area and shall provide one of the following:

1. A minimum ratio of skylight area to toplight daylight zone area under skylights of not less than 3 percent where all skylights have a VT of at least 0.40, or VT_{annual} of not less than 0.26, as determined in accordance with Section C303.1.3.
2. A minimum skylight effective aperture, determined in accordance with Equation 4-5, of:
 - 2.1. Not less than 1 percent using a skylight's VT rating; or
 - 2.2. Not less than 0.66 percent using a *tubular daylight device*'s VT_{annual} rating.

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$$\text{Skylight Effective Aperture} = (0.85 \times \text{Skylight Area} \times \text{Skylight VT} \times \text{WF}) / \text{Toplit daylight zone} \quad (\text{Equation 4-5})$$

Where:

Skylight area = Total fenestration area of skylights.

Skylight VT = Area weighted average visible transmittance of skylights.

WF = Area weighted average well factor, where well factor is 0.9 if light well depth is less than 2 feet (610 mm), or 0.7 if light well depth is 2 feet (610 mm) or greater, or 1.0 for *tubular daylighting devices* (TDD) with VT_{annual} ratings measured in accordance with NFRC 203.

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

EXCEPTIONS:

1. Skylights above daylight zones of enclosed spaces are not required in:
 - 1.1. Spaces designed as storm shelters complying with ICC 500.
 - 1.2. Spaces where the designed *general lighting* power densities are less than 0.5 W/ft² (5.4 W/m²) and at least 10 percent lower than the lighting power allowance in Section C405.4.2.
 - 1.3. Areas where it is documented that existing structures or natural objects block direct beam sunlight on at least half of the roof over the enclosed area for more than 1,500 daytime hours per year between 8 a.m. and 4 p.m.
 - 1.4. Spaces where the daylight zone under rooftop monitors is greater than 50 percent of the enclosed space floor area.
 - 1.5. Spaces where the total floor area minus the sidelit daylight zone area is less than 2,500 square feet (232 m²), and where the lighting in the daylight zone is controlled in accordance with Section ((~~C405.2.3.1~~) [C405.2.4](#)).
2. The skylight effective aperture, calculated in accordance with Equation 4-5, is permitted to be 0.66 percent in lieu of 1 percent if the VT_{annual} of the skylight or *TDD*, as measured by NFRC 203, is greater than 38 percent.

C402.4.2.1 Lighting controls in daylight zones under skylights. Daylight responsive controls shall be provided to control all electric lights within toplit daylight zones.

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

EXCEPTION: Skylights and *tubular daylighting devices* designed and installed to exclude direct sunlight entering the occupied space by the use of fixed or automated baffles, or the geometry of skylight and light well.

C402.4.2.3 Daylight zones. Daylight zones referenced in Sections C402.4.1.1 through C402.4.2.2 shall comply with Sections C405.2.5.2 and C405.2.5.3, as applicable. Daylight zones shall include toplit daylight zones and sidelit daylight zones.

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

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

$$PF = A/B \quad (\text{Equation 4-6})$$

Where:

PF = Projection factor (decimal).

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

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

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

C402.4.3.1 Reserved

C402.4.3.2 Reserved.

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

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

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

C402.4.4 Doors. *Opaque doors* shall be considered part of the gross area of above-grade walls that are part of the building thermal envelope, including the frame. *Opaque doors* shall comply with Table C402.1.4. Other doors shall comply with the provisions of Section C402.4.3 for vertical fenestration.

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

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

C402.5.1.1 Air barrier construction. The *continuous air barrier* shall be constructed to comply with the following:

1. The air barrier shall be continuous for all assemblies that are the thermal envelope of the building and across the joints and assemblies.
2. Air barrier joints and seams shall be sealed, including sealing transitions in places and changes in materials. The joints and seals shall be securely installed in or on the joint for its entire length so as not to dislodge, loosen or otherwise impair its ability to resist positive and negative pressure from wind, stack effect and mechanical ventilation.
3. Penetrations of the air barrier shall be caulked, gasketed or otherwise sealed in a manner compatible with the construction materials and location. Sealing shall allow for expansion, contraction and mechanical vibration. Joints and seams associated with penetrations shall be sealed in the same manner or taped. Sealing materials shall be securely installed around the penetration so as not to dislodge, loosen or otherwise impair the penetrations' ability to resist positive and negative pressure from wind, stack effect, and mechanical ventilation. Sealing of concealed fire sprinklers, where required, shall be in a manner that is recommended by the manufacturer. Caulking or other adhesive sealants shall not be used to fill voids between fire sprinkler cover plates and walls or ceilings.
4. Recessed lighting fixtures shall comply with Section C402.5.8. Where similar objects are installed which penetrate the air barrier, provisions shall be made to maintain the integrity of the air barrier.
5. Construction documents shall contain a diagram showing the building's pressure boundary in plan(s) and section(s) and a calculation of the area of the pressure boundary to be considered in the test.

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

C402.5.1.2 Air barrier compliance. A continuous air barrier for the opaque building envelope shall comply with the following:

1. Group R dwelling units that are accessed directly from the outdoors shall meet the provisions of Section C402.5.2.
2. All other buildings or portions of buildings shall meet the provisions of Section C402.5.3.

C402.5.2 Enclosure testing for dwelling and sleeping units accessed directly from the outdoors. For dwelling units accessed directly from outdoors, the *building thermal envelope* shall be tested in accordance with ASTM E779, ANSI/RESNET/ICC 380, ASTM E1827 or an equivalent method approved by the *code official*. The measured air leakage shall not exceed 0.25 cfm/ft² (1.27 L/s m²) of the *testing unit enclosure area* at a pressure differential of 0.2 inch water gauge (50 Pa). Where multiple dwelling units or sleeping units or other occupiable conditioned spaces are contained within one *building thermal envelope* and are accessed directly from the outdoors, each unit shall be considered an individual testing unit, and the building air leakage shall be the weighted average of all testing unit results, weighted by each testing unit's enclosure area. Units shall be tested separately with an unguarded blower door test as follows:

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1. Where buildings have fewer than eight testing units, each testing unit shall be tested.
2. For buildings with eight or more testing units, the greater of seven units or 20 percent of the testing units in the building shall be tested, including a top floor unit, a ground floor unit and a unit with the largest *testing unit enclosure area*. For each tested unit that exceeds the maximum air leakage rate, an additional two units shall be tested, including a mixture of testing unit types and locations.
3. Test shall be accomplished using either a) both pressurization and depressurization or b) pressurization alone, but not depressurization alone. The test results shall be plotted against the correct P for pressurization in accordance with Section 9.4 of ASTM E779.

Where the measured air leakage rate exceeds 0.25 cfm/ft^2 ($2.0 \text{ L/s} \times \text{m}^2$) corrective action shall be taken to seal leaks in the air barrier in all units exceeding the target value and all untested units. Post-corrective action testing and repeated corrective action measures will be taken until the required air leakage rating is achieved. Final passing air leakage test results shall be submitted to the *code official*.

C402.5.3 Building thermal envelope testing. The *building thermal envelope* shall be tested in accordance with ASTM E779, ANSI/RESNET/ICC 380, ASTM E3158 or ASTM E1827 or an equivalent method approved by the code official. The measured air leakage shall not exceed 0.25 cfm/ft^2 ($1.27 \text{ L/s} \times \text{m}^2$) of the *building thermal envelope* area at a pressure differential of 0.3 inch water gauge (75 Pa). Alternatively, portions of the building shall be tested and the measured air leakages shall be area weighted by the surface areas of the building envelope in each portion. The weighted average test results shall not exceed the whole building leakage limit. In the alternative approach, the following portions of the building shall be tested:

1. The entire envelope area of all stories that have any spaces directly under a roof.
2. The entire envelope area of all stories that have a building entrance, exposed floor, or loading dock, or are below grade.
3. Representative above-grade sections of the building totaling at least 25 percent of the wall area enclosing the remaining conditioned space.
4. Test shall be accomplished using either a) both pressurization and depressurization or b) pressurization alone, but not depressurization alone. The test results shall be plotted against the correct P for pressurization in accordance with Section 9.4 of ASTM E779.

Where the measured air leakage rate exceeds 0.25 cfm/ft^2 ($2.0 \text{ L/s} \times \text{m}^2$) corrective action shall be taken to seal leaks in the air barrier. Post-corrective action testing and repeated corrective action measures will be taken until the required air leakage rating is achieved. Final passing of the air leakage test results shall be submitted to the *code official*.

C402.5.4 Building test for mixed-use buildings. Where a building is three or fewer stories above grade plane and contains both commercial and residential uses, the air barrier of the R-2 and R-3 occupancy areas of the building is permitted to be separately tested according to Section R402.4.1.2. Alternatively, it is permissible to test the air barrier of the entire building according to Section C402.5.3, provided that the tested air leakage rate does not exceed the rate specified in Section C402.5.3.

C402.5.4.1 Low-rise residential building areas conforming to commercial energy code requirements. Where the residential building provisions of this code require Group R-2 occupancy areas of 1, 2, and 3-story buildings to comply with the commercial building provisions of the code, the entire building shall be tested to meet the standards for commercial uses.

C402.5.5 Rooms containing fuel-burning appliances. Where combustion air is supplied through openings in an exterior wall to a room or space containing a space conditioning fuel-burning appliance, one of the following shall apply:

1. The room or space containing the appliance shall be located outside of the *building thermal envelope*.
2. The room or space containing the appliance shall be enclosed and isolated from conditioned spaces inside the building thermal envelope. Such rooms shall comply with all of the following:
 - 2.1. The walls, floor and ceiling that separate the enclosed room or space from the conditioned spaces shall be insulated to be at least equivalent to the insulation requirement of below grade walls as specified in Table C402.1.3 or C402.1.4.
 - 2.2. The walls, floors and ceilings that separate the enclosed room or space from conditioned spaces be sealed in accordance with Section C402.5.1.1.
 - 2.3. The doors into the enclosed room or space shall be fully gasketed.
 - 2.4. Water lines and ducts in the enclosed room or space shall be insulated in accordance with Section C403.
 - 2.5. Where the air duct supplying combustion air to the enclosed room or space passes through conditioned space, the duct shall be insulated to an R-value of not less than R-16.

EXCEPTION: Fireplaces and stoves complying with Sections 901 through 905 of the *International Mechanical Code*, and Section 2111.13 of the *International Building Code*.

C402.5.6 Doors and access openings to shafts, chutes, stairways, and elevator lobbies. Doors and access openings from conditioned space to shafts, chutes, stairways and elevator lobbies shall be gasketed, weatherstripped or sealed.

EXCEPTIONS:

1. Door openings required to comply with Section 716 of the *International Building Code*.
2. Doors and door openings required to comply with UL 1784 by the *International Building Code*.

C402.5.7 Air intakes, exhaust openings, stairways and shafts. Stairway enclosures, elevator shaft vents and other outdoor air intakes and exhaust openings integral to the building envelope shall be provided with dampers in accordance with Section C403.7.8.

C402.5.8 Loading dock weatherseals. Cargo door openings and loading dock door openings shall be equipped with weatherseals that restrict infiltration and provide direct contact along the top and sides of vehicles that are parked in the doorway.

C402.5.9 Vestibules. All building entrances shall be protected with an enclosed vestibule, with all doors opening into and out of the vestibule equipped with self-closing devices. Vestibules shall be designed so that in passing through the vestibule it is not necessary for the interior and exterior doors to open at the same time. The installation of one or more revolving doors in the building entrance shall not eliminate the requirement that a vestibule be provided on any doors adjacent to revolving doors. For the purposes of this section, “building entrances” shall include exit-only doors in buildings where separate doors for entering and exiting are provided.

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

EXCEPTION: Vestibules are not required for the following:

1. Doors not intended to be used as building entrances.
2. Unfinished ground-level space greater than 3,000 square feet (298 m²) if a note is included on the permit documents at each exterior entrance to the space stating “Vestibule required at time of tenant build-out if entrance serves a space greater than 3,000 square feet in area.”
3. Doors opening directly from a *sleeping unit* or dwelling unit.
4. Doors between an enclosed space smaller than 3,000 square feet (298 m²) in area and the exterior of the building or the building entrance lobby, where those doors do not comprise one of the primary building entrance paths to the remainder of the building. The space must be enclosed and separated without transfer air paths from the primary building entrance paths. If there are doors between the space and the primary entrance path, then the doors shall be equipped with self-closing devices so the space acts as a vestibule for the primary building entrance.
5. Revolving doors.
6. Doors used primarily to facilitate vehicular movement or material handling and adjacent personnel doors.
7. In buildings less than 3 stories above grade or in spaces that do not directly connect with the building elevator lobby, doors that have an air curtain with a velocity of not less than 6.56 feet per second (2 m/s) at the floor that have been tested in accordance with ANSI/AMCA 220 and installed in accordance with the manufacturer’s instructions. Manual or automatic controls shall be provided that will operate the air curtain with the opening and closing of the door. Air curtains and their controls shall comply with Section C408.2.3.
8. Building entrances in buildings that are less than four stories above grade and less than 10,000 ft² in area.
9. Elevator doors in parking garages provided that the elevators have an enclosed lobby at each level of the garage.
10. Entrances to semi-heated spaces.
11. Doors that are used only to access outdoor seating areas that are separated from adjacent walking areas by a fence or other barrier.

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

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C402.5.10 Recessed lighting. Recessed luminaires installed in the *building thermal envelope* shall be all of the following:

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

C402.5.11 Operable openings interlocking. Where any operable openings to the outdoors are larger than 48 square feet (4.47 m²) in area, such openings shall be interlocked with the heating and cooling system as required by Section C403.4.1.6.

EXCEPTIONS:

1. Separately zoned areas associated with the preparation of food that contain appliances that contribute to the HVAC loads of a restaurant or similar type of occupancy.
2. Warehouses that utilize overhead doors for the function of the occupancy, where *approved* by the *code official*.
3. The outer entrance doors where located in the exterior wall and are part of a vestibule system.
4. Alterations to existing buildings.

**SECTION C403
MECHANICAL SYSTEMS**

C403.1 General. Mechanical systems and equipment serving heating, cooling, ventilating, and other needs shall comply with this section.

EXCEPTIONS:

1. Energy using equipment used by a manufacturing, industrial or commercial process other than for conditioning spaces or maintaining comfort and amenities for the occupants are exempt from all Section C403 subsections except for Section C403.3.2, Tables C403.3.2 (1) through (16) inclusive, Sections C403.3.4.1, C403.3.4.2, C403.3.4.3, C403.7.7, C403.9.2.1, C403.10.3, C403.11.2, and C403.11.3, as applicable. Data center and *computer room* HVAC equipment is not covered by this exception.
2. *Data center systems* are exempt from Sections C403.4 and C403.5, but shall comply with ASHRAE 90.4 Sections 6 and 8 according to Section C403.1.3.

C403.1.1 HVAC total system performance ratio (HVAC TSPR). For systems serving (~~office (including medical office), retail, library, and education occupancies and buildings, which are subject to the requirements of Section C403.3.5 without exceptions, and the dwelling units and residential common areas within Group R-2 multi-family buildings~~) occupancy areas included in Table C403.1.1, the *HVAC total system performance ratio (HVAC TSPR)* of the *proposed design* HVAC system shall be greater than or equal to the *HVAC TSPR* of the *standard reference design* as calculated according to Appendix D, Calculation of HVAC Total System Performance Ratio.

Table C403.1.1
Occupancy Classifications Requiring TSPR

<u>Occupancy Classification</u>	<u>Inclusions</u>	<u>Excluded</u>
<u>A</u>	<u>Library</u>	<u>All other Group A uses</u>
<u>B</u>	<u>Office, medical office</u>	<u>All other Group B uses</u>
<u>E</u>	<u>All occupancies included</u>	
<u>M</u>	<u>All occupancies included</u>	
<u>R</u>	<u>Dwelling units and associated common areas in within Group R-2 areas of buildings</u>	<u>Groups R-1 and R-3 occupancies, Sleeping units and associated residential common areas in Group R-2 areas of buildings</u>
<u>F, H, I, S, U</u>		<u>All occupancies</u>

EXCEPTIONS TO SECTION C403.1.1:

1. Buildings in which the sum of the *conditioned floor area* of (~~office (including medical office), retail, education, library and multifamily spaces~~) occupancies included in the Inclusions column of Table C403.1.1 is less than 5,000 square feet. Areas that are eligible for any of the exceptions below do not count towards the 5,000 square feet.
2. HVAC systems using district heating water, chilled water or steam.
3. HVAC systems connected to a *low-carbon district energy exchange system*.

4. HVAC systems not included in Table D601.10.1.
5. HVAC systems with chilled water supplied by absorption chillers, heat recovery chillers, water to water heat pumps, air to water heat pumps, or a combination of air and water cooled chillers on the same chilled water loop.
6. HVAC systems included in Table D601.10.1 with parameters in Table D601.10.2 not identified as applicable to that HVAC system type.
7. HVAC systems served by heating water plants that include air to water or water to water heat pumps.
8. Underfloor air distribution and displacement ventilation HVAC systems.
9. Space conditioning systems that do not include *mechanical cooling*.
10. Alterations to existing buildings that do not substantially replace the entire HVAC system and are not serving initial build-out construction.
11. HVAC systems meeting all the requirements of the *standard reference design* HVAC system in Table D602.11, Standard Reference Design HVAC Systems.
12. Buildings or areas of medical office buildings that comply fully with ASHRAE Standard 170 including, but not limited to, surgical centers, or that are required by other applicable codes or standards to provide 24/7 air handling unit operation.
13. HVAC systems serving the following areas and spaces:
 - 13.1. Laundry rooms.
 - 13.2. Elevator machine rooms.
 - 13.3. Mechanical and electrical rooms.
 - 13.4. Data centers and computer rooms.
 - 13.5. Laboratories with fume hoods.
 - 13.6. Locker rooms with more than two showers.
 - 13.7. Natatoriums and rooms with saunas.
 - 13.8. Restaurants and commercial kitchens with total cooking capacity greater than 100,000 Btu/h.
 - 13.9. Areas of buildings with commercial refrigeration equipment exceeding 100 kW of power input.
 - 13.10. Cafeterias and dining rooms.

SDCI Informative Note: For more information regarding TSPR, see SDCI Tip 425 (Seattle SDCI Tip 425—HVAC Total System Performance Ratio) and the free online calculation tools developed by PNNL for this use linked on Page 2 of the Tip.

C403.1.2 Calculation of heating and cooling loads. Design loads associated with heating, ventilating and air conditioning of the building shall be determined in accordance with the procedures described in ANSI/ASHRAE/ACCA Standard 183 or by an *approved* equivalent computational procedure, using the design parameters specified in Chapter 3. Heating and cooling loads shall be adjusted to account for load reductions that are achieved where energy recovery systems are utilized in the HVAC system in accordance with the ASHRAE *HVAC Systems and Equipment Handbook* by an *approved* equivalent computational procedure.

C403.1.3 Data centers. *Data center systems* shall comply [with this code and](#) with Sections 6 and 8 of ASHRAE Standard 90.4.

SDCI Informative Note: The ASHRAE Standard 90.4 reference in Chapter 6 has been updated to the 2022 edition.

C403.1.4 Use of electric resistance and fossil fuel-fired HVAC heating equipment. HVAC heating energy shall not be provided by electric resistance or fossil fuel combustion appliances. For the purposes of this section, electric resistance HVAC heating appliances include, but are not limited to, electric baseboard, electric resistance fan coil and VAV electric resistance terminal reheat units and electric resistance boilers. For the purposes of this section, fossil fuel combustion HVAC heating appliances include, but are not limited to, appliances burning natural gas, heating oil, propane, or other fossil fuels.

EXCEPTIONS:

1. Low heating capacity. Buildings or areas of buildings, other than *dwelling units* or sleeping units, that meet the interior temperature requirements of Chapter 12 of the *International Building Code* with a total installed HVAC heating capacity no greater than 8.5 Btu/h (2.5 watts) per square foot of *conditioned space* are permitted to be heated using electric resistance appliances.

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2. Dwelling and sleeping units. Dwelling or sleeping units are permitted to be heated using electric resistance appliances as long as the installed HVAC heating capacity in any separate space is not greater than ((:)) specified in 2.1 through 2.3. Where a single dwelling unit includes multiple habitable spaces that are all heated with electric resistance heat, individual spaces are permitted to have more electric resistance heating capacity than specified in 2.1 through 2.3, where the total electric resistance heating capacity for the dwelling unit is less than or equal to the total allowed.

SDCI Informative Note for exception 2: As an example, a one-bedroom apartment could, instead of placing 750 watts of heating in the living room and another 750 watts in the bedroom (1,500 watt total), place 1,000 watts in the living room and 500 watts in the bedroom, for the same 1,500 watt total.

- 2.1. Seven hundred fifty (750) watts in Climate Zone 4, (~~and 1000 watts in Climate Zone 5~~) in each habitable space with exterior fenestration.
- 2.2. One thousand (1000) watts in Climate Zone 4, (~~and 1300 watts in Climate Zone 5~~) for each habitable space that has two primary walls facing different cardinal directions, each with exterior fenestration. Bay windows and other minor offsets are not considered primary walls.
- 2.3. Two hundred fifty (250) watts in spaces adjoining the *building thermal envelope* but without exterior fenestration.

For the purposes of this section, habitable space is as defined in the International Building Code. (~~For buildings in locations with exterior design conditions below 4°F (-16°C), an additional 250 watts above that allowed for Climate Zone 5 is permitted in each space with fenestration.~~)

3. Small buildings. Buildings with less than 2,500 square feet (232 m²) of *conditioned floor area* are permitted to be heated using electric resistance appliances.
4. Defrost. Heat pumps are permitted to utilize electric resistance heating when a heat pump defrost cycle is required and is in operation.
5. Air-to-air heat pumps. Buildings are permitted to utilize electric resistance supplemental heating for air-to-air heat pumps that meet all of the following conditions:
 - 5.1. Internal electric resistance heaters have controls that prevent supplemental heater operation when the heating load can be met by the heat pump alone during both steady-state operation and setback recovery.
 - 5.2. The heat pump controls are configured to use the compressor as the first stage of heating down to an outdoor air temperature of 17°F (-8°C) or lower except when in defrost.

EXCEPTIONS TO 5.2:

1. Packaged terminal heat pumps (PTHPs) that comply with the minimum heating efficiency requirements in Table C403.3.2(4) are exempt from heating pump controls capable of operating the compressor as the first stage of heating down to an outdoor air temperature of 17°F (-8°C) or lower.
2. Heat pumps whose minimum efficiency is regulated by NAECA and whose ratings meet the requirements shown in Table C403.3.2(2) and include all usage of internal electric resistance heating are exempt from heat pump controls capable of operating the compressor as the first state of heating down to an outdoor air temperature of 17°F (-8°C) or lower except that thermostats that are

~~not integral to the heat pump equipment shall be configured to use the compressor as the first stage of heating down to an outdoor air temperature of 17°F (- 8°C) or lower except when in defrost.~~

- 5.3. The heat pump complies with **one all** of the following:
 - 5.3.1. Controlled by a digital or electronic thermostat designed for heat pump use that energizes the supplemental heat only when the heat pump has insufficient capacity to maintain set point or to warm up the space at a sufficient rate.
 - 5.3.2. Controlled by a multistage space thermostat and an outdoor air thermostat wired to energize supplemental heat only on the last stage of the space thermostat and when outdoor air temperature is less than 32°F (0°C) except when in defrost.
 - 5.3.3. The minimum efficiency of the heat pump is regulated by NAECA, its rating meets the requirements shown in Table C403.3.2(2), and its rating includes all usage of internal electric resistance heating.
- 5.4. The heat pump rated heating capacity is sized to meet the heating load at an outdoor air temperature of 32°F (0°C) or lower and has a rated heating capacity at 47°F (8°C) no less than 2 times greater than supplemental heating capacity in Climate Zone 4 and no less than the supplemental heating capacity in Climate Zone 5, or utilizes the smallest available factory-available internal electric resistance heater.

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6. Air-to-water heat pumps. Buildings are permitted to utilize electric resistance (~~((for Climate Zone 4 or 5) or fossil fuel fired (for Climate Zone 5))~~) auxiliary heating to supplement heat pump heating for hydronic heating systems that meet all of the following conditions:
 - 6.1. Controls for the auxiliary heating sources are configured to lock out the supplemental heat when the outside air temperature is above 36°F (2°C), unless the hot water supply temperature setpoint to the building heat coils cannot be maintained for 20 minutes.
 - 6.2. The heat pump controls are configured to use the compressor as the first stage of heating down to the lowest exterior design temperature for which the equipment is rated except during startup or defrost operation.
 - 6.3. The heat pump rated heating capacity at 47°F (8°C) is no less than 75 percent of the design heating load at 29°F (-2°C).
7. Ground source heat pumps. Buildings are permitted to utilize electric resistance supplemental heating for hydronic heating systems with ground source heat pump equipment that meets all of the following conditions:
 - 7.1. Controls for the auxiliary heating sources are configured to lock out the supplemental heat when the equipment source-side entering water temperature is above 42°F (6°C), unless the hot water supply temperature setpoint to the building heat coils cannot be maintained for 20 minutes.
 - 7.2. The heat pump controls are configured to use the compressor as the first stage of heating.
 - 7.3. The ground source heat exchanger shall be sized so that the heat pump annual heating output is no less than 70 percent of the total annual heating output in the final year of a 30-year simulation using IGSHPA listed simulation software.
8. Small systems. Buildings in which electric resistance or fossil fuel appliances, including decorative appliances, either provide less than 5 percent of the total building HVAC system heating capacity or serve less than 5 percent of the *conditioned floor area*.
9. Specific conditions. Portions of buildings that require fossil fuel or electric resistance space heating for specific conditions *approved* by the *code official* for research, health care, process or other specific needs that cannot practicably be served by heat pump or other space heating systems. This does not constitute a blanket exception for any occupancy type.
10. Kitchen make-up air. Make-up air for commercial kitchen exhaust systems required to be tempered by Section 508.1.1 of the *International Mechanical Code* is permitted to be heated by using fossil fuel in Climate Zone 5 or electric resistance in Climate Zone 4 or 5.
11. District energy. Steam or hot water district energy systems that utilize fossil fuels as their primary source of heat energy, that serve multiple buildings, and that were already in existence prior to the effective date of this code, including more energy-efficient upgrades to such existing systems, are permitted to serve as the primary heating energy source.
12. Heat tape. Heat tape is permitted where it protects water-filled equipment and piping located outside of the *building thermal envelope*, provided that it is configured and controlled to be automatically turned off when the outside air temperature is above 40°F (4°C).
13. Temporary systems. Temporary electric resistance heating systems are permitted where serving future tenant spaces that are unfinished and unoccupied, provided that the heating equipment is sized and controlled to achieve interior space temperatures no higher than 40°F (4°C).
14. Pasteurization. Electric resistance heat controls are permitted to reset the supply water temperature of hydronic heating systems that serve service water heating heat exchangers during pasteurization cycles of the service hot water storage volume. The hydronic heating system supply water temperature shall be configured to be 145°F (63°C) or lower during the pasteurization cycle.
15. Freeze protection. Heating systems sized for spaces with indoor design conditions of 45°F (7°C) and intended for freeze protection are permitted to use electric resistance. The building envelope of any such space shall be insulated in compliance with Section C402.1.
16. DOAS ERV auxiliary heat. Dedicated outdoor air systems with energy recovery ventilation are permitted to utilize (~~fossil fuel for Climate Zone 5 or~~) electric resistance (~~(in Climate Zone 4 or 5)~~) for auxiliary heating to preheat outdoor air for defrost or as auxiliary supplemental heat to temper supply air to 55°F (13°C) or lower for buildings or portions of buildings that do not have hydronic heating systems.
17. Low-carbon district energy systems. Low-carbon district energy systems that meet the definitions of *low-carbon district energy exchange system* or *low-carbon district heating and cooling or heating only systems*.
18. Essential facilities. Groups I-2 and I-3 occupancies that by regulation are required to have in place redundant emergency backup systems, and research laboratories, are permitted to use fossil fuels for emergency generators

and for redundant emergency space heating and water heating appliances, provided that such systems are sized and controlled to operate only upon loss of electrical power.

19. Standby HVAC heating equipment. Standby HVAC heating equipment provided in addition to the primary heating system, and controlled such that it will only be used when the primary heating equipment is not available, is permitted to be electric resistance.
20. Emergency generators. Generators serving emergency power, legally required standby power, or optional standby power are permitted to use fossil fuels.
21. Wastewater heat recovery heat pumps. Buildings are permitted to utilize electric resistance auxiliary heating to supplement heat pump heating for hydronic heating systems with wastewater heat recovery or other approved waste heat recovery systems provided the heat pump equipment that meets all of the following conditions:
 - 21.1. Controls for the auxiliary resistance heating are configured to lock out the supplemental heat when the equipment source-side entering water temperature is above 42°F, unless the hot water supply temperature setpoint to the building heat coils cannot be maintained for 20 minutes.
 - 21.2. The heat pump controls are configured to use the compressor as the first stage of heating.
 - 21.3. The wastewater heat exchanger and heat pumps or other heat pump supplemental systems shall be sized so that the heat pump rated heating capacity at heat pump design entering water temperature conditions or other heat pump heating systems are no less than 75 percent of the design heating load at 29°F. Wastewater heat exchanger source side shall be sized for a design wastewater entering temperature of 55°F or lower.
22. Mechanical systems located outside of the building thermal envelope. Mechanical systems providing heat outside of the thermal envelope that comply with Section C403.11 are permitted to utilize electric resistance appliances. Snow- and ice-melt systems that comply with Section C403.11.2 are permitted to utilize electric resistance heat to back up the primary electric heat pump heating system in accordance with Exceptions 6 and 7 of Section C403.1.4.

C403.2 System design. Mechanical systems shall be designed to comply with Sections C403.2.1 and C403.2.4. Where elements of a building's mechanical systems are addressed in Sections C403.3 through C403.13, such elements shall comply with the applicable provisions of those sections.

C403.2.1 Zone isolation required. HVAC systems, DOAS and exhaust systems serving areas that are intended to operate or be occupied nonsimultaneously shall be divided into separate isolation areas. Zones intended to be occupied simultaneously may be grouped into a single isolation area provided the combined total area does not exceed 25,000 square feet (2323 m²) of conditioned floor area and does not include more than one floor. Each isolation area shall be equipped with isolation devices and controls configured to automatically shut off the supply of conditioned air and outdoor air to and exhaust air from the isolation area. Each isolation area shall be controlled independently by a device meeting the requirements of Section C403.4.2.2. Central systems and plants shall be provided with controls and devices that will allow system and equipment operation for any length of time while serving only the smallest isolation area served by the system or plant.

EXCEPTIONS:

1. Exhaust air and outdoor air connections to isolation areas where the fan system to which they connect is not greater than 5,000 cfm (2360 L/s).
2. Exhaust airflow from a single isolation area of less than 10 percent of the design airflow of the exhaust system to which it connects.
3. Isolation areas intended to operate continuously or intended to be inoperative only when all other isolation areas in a *zone* are inoperative.

C403.2.2 Ventilation and exhaust.

C403.2.2.1 Ventilation. Ventilation, either natural or mechanical, shall be provided in accordance with Chapter 4 of the *International Mechanical Code*. Where mechanical ventilation is provided, the system shall be configured to provide no greater than 150 percent of the minimum outdoor air required by Chapter 4 of the *International Mechanical Code* or other applicable code or standard, whichever is greater.

EXCEPTIONS:

1. The mechanical system may supply outdoor air at rates higher than the limit above when it is used for particulate or VOC dilution, economizing or night flushing, dehumidification, pressurization, exhaust make-up, or other process air delivery. Outdoor air shall be reduced to the minimum ventilation rates when not required for the preceding uses.
2. Air systems supplying dwelling or sleeping units within Group R-1, R-2 or I-2 occupancies.
3. Alterations that replace less than half of the total heating and cooling capacity of the system.
4. Systems with energy recovery complying with the requirements of Section C403.7.6.1 that utilize sensible

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only active chilled beams for space cooling without any additional zonal fan power. Active chilled beams shall be permitted to utilize the increased outdoor airflow to increase space sensible capacity and to maintain space latent cooling loads without additional controls to reduce the outdoor airflow to each zone.

5. Systems that include energy recovery ventilation with an 80 percent minimum sensible recovery effectiveness in accordance with Section C403.3.5.1 and with controls capable and configured to lock-out the use of supplemental heat may provide ventilation up to a maximum of 200 percent of the minimum outdoor air required.

C403.2.2.2 Exhaust. Exhaust shall be provided in accordance with Chapters 4 and 5 of the *International Mechanical Code*. Where exhaust is provided, the system shall be configured to provide no greater than 150 percent of the minimum exhaust air required by Chapters 4 and 5 of the *International Mechanical Code* or other applicable code or standard, whichever is greater.

EXCEPTIONS:

1. The mechanical system may exhaust air at rates higher than the limit above when it is used for particulate or VOC dilution, economizer, night flushing, dehumidification, pressure equalization, relief, or other process exhaust air requirements. Outdoor air and exhaust air shall be reduced to the minimum ventilation rates when not required for the preceding uses.
2. Domestic range hood exhaust in Group R occupancies.
3. Exhaust from Group I occupancies.

C403.2.3 Fault detection and diagnostics. New buildings with an HVAC system serving a gross conditioned floor area of 100,000 square feet (9290 m²) or larger shall include a fault detection and diagnostics (FDD) system to monitor the HVAC system's performance and automatically identify faults. The FDD system shall:

1. Include permanently installed sensors and devices to monitor the HVAC system's performance.
2. Sample the HVAC system's performance at least once every 15 minutes.
3. Automatically identify and report HVAC system faults.
4. Automatically notify authorized personnel of identified HVAC system faults.
5. Automatically provide prioritized recommendations for repair of identified faults based on analysis of data collected from the sampling of HVAC system performance.
6. Be capable of transmitting the prioritized fault repair recommendations to remotely located authorized personnel.

EXCEPTION: Group R-1 and R-2 occupancies.

C403.2.4 Variable flow capacity. For fan and pump motors 5.0 hp and greater including motors in or serving custom and packaged air handlers serving variable air volume fan systems, constant volume fans, heating and cooling hydronic pumping systems, pool and service water pumping systems, domestic water pressure-booster systems, cooling tower fan, and other pump or fan motors where variable flows are required, there shall be:

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

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

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

C403.3 Equipment selection. Heating and cooling equipment installed in mechanical systems shall be sized in accordance with Section C403.3.1 and shall be not less efficient in the use of energy than as specified in Section C403.3.2.

C403.3.1 Equipment and system sizing. The output capacity of heating and cooling equipment shall be not greater than that of the smallest available equipment size that exceeds the loads calculated in accordance with Section C403.1.2. 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 are configured to sequence the operation of each unit based on load.

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C403.3.2 HVAC equipment performance requirements. Equipment shall meet the minimum efficiency requirements of Tables C403.3.2(1) through C403.3.2 (16) when tested and rated in accordance with the applicable test procedure. After new equipment efficiency values including HSPF2, EER2, and SEER2 have been published by the US Department of Energy, equipment is permitted to meet those values in lieu of the table values. Plate-type liquid-to-liquid heat exchangers shall meet the minimum requirements of AHRI 400. 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.

Air-to-water heat pump manufacturers shall report the hourly heating output or heating efficiency with and without defrost operation at 32°F, in addition to meeting the efficiency requirements of Table C403.3.2(15) at the AHRI 550/590 applicable leaving water temperatures. The hourly heating output or heating efficiency with and without defrost operation shall be documented on the mechanical permit application documents.

EXCEPTION: Heat recovery chillers and air-to-water heat pumps covered under Table C403.3.2(15), are not required to be listed in the AHRI certification program for AHRI 550/590. The equipment heating and cooling efficiency ratings shall be supported by data furnished by the manufacturer at AHRI 550/590 conditions. Where multiple rating conditions or performance requirements are provided, the equipment shall satisfy all stated requirements.

SDCI Informative Note: Table C403.3.2.(13) is from ASHRAE 90.1-2019. At the time of the adoption of the 2021 SEC it was not clear whether any air-to-water heat pumps or heat recovery chillers would be listed in the AHRI Certified Product Directory. <https://www.ahridirectory.org/> According to AHRI 550/590 Section 5.3, “Full and part-load application ratings shall include the range of Rating Conditions listed in Table 2 or be within the operating limits of the equipment.”

C403.3.2.1 Gas-fired and oil-fired forced air furnaces. Forced air furnaces with input ratings $\geq 225,000$ 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 $\geq 225,000$ 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.

SDCI Informative Note: Fossil fuel-fired heating equipment is generally prohibited by Section C403.1.4.

C403.3.2.2 Hydronic and multiple-zone HVAC system controls and equipment. Hydronic and multiple-zone HVAC system controls and equipment shall comply with this section.

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

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

C403.3.2.3 Chillers. Chilled water plants and buildings with more than 500 tons total **cooling** capacity shall not have more than 100 tons provided by air-cooled chillers.

EXCEPTIONS:

1. Where the designer demonstrates that the water quality at the building site fails to meet manufacturer’s specifications for the use of water-cooled equipment.
2. Air-cooled chillers with minimum efficiencies at least 10 percent higher than those listed in Table C403.3.2(3).
3. Replacement of existing air-cooled chiller equipment.
4. Air-to-water heat pump units that are configured to provide both heating and cooling and that are rated in accordance with AHRI 550/590.

C403.3.2.4 Water-cooled centrifugal chilling packages. Equipment not designed for operation at AHRI Standard 550/590 test conditions of 44.00°F (6.67°C) leaving and 54.00°F (12.22°C) entering chilled-water temperatures and with 85.00°F (29.44°C) entering and 94.30°F (34.61°C) leaving condenser-fluid temperatures, shall have maximum full-load kW/ton (FL) and *part-load* ratings adjusted using the following equations.

$$FL_{adj} = FL/K_{adj} \quad \text{(Equation 4-7)}$$

$$PLV_{adj} = IPLV \cdot IP/K_{adj} \quad \text{(Equation 4-8)}$$

Where:

$$K_{adj} = A \times B$$

FL = Full-load kW/ton values as specified in Table C403.3.2(7)

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

IPLV.IP = Value as specified in Table C403.3.2(7)

PLV_{adj} = Maximum NPLV rating, adjusted for nonstandard conditions

$$A = 0.00000014592 \times (\text{LIFT})^4 - 0.0000346496 \times (\text{LIFT})^3 + 0.00314196 \times (\text{LIFT})^2 - 0.147199 \times \text{LIFT} + 3.93073$$

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

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

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

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

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

- $36.00\text{°F} \leq L_{vg}^{Evap} \leq 60.00\text{°F}$
- $L_{vg}^{Cond} \leq 115.00\text{°F}$
- $20.00\text{°F} \leq \text{LIFT} \leq 80.00\text{°F}$

Manufacturers shall calculate the FL_{adj} and PLV_{adj} before determining whether to label the chiller. Centrifugal chillers designed to operate outside of these ranges are not covered by this code.

C403.3.2.5 Positive displacement (air- and water-cooled) chilling packages. Equipment with a leaving fluid temperature higher than 32°F (0°C) and water-cooled positive displacement chilling packages with a condenser leaving fluid temperature below 115°F (46°C) shall meet the requirements of the tables in Section C403.3.2 when tested or certified with water at standard rating conditions, in accordance with the referenced test procedure.

C403.3.2.6 Packaged and split system electric heating and cooling equipment. Packaged and split system equipment providing both electric heating and cooling, and cooling-only equipment with electric heat in the main supply duct before VAV boxes, in each case with a total cooling capacity greater than 6,000 Btu/h shall be a heat pump configured to operate in heat pump mode whenever the outdoor air temperature is above 25°F (-3.9°C) and the unit is not in defrost. The unit shall have reverse-cycle demand defrost.

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

C403.3.2.7 Humidification. If an air economizer is required on a cooling system for which humidification equipment is to be provided to maintain minimum indoor humidity levels, then the humidifier shall be of the adiabatic type (direct evaporative media or fog atomization type).

EXCEPTIONS:

1. Health care facilities licensed by the state where chapter 246-320 or 246-330 WAC requires steam injection humidifiers in duct work downstream of final filters.
2. Systems with water economizer.
3. 100 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.

C403.3.2.8 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 C403.3.3, as limited by Section C403.5.1.

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**TABLE C403.3.2.8
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.

**Table C403.3.2(1)
Minimum Efficiency Requirements—Electrically Operated Unitary Air Conditioners and Condensing Units^{c,d}**

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure ^a
Air conditioners, air cooled	< 65,000 Btu/h ^b	All	Split System, three phase and applications outside U.S. single phase ^b	13.4 SEER2	AHRI 201/240-2023
			Single package, three phase and applications outside U.S. single phase ^b	13.4 SEER2	
Space constrained, air cooled	≤ 30,000 Btu/h ^b	All	Split System, three phase and applications outside U.S. single phase ^b	11.7 SEER2	
			Single package, three phase and applications outside U.S. single phase ^b	11.7 SEER2	
Small duct high velocity, air cooled	≤ 65,000 Btu/h ^b	All	Split System, three phase and applications outside U.S. single phase ^b	12.1 SEER2	
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 14.8 IEER	AHRI 340/360
		All other	Split System and Single Package	11.0 EER 14.6 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 14.2 IEER	
		All other	Split System and Single Package	10.8 EER 14.0 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 13.2 IEER	
		All other	Split System and Single Package	9.8 EER 13.0 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 12.5 IEER	
		All other	Split System and Single Package	9.5 EER 12.3 IEER	

Table C403.3.2(1)—continued
Minimum Efficiency Requirements—Electrically Operated Unitary Air Conditioners and Condensing Units^{c,d}

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure ^a
Air conditioners, water cooled	< 65,000 Btu/h ^b	All	Split System and Single Package	12.1 EER 12.3 IEER	AHRI 210/240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.1 EER 13.9 IEER	AHRI 340/360
		All other	Split System and Single Package	11.9 EER 13.7 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.5 EER 13.9 IEER	
		All other	Split System and Single Package	12.3 EER 13.7 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.4 EER 13.6 IEER	
		All other	Split System and Single Package	12.2 EER 13.4 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.2 EER 13.5 IEER	
All other		Split System and Single Package	12.0 EER 13.3 IEER		
Air conditioners, evaporatively cooled	< 65,000 Btu/h ^b	All	Split System and Single Package	12.1 EER 12.3 IEER	AHRI 210/240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.1 EER 12.3 IEER	AHRI 340/360
		All other	Split System and Single Package	11.9 EER 12.1 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	12.0 EER 12.2 IEER	
		All other	Split System and Single Package	11.8 EER 12.0 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.9 EER 12.1 IEER	
		All other	Split System and Single Package	11.7 EER 11.9 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.7 EER 11.9 EER	
All other		Split System and Single Package	11.5 EER 11.7 EER		
Condensing units, air cooled	≥ 135,000 Btu/h			10.5 EER 11.8 IEER	AHRI 365
Condensing units, water cooled	≥ 135,000 Btu/h			13.5 EER 14.0 IEER	
Condensing units, evaporatively cooled	≥ 135,000 Btu/h			13.5 EER 14.0 IEER	

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

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

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- b Single-phase, U.S. air-cooled air conditioners less than 65,000 Btu/h are regulated as consumer products by the U.S. Department of Energy Code of Federal Regulations DOE 10 C.F.R. 430. SEER and SEER2 values for single-phase products are set by the U.S. Department of Energy.
- c DOE 10 C.F.R. 430 Subpart B Appendix MI includes the test procedure updates effective 1/1/2023 that will be incorporated in AHRI 210/240-2023.
- d This table is a replica of ASHRAE 90.1 Table 6.8.1-1 Electrically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements.

**Table C403.3.2(2)
Electrically Operated Air-Cooled Unitary Heat Pumps—Minimum Efficiency Requirements**

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure ^a
Air cooled (cooling mode)	< 65,000 Btu/h	All	Split System, three phase and applications outside U.S. single phase ^b	14.3 SEER2	AHRI 201/240-2023
			Single Package, three phase and applications outside U.S. single phase ^b	13.4 SEER2	
Space constrained, air cooled	≤ 30,000 Btu/h	All	Split System, three phase and applications outside U.S. single phase ^b	11.7 SEER2	
			Single Package, three phase and applications outside U.S. single phase ^b	11.7 SEER2	
Single duct high velocity, air cooled (cooling mode)	≤ 65,000 Btu/h	All	Split System, three phase and applications outside U.S. single phase ^b	12.0 SEER2	
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 14.1 IEER	AHRI 340/360
		All other	Split System and Single Package	10.8 EER 13.9 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.6 EER 13.5 IEER	
		All other	Split System and Single Package	10.4 EER 13.3 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 12.5 IEER	
		All other	Split System and Single Package	9.3 EER 12.3 IEER	
Air cooled (heating mode)	< 65,000 Btu/h ^b	-	Split System, three phase and applications outside U.S. single phase ^b	7.5 HSPF	AHRI 201/240-2023
		-	Single Package, three phase and applications outside U.S. single phase ^b	6.7 HSPF	
Space constrained, air cooled (heating mode)	≤ 30,000 Btu/h	-	Split System, three phase and applications outside U.S. single phase ^b	6.3 HSPF	
		-	Single Package, three phase and applications outside U.S. single phase ^b	6.3 HSPF	
Small-duct high velocity air cooled (heating mode)	< 65,000 Btu/h	-	Split System, three phase and applications outside U.S. single phase ^b	6.1 HSPF	
Air cooled (heating mode)	≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity)	-	47°F db/43°F wb Outdoor Air	3.40 COP _H	AHRI 340/360
			17°F db/15°F wb Outdoor Air	2.25 COP _H	
	≥ 135,000 Btu/h and < 240,000 Btu/h (cooling capacity)	-	47°F db/43°F wb Outdoor Air	3.30 COP _H	
			17°F db/15°F wb Outdoor Air	2.05 COP _H	
	≥ 240,000 Btu/h (cooling capacity)		47°F db/43°F wb Outdoor Air	3.20 COP _H	
			17°F db/15°F wb Outdoor Air	2.05 COP _H	

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

- a Chapter 6 contains a complete specification of the referenced standards, which include test procedures, including the reference year version of the test procedure.
- b Single-phase, U.S. air-cooled heat pumps less than 65,000 Btu/h are regulated as consumer products by the U.S. Department of Energy Code of Federal Regulations DOE 10 C.F.R. 430. SEER, SEER2, and HSPF values for single-phase products are set by the U.S. Department of Energy.
- c DOE 10 C.F.R. 430 Subpart B Appendix MI includes the test procedure updates effective 1/1/2023 that will be incorporated into AHRI 210/240-2023.
- d This table is a replica of ASHRAE 90.1 Table 6.8.1-2 Electrically Operated Air-Cooled Unitary Heat Pumps—Minimum Efficiency Requirements.

Table C403.3.2(3)
Water Chilling Packages—Minimum Efficiency Requirements^{a,b,e,f}

Equipment Type	Size Category	Units	Path A		Path B		Test Procedure ^c
			FL	IPLV,IP	FL	IPLV,IP	
Air-cooled chillers	< 150 tons	EER(Btu/Wh)	≥ 10.100	≥ 13.700	≥ 9.700	≥ 15.800	
	≥ 150 tons	EER(Btu/Wh)	≥ 10.100	≥ 14.000	≥ 9.700	≥ 16.100	
Air cooled without condenser, electrically operated	All capacities	EER(Btu/Wh)	Air-cooled chillers without condensers shall be rated with matching condensers and comply with the air-cooled chiller efficiency requirements				
Water cooled, electrically operated, positive displacement	< 75 tons	kW/ton	≤ 0.750	≤ 0.600	≤ 0.780	≤ 0.500	
	≥ 75 tons and < 150 tons	kW/ton	≤ 0.720	≤ 0.560	≤ 0.750	≤ 0.490	AHRI 550/590
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.660	≤ 0.540	≤ 0.680	≤ 0.440	
	≥ 300 tons and < 600 tons	kW/ton	≤ 0.610	≤ 0.520	≤ 0.625	≤ 0.410	
	≥ 600 tons	kW/ton	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380	
Water cooled, electrically operated, centrifugal	< 150 tons	kW/ton	≤ 0.610	≤ 0.550	≤ 0.695	≤ 0.440	
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.610	≤ 0.550	≤ 0.695	≤ 0.400	
	≥ 300 tons and < 400 tons	kW/ton	≤ 0.560	≤ 0.520	≤ 0.595	≤ 0.390	
	≥ 400 tons and < 600 tons	kW/ton	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380	
	≥ 600 tons	kW/ton	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380	
Air cooled absorption, single effect	All capacities	COP(W/W)	≥ 0.600	NR	NA ^d	NA ^d	
Water cooled absorption, single effect	All capacities	COP(W/W)	≥ 0.700	NR	NA ^d	NA ^d	AHRI 560
Absorption double effect, indirect fired	All capacities	COP(W/W)	≥ 1.000	≥ 1.050	NA ^d	NA ^d	
Absorption double effect, direct fired	All capacities	COP(W/W)	≥ 1.000	≥ 1.000	NA ^d	NA ^d	

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

NR = No requirement.

- a Chapter 6 contains a complete specification of the referenced standards, which includes test procedures, including the referenced year version of the test procedure.
- b The requirements for centrifugal chiller shall be adjusted for nonstandard rating conditions per Section C403.3.2.4 and are applicable only for the range of conditions listed there. The requirements for air-cooled, water-cooled positive displacement and absorption chillers are at standard rating conditions defined in the referenced test procedure.
- c Both the full load and IPLV,IP requirements must be met or exceeded to comply with this standard. When there is a Path B, compliance can be with either Path A or Path B for any application.
- d NA means the requirements are not applicable for Path B and only Path A can be used for compliance.
- e FL is the full-load performance requirements, and IPLV,IP is for the part-load performance requirements.
- f This table is a replica of ASHRAE 90.1 Table 6.8.1-3 Water-Chilling Packages—Minimum Efficiency Requirements.

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Table C403.3.2(4)
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—
Minimum Efficiency Requirements^e

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure ^a
PTAC (cooling mode) Standard size	< 7,000 Btu/h	95°F db/75°F wb outdoor air ^c	11.9 EER	AHRI 310/380
	≥ 7,000 Btu/h and ≤ 15,000 Btu/h		14.0 - (0.300 × Cap/1000) EER ^d	
	> 15,000 Btu/h		9.5 EER	
PTAC (cooling mode) Nonstandard size ^a	< 7,000 Btu/h	95°F db/75°F wb outdoor air ^c	9.4 EER	AHRI 310/380
	≥ 7,000 Btu/h and ≤ 15,000 Btu/h		10.9 - (0.213 × Cap/1000) EER ^d	
	> 15,000 Btu/h		7.7 EER	
PTHP (cooling mode) Standard size	< 7,000 Btu/h	95°F db/75°F wb outdoor air ^c	11.9 EER	AHRI 310/380
	≥ 7,000 Btu/h and ≤ 15,000 Btu/h		14.0 - (0.300 × Cap/1000) EER ^d	
	> 15,000 Btu/h		9.5 EER	
PTHP (cooling mode) Nonstandard size ^b	< 7,000 Btu/h	95°F db/75°F wb outdoor air ^c	9.3 EER	AHRI 310/380
	≥ 7,000 Btu/h and ≤ 15,000 Btu/h		10.8 - (0.213 × Cap/1000) EER ^d	
	> 15,000 Btu/h		7.6 EER	
PTHP (heating mode) Standard size	< 7,000 Btu/h	47°F db/43°F wb outdoor air	3.3 COP _H	AHRI 310/380
	≥ 7,000 Btu/h and ≤ 15,000 Btu/h		3.7 - (0.052 × Cap/1000) COP _H ^d	
	> 15,000 Btu/h		2.90 COP _H	
PTHP (heating mode) Nonstandard size ^b	< 7,000 Btu/h	47°F db/43°F wb outdoor air	2.7 COP _H	AHRI 310/380
	≥ 7,000 Btu/h and ≤ 15,000 Btu/h		2.9 - (0.026 × Cap/1000) COP _H ^d	
	> 15,000 Btu/h		2.5 COP _H	
SPVAC (cooling mode)	< 65,000 Btu/h	95°F db/75°F wb outdoor air ^c	11.0 EER	AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h		10.0 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h		10.0 EER	
SPVHP (cooling mode)	< 65,000 Btu/h	95°F db/75°F wb outdoor air ^c	11.0 EER	AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h		10.0 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h		10.0 EER	
SPVHP (heating mode)	< 65,000 Btu/h	47°F db/43°F wb outdoor air	3.3 COP	AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h		3.0 COP	
	≥ 135,000 Btu/h and < 240,000 Btu/h		3.0 COP	
Room air conditioners without reverse cycle with louvered sides for applications outside U.S.	< 6,000 Btu/h	-	11.0 CEER	ANSI/AHAMRAC-1
	≥ 6,000 Btu/h and < 8,000 Btu/h	-	11.0 CEER	
	≥ 8,000 Btu/h and < 14,000 Btu/h	-	10.9 CEER	
	≥ 14,000 Btu/h and < 20,000 Btu/h	-	10.7 CEER	
	≥ 20,000 Btu/h and < 28,000 Btu/h	-	9.4 CEER	
	≥ 28,000 Btu/h	-	9.0 CEER	

Table C403.3.2(4)—continued
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—Minimum Efficiency Requirements^a

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure ^a
Room air conditioners without louvered sides	< 6,000 Btu/h	-	10.0 CEER	ANSI/AHAMRAC-1
	≥ 6,000 Btu/h and < 8,000 Btu/h	-	10.0 CEER	
	≥ 8,000 Btu/h and < 11,000 Btu/h	-	9.6 CEER	
	≥ 11,000 Btu/h and < 14,000 Btu/h	-	9.5 CEER	
	≥ 14,000 Btu/h and < 20,000 Btu/h	-	9.3 CEER	
	≥ 20,000 Btu/h	-	9.4 CEER	
Room air conditioners with reverse cycle, with louvered sides for applications outside U.S.	< 20,000 Btu/h	-	9.8 CEER	ANSI/AHAMRAC-1
	≥ 20,000 Btu/h	-	9.3 CEER	
Room air conditioners with reverse cycle without louvered sides for applications outside U.S.	< 14,000 Btu/h	-	9.3 CEER	ANSI/AHAMRAC-1
	≥ 14,000 Btu/h	-	8.7 CEER	
Room air conditioners, casement only for applications outside U.S.	All capacities	-	9.5 CEER	ANSI/AHAMRAC-1
Room air conditioners, casement-slider for application outside U.S.	All capacities	-	10.4 CEER	ANSI/AHAMRAC-1

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 7,000 Btu/h, use 7,000 Btu/h in the calculation. If the unit’s capacity is greater than 15,000 Btu/h, use 15,000 Btu/h in the calculations.

- a Chapter 6 contains a complete specification of the referenced standards, which include test procedures, including the referenced year version of the test procedure.
- b Nonstandard size units must be factory labeled as follows: “MANUFACTURED FOR NONSTANDARD SIZE APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW STANDARD PROJECTS.” Nonstandard size efficiencies apply only to units being installed in existing sleeves having an external wall opening of less than 16 inches (406 mm) high or less than 42 inches (1067 mm) wide and having a cross-sectional area less than 670 square inches (0.43 m²).
- c The cooling-mode wet bulb temperature requirement only applies for units that reject condensate to the condenser coil.
- d “Cap” in EER and COPH equations for PTACs and PTHPs means cooling capacity in Btu/h at 95°F outdoor dry-bulb temperature.
- e This table is a replica of ASHRAE 90.1 Table 6.8.1-4 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—Minimum Efficiency Requirements.

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Table C403.3.2(5)
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,c}	Test Procedure ^a
Warm-air furnace, gas fired for application outside the U.S.	< 225,000 Btu/h	Maximum capacity ^c	80% AFUE (nonweatherized) or 1% AFUE (weatherized) or 80% $E_t^{b,d}$	DOE 10 C.F.R. 430 Appendix N or Section 2.39, Thermal Efficiency, ANSI Z21.47
Warm-air furnace, gas fired	< 225,000 Btu/h	Maximum capacity ^c	80% $E_t^{b,d}$ before 1/1/2023 81% E_t^d after 1/1/2023	Section 2.39, Thermal Efficiency, ANSI Z21.47
Warm-air furnace, oil fired	< 225,000 Btu/h	Maximum capacity ^c	83% AFUE (nonweatherized) or 78% AFUE (weatherized) or 80% $E_t^{b,d}$	DOE 10 C.F.R. 430 Appendix N or Section 42, Combustion UL 727
Warm-air furnace, oil fired	< 225,000 Btu/h	Maximum capacity ^c	80% E_t before 1/1/2023 82% E_t^d after 1/1/2023	Section 42, Combustion UL 727
Electric furnaces for applications outside the U.S.	< 225,000 Btu/h	All	96% AFUE	DOE 10 C.F.R. 430 Appendix N
Warm air duct furnaces, gas fired	All capacities	Maximum capacity ^c	80% E_c^e	Section 2.10, Efficiency, ANSI Z83.8
Warm air unit heaters, gas fired	All capacities	Maximum capacity ^c	80% $E_c^{e,f}$	Section 2.10, Efficiency, ANSI Z83.8
Warm air unit heaters, oil fired	All capacities	Maximum capacity ^c	80% $E_c^{e,f}$	Section 40, Combustion, UL 731

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

- a Chapter 6 contains a complete specification of the referenced standards, which include test procedures, including the referenced year version of the test procedure.
- b Combination units (i.e., furnaces contained within the same cabinet as an air conditioner) not covered by DOE 10 C.F.R. 430 (i.e., 3-phase power or with cooling capacity greater than or equal to 65,000 Btu/h) may comply with either rating. All other units greater than 225,000 Btu/h sold in the U.S. must meet the AFUE standards for consumer products and testing using U.S. DOE’s AFUE test procedure at DOE 10 C.F.R. 430 Subpart B, Appendix N.
- c Compliance of multiple firing rate units shall be at the maximum firing rate.
- d E_t = Thermal efficiency. Units must also include an interrupted or intermittent ignition device (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.
- e E_c = Combustion efficiency (100% less flue losses). See test procedure for detailed discussion.
- f Units must also include an interrupted or intermittent ignition device (IID) and have either power venting or an automatic flue damper.
- g This table is a replica of ASHRAE 90.1 Table 6.8.1-5 Warm-Air Furnaces and Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces, and Unit Heaters—Minimum Efficiency Requirements.

Table C403.3.2(6)
Gas- and Oil-Fired Boilers—Minimum Efficiency Requirements

Equipment Type ^a	Subcategory or Rating Condition	Size Category (Input)	Minimum Efficiency	Test Procedure ^a
Boilers, hot water	Gas-fired	< 300,000 Btu/h ^{g,h} for applications outside the U.S.	82% AFUE	DOE 10 C.F.R. 430 Appendix N
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h ^e	84% E_t^d	DOE 10 C.F.R. 431.86
		> 2,500,000 Btu/h and ≤ 10,000,000 Btu/h ^b	85% E_t^d	
		> 10,000,000 Btu/h ^b	82% E_c^c	
	Oil-fired ^f	< 300,000 Btu/h ^{g,h}	84% AFUE	DOE 10 C.F.R. 430 Appendix N
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h ^e	87% E_t^d	DOE 10 C.F.R. 431.86
		> 2,500,000 Btu/h ^b	88% E_c^c	
		> 10,000,000 Btu/h ^b	84% E_c^d	
Boilers, steam	Gas-fired	< 300,000 Btu/h ^g	81% AFUE	DOE 10 C.F.R. 430 Appendix N
	Gas-fired - all, except natural draft	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h ^b	82% E_t^d	DOE 10 C.F.R. 431.86
		> 2,500,000 Btu/h ^a	79% E_t^d	
		> 10,000,000 Btu/h ^b	79% E_t^d	
	Gas-fired - natural draft	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h ^b	81% E_t^d	
		> 2,500,000 Btu/h ^b	82% E_t^d	
		> 10,000,000 Btu/h ^b	79% E_t^d	
	Oil-fired ^f	< 300,000 Btu/h	82% AFUE	DOE 10 C.F.R. 430 Appendix N
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h ^b	84% E_t^d	DOE 10 C.F.R. 431.86
		> 2,500,000 Btu/h ^b	85% E_t^d	
		> 10,000,000 Btu/h ^b	81% E_t^d	

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

- a Chapter 6 contains a complete specification of the referenced standards, which include test procedures, including the reference year version of the test procedure.
- b 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.
- c E_c = Combustion efficiency (100 percent less flue losses).
- d E_t = Thermal efficiency.
- e Maximum capacity - Minimum and maximum ratings as provided for and allowed by the unit's controls.
- f Includes oil-fired (residual).
- g Boilers shall not be equipped with a constant burning pilot light.
- h A boiler not equipped with a tankless domestic water heating coil shall be equipped with an automatic means for adjusting the temperature of the water such that an incremental change in inferred heat load produces a corresponding incremental change in the temperature of the water supplied.
- i This table is a replica of ASHRAE 90.1 Table 6.8.1-6 Gas- and Oil-Fired Boilers—Minimum Efficiency Requirements.

GENERAL REQUIREMENTS

**Table C403.3.2(7)
Heat Rejection Equipment—Minimum Efficiency Requirementsⁱ**

Equipment Type^a	Total System Heat Rejection Capacity at Rated Conditions	Subcategory or Rating Condition^h	Performance Required^{b,c,d,f,g}	Test Procedure^{a,e}
Propeller or axial fan open-circuit cooling towers	All	95°F Entering Water 85°F Leaving Water 75°F Entering wb	≥ 40.2 gpm/hp	CTI ATC-105 and CTI STD-201 RS
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 RS
Propeller or axial fan closed-circuit cooling towers	All	102°F Entering Water 90°F Leaving Water 75°F Entering wb	≥ 16.1 gpm/hp	CTI ATC-105S and CTI STD-201 RS
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 RS
Propeller or axial fan dry coolers (air-cooled fluid coolers)	All	115°F Entering Water 105°F Leaving Water 95°F Entering wb	≥ 4.5 gpm/hp	CTI ATC-106
Propeller or axial fan evaporative condensers	All	R-448A Test Fluid 165°F Entering Gas Temperature 105°F Condensing Temperature 75°F Entering wb	≥ 160,000 Btu/h • hp	CTI ATC-106
Propeller or axial fan evaporative condensers	All	Ammonia Test Fluid 140°F Entering Gas Temperature 96.3°F Condensing Temperature 75°F Entering wb	≥ 134,000 Btu/h • hp	CTI ATC-106
Centrifugal fan evaporative condensers	All	R-448A Test Fluid 165°F Entering Gas Temperature 105°F Condensing Temperature 75°F Entering wb	≥ 137,000 Btu/h • hp	CTI ATC-106
Centrifugal fan evaporative condensers	All	Ammonia Test Fluid 140°F Entering Gas Temperature 96.3°F Condensing Temperature 75°F Entering wb	≥ 110,000 Btu/h • hp	CTI ATC-106
Air cooled condensers	All	125°F Condensing Temperature 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 Chapter 6 contains a complete specification of the referenced standards, which include test procedures, including the reference year version of the test procedure.
- 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 the table divided by the fan motor nameplate 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 divided by the sum of the fan motor nameplate power and the integral spray pump motor nameplate power.

- d For purposes of this table, dry-cooler performance is defined as the process water-flow rating of the unit at the thermal rating condition listed in the table divided by the total fan motor nameplate power of the unit, and air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the total fan motor nameplate power of the unit.
- e 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 separate wet and dry heat exchange sections. The certification requirements do not apply to field-erected cooling towers.
- f All cooling towers shall comply with the minimum efficiency listed in the table for that specific type of tower with the capacity effect of any project-specific accessories and/or options included in the capacity of the cooling tower.
- g For purposes of this table, evaporative condenser performance is defined as the heat rejected at the specified rating condition in the table, divided by the sum of the fan motor nameplate power and the integral spray pump nameplate power.
- h Requirements for evaporative condensers are listed with ammonia (R-717) and R-448A as test fluids in the table. Evaporative condensers intended for use with halocarbon refrigerants other than R-448A must meet the minimum efficiency requirements listed above with R-448A as the test fluid. For ammonia, the condensing temperature is defined as the saturation temperature corresponding to the refrigerant pressure at the condenser entrance. For R-448A, which is a zeotropic refrigerant, the condensing temperature is defined as the arithmetic average of the dew point and the bubble point temperatures corresponding to the refrigerant pressure at the condenser entrance.
- i This table is a replica of ASHRAE 90.1 Table 6.8.1-7 Performance Requirements for Heat Rejection Equipment—Minimum Efficiency Requirements.

Table C403.3.2(8)
Electrically Operated Variable Refrigerant Flow Air Conditioners—Minimum Efficiency Requirements^b

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure ^a
	< 65,000 Btu/h	All	VRF Multi-Split System	13.0 SEER	
VRF Air Conditioners, Air Cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split System	11.2 EER 15.5 IEER	AHRI 1230
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split System	11.0 EER 14.9 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split System	10.0 EER 13.9 IEER	

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

- a Chapter 6 contains a complete specification of the referenced standards, which include test procedures, including the reference year version of the test procedure.
- b This table is a replica of ASHRAE 90.1 Table 6.8.1-8 Electrically Operated Variable-Refrigerant-Flow Air Conditioners—Minimum Efficiency Requirements.

Table C403.3.2(9)
Electrically Operated Variable Refrigerant Flow Air-to-Air and Applied Heat Pumps—Minimum Efficiency Requirements^b

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure ^a
	< 65,000 Btu/h	All	VRF Multi-Split System	13.0 SEER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split System	11.0 EER 14.6 IEER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split System with Heat Recovery	10.8 EER 14.4 IEER	
VRF Air Cooled (cooling mode)	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split System	10.6 EER 13.9 IEER	AHRI 1230
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split System with Heat Recovery	10.4 EER 13.7 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split System	9.5 EER 12.7 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split System with Heat Recovery	9.3 EER 12.5 IEER	
	< 65,000 Btu/h	All	VRF Multi-Split System 86°F entering water	12.0 EER 16.0 IEER	

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Table C403.3.2(9)—continued
Electrically Operated Variable Refrigerant Flow Air-to-Air and Applied Heat Pumps—Minimum Efficiency Requirements^b

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure ^a
	< 65,000 Btu/h	All	VRF Multi-Split System with Heat Recovery 86°F entering water	11.8 EER 15.8 IEER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	VRF Multi-Split System 86°F entering water	12.0 EER 16.0 IEER	
VRF Water Source (cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	All	VRF Multi-Split System with Heat Recovery 86°F entering water	11.8 EER 15.8 IEER	AHRI 1230
	≥ 135,000 Btu/h and < 240,000 Btu/h	All	VRF Multi-Split System 86°F entering water	10.0 EER 14.0 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	All	VRF Multi-Split System with Heat Recovery 86°F entering water	9.8 EER 13.8 IEER	
	≥ 240,000 Btu/h	All	VRF Multi-Split System 86°F entering water	10.0 EER 12.0 IEER	
	≥ 240,000 Btu/h	All	VRF Multi-Split System with Heat Recovery 86°F entering water	9.8 EER 11.8 IEER	
	< 135,000 Btu/h	All	VRF Multi-Split System 59°F entering water	16.2 EER	
	< 135,000 Btu/h	All	VRF Multi-Split System with Heat Recovery 59°F entering water	16.0 EER	
VRF Groundwater Source (cooling mode)	≥ 135,000 Btu/h	All	VRF Multi-Split System 59°F entering water	13.8 EER	AHRI 1230
	≥ 135,000 Btu/h	All	VRF Multi-Split System with Heat Recovery 59°F entering water	13.6 EER	
	< 135,000 Btu/h	All	VRF Multi-Split System 77°F entering water	13.4 EER	
VRF Ground Source (cooling mode)	< 135,000 Btu/h	All	VRF Multi-Split System with Heat Recovery 77°F entering water	13.2 EER	AHRI 1230
	≥ 135,000 Btu/h	All	VRF Multi-Split System 77°F entering water	11.0 EER	
	≥ 135,000 Btu/h	All	VRF Multi-Split System with Heat Recovery 77°F entering water	10.8 EER	
	< 65,000 Btu/h (cooling capacity)		VRF Multi-Split System	7.7 HSPF	
VRF Air Cooled (heating mode)	≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity)		VRF Multi-Split System 47°F db/43°F wb outdoor air 17°F db/15°F wb outdoor air	3.3 COP 2.25 COP	AHRI 1230
	≥ 135,000 Btu/h (cooling capacity)		VRF Multi-Split System 47°F db/43°F wb outdoor air 17°F db/15°F wb outdoor air	3.2 COP 2.05 COP	
	< 65,000 Btu/h (cooling capacity)		VRF Multi-Split System 68°F entering water	4.3 COP	
	≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity)		VRF Multi-Split System 68°F entering water	4.3 COP	

Table C403.3.2(9)—continued
Electrically Operated Variable Refrigerant Flow Air-to-Air and Applied Heat Pumps—Minimum Efficiency Requirements^b

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure ^a
VRF Water Source (heating mode)	≥ 135,000 Btu/h and < 240,000 Btu/h (cooling capacity)		VRF Multi-Split System 68°F entering water	4.0 COP	AHRI 1230
	≥ 240,000 Btu/h (cooling capacity)		VRF Multi-Split System 68°F entering water	3.9 COP	
VRF Groundwater Source	< 135,000 Btu/h (cooling capacity)		VRF Multi-Split System 50°F entering water	3.6 COP	AHRI 1230
(heating mode)	≥ 135,000 Btu/h (cooling capacity)		VRF Multi-Split System 50°F entering water	3.3 COP	
VRF Ground Source	< 135,000 Btu/h (cooling capacity)		VRF Multi-Split System 32°F entering water	3.1 COP	AHRI 1230
(heating mode)	≥ 135,000 Btu/h (cooling capacity)		VRF Multi-Split System 32°F entering water	2.8 COP	

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

- a Chapter 6 contains a complete specification of the referenced standards, which include test procedures, including the reference year version of the test procedure.
- b This table is a replica of ASHRAE 90.1 Table 6.8.1-9 Electrically Operated Variable-Refrigerant-Flow and Applied Heat Pumps—Minimum Efficiency Requirements.

Table C403.3.2(10)
Floor-Mounted Air Conditioners and Condensing Units Serving Computer Rooms—Minimum Efficiency Requirements^b

Equipment Type	Standard Model	Net Sensible Cooling Capacity	Minimum Net Sensible COP	Rating Conditions Return Air (dry bulb/dew point)	Test Procedure ^a
Air cooled	Downflow	< 80,000 Btu/h	2.70	85°F/52°F (Class 2)	AHRI 1360
		≥ 80,000 Btu/h and < 295,000 Btu/h	2.58		
		≥ 295,000 Btu/h	2.36		
	Upflow - Ducted	< 80,000 Btu/h	2.67		
		≥ 80,000 Btu/h and < 295,000 Btu/h	2.55		
		≥ 295,000 Btu/h	2.33		
	Upflow - Nonducted	> 65,000 Btu/h	2.16	75°F/52°F (Class 1)	
		≥ 65,000 Btu/h and < 240,000 Btu/h	2.04		
		≥ 240,000 Btu/h	1.89		
	Horizontal	> 65,000 Btu/h	2.65	95°F/52°F (Class 3)	
		≥ 65,000 Btu/h and < 240,000 Btu/h	2.55		
		≥ 240,000 Btu/h	2.47		

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Table C403.3.2(10)—continued
Floor-Mounted Air Conditioners and Condensing Units Serving Computer Rooms—Minimum Efficiency Requirements^b

Equipment Type	Standard Model	Net Sensible Cooling Capacity	Minimum Net Sensible COP	Rating Conditions Return Air (dry bulb/dew point)	Test Procedure ^a
Air cooled with fluid economizer	Downflow	< 80,000 Btu/h	2.70	85°F/52°F (Class 1)	AHRI 1360
		≥ 80,000 Btu/h and < 295,000 Btu/h	2.58		
		≥ 295,000 Btu/h	2.36		
	Upflow - Ducted	< 80,000 Btu/h	2.67		
		≥ 80,000 Btu/h and < 295,000 Btu/h	2.55		
		≥ 295,000 Btu/h	2.33		
	Upflow - Nonducted	> 65,000 Btu/h	2.09	75°F/52°F (Class 1)	
		≥ 65,000 Btu/h and < 240,000 Btu/h	1.99		
		≥ 240,000 Btu/h	1.81		
	Horizontal	> 65,000 Btu/h	2.65	95°F/52°F (Class 3)	
		≥ 65,000 Btu/h and < 240,000 Btu/h	2.55		
		≥ 240,000 Btu/h	2.47		
Water cooled	Downflow	< 80,000 Btu/h	2.82	85°F/52°F (Class 1)	AHRI 1360
		≥ 80,000 Btu/h and < 295,000 Btu/h	2.73		
		≥ 295,000 Btu/h	2.67		
	Upflow - Ducted	< 80,000 Btu/h	2.79		
		≥ 80,000 Btu/h and < 295,000 Btu/h	2.70		
		≥ 295,000 Btu/h	2.64		
	Upflow - Nonducted	> 65,000 Btu/h	2.43	75°F/52°F (Class 1)	
		≥ 65,000 Btu/h and < 240,000 Btu/h	2.32		
		≥ 240,000 Btu/h	2.20		
	Horizontal	> 65,000 Btu/h	2.79	95°F/52°F (Class 3)	
		≥ 65,000 Btu/h and < 240,000 Btu/h	2.68		
		≥ 240,000 Btu/h	2.60		
Water cooled with fluid economizer	Downflow	< 80,000 Btu/h	2.77	85°F/52°F (Class 1)	AHRI 1360
		≥ 80,000 Btu/h and < 295,000 Btu/h	2.68		
		≥ 295,000 Btu/h	2.61		
	Upflow - Ducted	< 80,000 Btu/h	2.74		
		≥ 80,000 Btu/h and < 295,000 Btu/h	2.65		
		≥ 295,000 Btu/h	2.58		
	Upflow - Nonducted	> 65,000 Btu/h	2.35	75°F/52°F (Class 1)	
		≥ 65,000 Btu/h and < 240,000 Btu/h	2.24		
		≥ 240,000 Btu/h	2.12		
	Horizontal	> 65,000 Btu/h	2.71	95°F/52°F (Class 3)	
		≥ 65,000 Btu/h and < 240,000 Btu/h	2.60		
		≥ 240,000 Btu/h	2.54		

Table C403.3.2(10)—continued
Floor-Mounted Air Conditioners and Condensing Units Serving Computer Rooms—Minimum Efficiency Requirements^b

Equipment Type	Standard Model	Net Sensible Cooling Capacity	Minimum Net Sensible COP	Rating Conditions Return Air (dry bulb/dew point)	Test Procedure ^a
Glycol cooled	Downflow	< 80,000 Btu/h	2.56	85°F/52°F (Class 1)	AHRI 1360
		≥ 80,000 Btu/h and < 295,000 Btu/h	2.24		
		≥ 295,000 Btu/h	2.21		
	Upflow - Ducted	< 80,000 Btu/h	2.53		
		≥ 80,000 Btu/h and < 295,000 Btu/h	2.21		
		≥ 295,000 Btu/h	2.18		
	Upflow - Nonducted	> 65,000 Btu/h	2.08	75°F/52°F (Class 1)	
		≥ 65,000 Btu/h and < 240,000 Btu/h	1.90		
		≥ 240,000 Btu/h	1.81		
	Horizontal	> 65,000 Btu/h	2.48	95°F/52°F (Class 3)	
		≥ 65,000 Btu/h and < 240,000 Btu/h	2.18		
		≥ 240,000 Btu/h	2.18		
Glycol cooled with fluid economizer	Downflow	< 80,000 Btu/h	2.51	85°F/52°F (Class 1)	AHRI 1360
		≥ 80,000 Btu/h and < 295,000 Btu/h	2.19		
		≥ 295,000 Btu/h	2.15		
	Upflow - Ducted	< 80,000 Btu/h	2.48		
		≥ 80,000 Btu/h and < 295,000 Btu/h	2.16		
		≥ 295,000 Btu/h	2.12		
	Upflow - Nonducted	> 65,000 Btu/h	2.00	75°F/52°F (Class 1)	
		≥ 65,000 Btu/h and < 240,000 Btu/h	1.82		
		≥ 240,000 Btu/h	1.73		
	Horizontal	> 65,000 Btu/h	2.44	95°F/52°F (Class 3)	
		≥ 65,000 Btu/h and < 240,000 Btu/h	2.10		
		≥ 240,000 Btu/h	2.10		

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

- a. Chapter 6 contains a complete specification of the referenced standards, which include test procedures, including the reference year version of the test procedure.
- b. This table is a replica of ASHRAE 90.1 Table 6.8.1-10 Floor-Mounted Air Conditioners and Condensing Units Serving Computer Rooms—Minimum Efficiency Requirements.

Table C403.3.2(11)
Vapor-Compression-Based Indoor Pool Dehumidifiers—Minimum Efficiency Requirements^b

Equipment Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure ^a
Single package indoor (with or without economizer)	Rating Conditions: A or C	3.5 MRE	AHRI 910
Single package indoor water cooled (with or without economizer)	Rating Conditions: A, B or C	3.5 MRE	
Single package indoor air cooled (with or without economizer)	Rating Conditions: A, B or C	3.5 MRE	
Split system indoor air cooled (with or without economizer)	Rating Conditions: A, B or C	3.5 MRE	

- a. Chapter 6 contains a complete specification of the referenced standards, which include test procedures, including the reference year version of the test procedure.
- b. This table is a replica of ASHRAE 90.1 Table 6.8.1-11 Vapor-Compressor-Based Indoor Pool Dehumidifiers—Minimum Efficiency Requirements.

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Table C403.3.2(12)
Electrically Operated DX-DOAS Units, Single-Package and Remote Condenser, Without Energy Recovery—
Minimum Efficiency Requirements^b

Equipment Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure ^a
Air cooled (dehumidification mode)		4.0 ISMRE	AHRI 920
Air source heat pumps (dehumidification mode)		4.0 ISMRE	AHRI 920
Water cooled (dehumidification mode)	Cooling tower condenser water	4.9 ISMRE	AHRI 920
	Chilled water	6.0 ISMRE	
Air source heat pump (heating mode)		2.7 ISCOP	AHRI 920
Water source heat pump (dehumidification mode)	Ground source, closed loop	4.8 ISMRE	AHRI 920
	Ground-water source	5.0 ISMRE	
	Water source	4.0 ISMRE	
Water source heat pump (heating mode)	Ground source, closed loop	2.0 ISCOP	AHRI 920
	Ground-water source	3.2 ISCOP	
	Water source	3.5 ISCOP	

- a Chapter 6 contains a complete specification of the referenced standards, which include test procedures, including the reference year version of the test procedure.
- b This table is a replica of ASHRAE 90.1 Table 6.8.1-13 Electrically Operated DX-DOAS Units, Single-Package and Remote Condenser, without Energy Recovery—Minimum Efficiency Requirements.

Table C403.3.2(13)
Electrically Operated DX-DOAS Units, Single-Package and Remote Condenser, with Energy Recovery—
Minimum Efficiency Requirements^b

Equipment Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure ^a
Air cooled (dehumidification mode)		5.2 ISMRE	AHRI 920
Air source heat pumps (dehumidification mode)		5.2 ISMRE	AHRI 920
Water cooled (dehumidification mode)	Cooling tower condenser water	5.3 ISMRE	AHRI 920
	Chilled water	6.6 ISMRE	
Air source heat pump (heating mode)		3.3 ISCOP	AHRI 920
Water source heat pump (dehumidification mode)	Ground source, closed loop	5.2 ISMRE	AHRI 920
	Ground-water source	5.8 ISMRE	
	Water source	4.8 ISMRE	
Water source heat pump (heating mode)	Ground source, closed loop	3.8 ISCOP	AHRI 920
	Ground-water source	4.0 ISCOP	
	Water source	4.8 ISCOP	

- a Chapter 6 contains a complete specification of the referenced standards, which include test procedures, including the reference year version of the test procedure.
- b This table is a replica of ASHRAE 90.1 Table 6.8.1-14 Electrically Operated DX-DOAS Units, Single-Package and Remote Condenser, with Energy Recovery—Minimum Efficiency Requirements.

Table C403.3.2(14)
Electrically Water Source Heat Pumps—Minimum Efficiency Requirements^c

Equipment Type	Size Category ^b	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure ^a
	< 17,000 Btu/h	All	86°F entering water	12.2 EER	
Water to air, water loop (cooling mode)	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	13.0 EER	ISO 13256-1
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	13.0 EER	
Water to air, ground water (cooling mode)	< 135,000 Btu/h	All	59°F entering water	18.0 EER	

Table C403.3.2(14)—continued
Electrically Water Source Heat Pumps—Minimum Efficiency Requirements^c

Equipment Type	Size Category ^b	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure ^a
Brine to air, ground loop (cooling mode)	< 135,000 Btu/h	All	77°F entering water	14.1 EER	
Water to water, water loop (cooling mode)	< 135,000 Btu/h	All	86°F entering water	10.6 EER	
Water to water, ground water (cooling mode)	< 135,000 Btu/h	All	59°F entering water	16.3 EER	ISO 13256-2
Brine to water, ground loop (cooling mode)	< 135,000 Btu/h	All	77°F entering fluid	12.1 EER	
Water to air, water loop (heating mode)	< 135,000 Btu/h (cooling capacity)		68°F entering water	4.3 COP _H	
Water to air, ground water (heating mode)	< 135,000 Btu/h (cooling capacity)		50°F entering water	3.7 COP _H	ISO 13256-1
Brine to air, ground loop (heating mode)	< 135,000 Btu/h (cooling capacity)		32°F entering fluid	3.2 COP _H	
Water to water, water loop (heating mode)	< 135,000 Btu/h (cooling capacity)		68°F entering water	3.7 COP _H	ISO 13256-1
Water to water, ground water (heating mode)	< 135,000 Btu/h (cooling capacity)		50°F entering water	3.1 COP _H	ISO 13256-2
Brine to water, ground loop (heating mode)	< 135,000 Btu/h (cooling capacity)		32°F entering fluid	2.5 COP _H	ISO 13256-2

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

- a Chapter 6 contains a complete specification of the referenced standards, which include test procedures, including the reference year version of the test procedure.
- b Single-phase, U.S. air-cooled heat pumps less than 19 kW are regulated as consumer products by DOE 10 C.F.R. 430. SCOPC, SCOP2C, SCOPH and SCOP2H values for single-phase products are set by the U.S. DOE.
- c This table is a replica of ASHRAE 90.1 Table 6.8.1-15 Electrically Operated Water-Source Heat Pumps—Minimum Efficiency Requirements.

Table C403.3.2(15)
Heat-Pump and Heat Recovery Chiller Packages—Minimum Efficiency Requirements^{g,h,i,j,k}

HEATING OPERATION														
Equipment Type	Size Category, ton _R	Cooling-Only Operation Cooling Efficiency ^c Air-Source EER (FL/IPLV), Btu/W×h Water-Source Power Input per Capacity (FL/IPLV), kW/ton _R		Heating Source Conditions (entering/leaving water) or OAT (db/wb), °F	Heat-Pump Heating Full-Load Efficiency (COP _H) ^b , W/W				Heat Recovery Chiller Full-Load Efficiency (COP _{HR}) ^{c,d} , W/W Simultaneous Cooling and Heating Full-Load Efficiency (COP _{SHC}) ^c , W/W				Test Procedure ^a	
					Leaving Heating Water Temperature				Leaving Heating Water Temperature					
					Low	Medium	High	Boost	Low	Medium	High	Boost		
		105°F	120°F		140°F	140°F	105°F	120°F	140°F	140°F				
		Path A	Path B											
Air source	All sizes	≥9.595 FL ≥13.02 IPLV.IP	≥9.215 FL ≥15.01 IPLV.IP	47 db 43 wb ^e	≥3.290	≥2.770	≥2.310	NA	NA	NA	NA	NA	AHRI 550/590	
		≥9.595 FL ≥13.30 IPLV.IP	≥9.215 FL ≥15.30 IPLV.IP	17 db 15 wb ^e	≥2.230	≥1.950	≥1.630	NA	NA	NA	NA	NA		
Water-source electrically operated positive displacement	< 75	≥0.7885 FL ≥0.6316 IPLV.IP	≥0.7875 FL ≥0.5145 IPLV.IP	54/44 ^f 75/65 ^f	≥4.640 NA	≥3.680 NA	≥2.680 NA	NA ≥3.550	≥8.330 NA	≥6.410 NA	≥4.420 NA	NA ≥6.150		
		≥75 and < 150	≥0.7579 FL ≥0.5895 IPLV.IP	≥0.7140 FL ≥0.4620 IPLV.IP	54/44 ^f 75/65 ^f	≥4.640 NA	≥3.680 NA	≥2.680 NA	NA ≥3.550	≥8.330 NA	≥6.410 NA	≥4.420 NA		NA ≥6.150
	≥ 150 and < 300	≥0.6947 FL ≥0.5684 IPLV.IP	≥0.7140 FL ≥0.4620 IPLV.IP	54/44 ^f 75/65 ^f	≥4.640 NA	≥3.680 NA	≥2.680 NA	NA ≥3.550	≥8.330 NA	≥6.410 NA	≥4.420 NA	NA ≥6.150		
		≥300 and < 600	≥0.6421 FL ≥0.5474 IPLV.IP	≥0.6563 FL ≥0.4305 IPLV.IP	54/44 ^f 75/65 ^f	≥4.930 NA	≥3.960 NA	≥2.970 NA	NA ≥3.990	≥8.900 NA	≥6.980 NA	≥5.000 NA		NA ≥6.850
	≥ 600	≥0.5895 FL ≥0.5263 IPLV.IP	≥0.6143 FL ≥0.3990 IPLV.IP	54/44 ^f 75/65 ^f	≥4.930 NA	≥3.960 NA	≥2.970 NA	NA ≥3.990	≥8.900 NA	≥6.980 NA	≥5.000 NA	NA ≥6.850		
		< 75	≥0.6421 FL ≥0.5789 IPLV.IP	≥0.7316 FL ≥0.4632 IPLV.IP	54/44 ^f 75/65 ^f	≥4.640 NA	≥3.680 NA	≥2.680 NA	NA ≥3.550	≥8.330 NA	≥6.410 NA	≥4.420 NA		NA ≥6.150
	Water-source electrically operated centrifugal	≥ 75 and < 150	≥0.5895 FL ≥0.5474 IPLV.IP	≥0.6684 FL ≥0.4211 IPLV.IP	54/44 ^f 75/65 ^f	≥4.640 NA	≥3.680 NA	≥2.680 NA	NA ≥3.550	≥8.330 NA	≥6.410 NA	≥4.420 NA		NA ≥6.150
			≥150 and < 300	≥0.5895 FL ≥0.5263 IPLV.IP	≥0.6263 FL ≥0.4105 IPLV.IP	54/44 ^f 75/65 ^f	≥4.640 NA	≥3.680 NA	≥2.680 NA	NA ≥3.550	≥8.330 NA	≥6.410 NA		≥4.420 NA
		≥ 300 and < 600	≥0.5895 FL ≥0.5263 IPLV.IP	≥0.6158 FL ≥0.4000 IPLV.IP	54/44 ^f 75/65 ^f	≥4.640 NA	≥3.680 NA	≥2.680 NA	NA ≥3.990	≥8.900 NA	≥6.980 NA	≥5.000 NA		NA ≥6.850
			≥ 600	≥0.5895 FL ≥0.5263 IPLV.IP	≥0.6158 FL ≥0.4000 IPLV.IP	54/44 ^f 75/65 ^f	≥4.640 NA	≥3.680 NA	≥2.680 NA	NA ≥3.990	≥8.900 NA	≥6.980 NA		≥5.000 NA

For SI: °C = [(°F) - 32]/1.8.

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

b Cooling-only rating conditions are standard rating conditions defined in AHRI 550/590, Table 1.

c Heating full-load rating conditions are at rating conditions defined in AHRI 550/590, Table 1.

d For water-cooled heat recovery chillers that have capabilities for heat rejection to a heat recovery condenser and a tower condenser, the COP_{HR} applies to operation at full load with 100 percent heat recovery (no tower rejection). Units that only have capabilities for partial heat recovery shall meet the requirements of Table C403.3.2(3).

e Outdoor air entering dry-bulb (db) temperature and wet-bulb (wb) temperature.

- f Source-water entering and leaving water temperature.
- g This table is a replica of ASHRAE 90.1 Table 6.8.1-16 Heat-Pump and Heat Recovery Chiller Packages—Minimum Efficiency Requirements.
- h AHRI ratings are not required for equipment sizes larger than those covered by the test standard.
- i Air-to-water heat pumps that are configured to operate only in heating and not in cooling only need to comply with the minimum heating efficiencies.
- j Units that are both an air-to-water heat pump and a heat recovery chiller are required to comply with either the applicable air source efficiency requirements or the heat recovery chiller requirements but not both.
- k Heat pumps and heat recovery chillers are only required to comply with one of the four leaving heating water temperature criteria. The leaving heater water temperature criteria that are closest to the design leaving water temperature shall be utilized.

**Table C403.3.2(16)
Ceiling-Mounted Computer-Room Air Conditioners—Minimum Efficiency Requirements^b**

Equipment Type	Standard Model	Net Sensible Cooling Capacity	Minimum Net Sensible COP	Rating Conditions Return Air (dry-bulb/dew point)	Test Procedure ^a
Air cooled with free air discharge condenser	Ducted	< 29,000 Btu/h	2.05	75°F/52°F (Class 1)	AHRI 1360
		≥ 29,000 Btu/h and < 65,000 Btu/h	2.02		
		≥ 65,000 Btu/h	1.92		
	Nonducted	< 29,000 Btu/h	2.08		
		≥ 29,000 Btu/h and < 65,000 Btu/h	2.05		
		≥ 65,000 Btu/h	1.94		
Air cooled with free air discharge condenser with fluid economizer	Ducted	< 29,000 Btu/h	2.01	75°F/52°F (Class 1)	AHRI 1360
		≥ 29,000 Btu/h and < 65,000 Btu/h	1.97		
		≥ 65,000 Btu/h	1.87		
	Nonducted	< 29,000 Btu/h	2.04		
		≥ 29,000 Btu/h and < 65,000 Btu/h	2.00		
		≥ 65,000 Btu/h	1.89		
Air cooled with ducted condenser	Ducted	< 29,000 Btu/h	1.86	75°F/52°F (Class 1)	AHRI 1360
		≥ 29,000 Btu/h and < 65,000 Btu/h	1.83		
		≥ 65,000 Btu/h	1.73		
	Nonducted	< 29,000 Btu/h	1.89		
		≥ 29,000 Btu/h and < 65,000 Btu/h	1.86		
		≥ 65,000 Btu/h	1.75		
Air cooled with fluid economizer and ducted condenser	Ducted	< 29,000 Btu/h	1.82	75°F/52°F (Class 1)	AHRI 1360
		≥ 29,000 Btu/h and < 65,000 Btu/h	1.78		
		≥ 65,000 Btu/h	1.68		
	Nonducted	< 29,000 Btu/h	1.85		
		≥ 29,000 Btu/h and < 65,000 Btu/h	1.81		
		≥ 65,000 Btu/h	1.70		
Water cooled	Ducted	< 29,000 Btu/h	2.38	75°F/52°F (Class 1)	AHRI 1360
		≥ 29,000 Btu/h and < 65,000 Btu/h	2.28		
		≥ 65,000 Btu/h	2.18		
	Nonducted	< 29,000 Btu/h	2.41		
		≥ 29,000 Btu/h and < 65,000 Btu/h	2.31		
		≥ 65,000 Btu/h	2.20		

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Table C403.3.2(16)—continued
Ceiling-Mounted Computer-Room Air Conditioners—Minimum Efficiency Requirements^b

Equipment Type	Standard Model	Net Sensible Cooling Capacity	Minimum Net Sensible COP	Rating Conditions Return Air (dry-bulb/dew point)	Test Procedure ^a
Water cooled with fluid economizer	Ducted	< 29,000 Btu/h	2.33	75°F/52°F (Class 1)	AHRI 1360
		≥ 29,000 Btu/h and < 65,000 Btu/h	2.23		
		≥ 65,000 Btu/h	2.13		
	Nonducted	< 29,000 Btu/h	2.36		
		≥ 29,000 Btu/h and < 65,000 Btu/h	2.26		
		≥ 65,000 Btu/h	2.16		
Glycol cooled	Ducted	< 29,000 Btu/h	1.97	75°F/52°F (Class 1)	AHRI 1360
		≥ 29,000 Btu/h and < 65,000 Btu/h	1.93		
		≥ 65,000 Btu/h	1.78		
	Nonducted	< 29,000 Btu/h	2.00		
		≥ 29,000 Btu/h and < 65,000 Btu/h	1.98		
		≥ 65,000 Btu/h	1.81		
Glycol cooled with fluid economizer	Ducted	< 29,000 Btu/h	1.92	75°F/52°F (Class 1)	AHRI 1360
		≥ 29,000 Btu/h and < 65,000 Btu/h	1.88		
		≥ 65,000 Btu/h	1.73		
	Nonducted	< 29,000 Btu/h	1.95		
		≥ 29,000 Btu/h and < 65,000 Btu/h	1.93		
		≥ 65,000 Btu/h	1.76		

For SI: 1 British thermal unit per hour = 0.2931 W, °C = [(°F) - 32]/1.8, COP = (Btu/h × hp)(2,550.7).

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

b This table is a replica of ASHRAE 90.1 Table 6.8.1-17 Ceiling-Mounted Computer-Room Air Conditioners—Minimum Efficiency Requirements.

C403.3.4 Boiler requirements. *Boiler systems* shall comply with the following:

C403.3.4.1 Combustion air positive shut-off. Combustion air positive shut-off shall be provided on all newly installed *boiler systems* as follows:

1. All *boiler systems* with an input capacity of 2,500,000 Btu/h and above, in which the boiler is designed to operate with a nonpositive vent static pressure.
2. All *boiler systems* where one stack serves two or more boilers with a total combined input capacity per stack of 2,500,000 Btu/h.

C403.3.4.2 Boiler system oxygen concentration controls. Boiler system combustion air fans with motors 10 horsepower or larger shall meet one of the following for newly installed boilers:

1. The fan motor shall be variable speed; or
2. The fan motor shall include controls that limit the fan motor demand to no more than 30 percent of the total design wattage at 50 percent of design air volume.

C403.3.4.3 Boiler oxygen concentration controls. Newly installed boilers with an input capacity of 5,000,000 Btu/h and greater and a steady state full-load combustion efficiency less than 90 percent shall maintain stack-gas oxygen concentrations not greater than the values specified in Table C403.3.4.3. Combustion air volume shall be controlled with respect to measured flue gas oxygen concentration. The use of a common gas and combustion air control linkage or jack shaft is prohibited.

EXCEPTION: These concentration limits do not apply where 50 percent or more of the boiler system capacity serves Group R-2 occupancies.

Table C403.3.4.3
Boiler Stack-Gas Oxygen Concentrations

Boiler System Type	Maximum Stack-Gas Oxygen Concentration ^a
Less than 10% of the boiler system capacity is used for process applications at design conditions	5%
All others	3%

^a Concentration levels measured by volume on a dry basis over firing rates of 20 to 100 percent.

C403.3.4.4 Boiler turndown. *Boiler systems* with design input of greater than 1,000,000 Btu/h (293 kW) shall comply with the turndown ratio specified in Table C403.3.4.4.

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

Table C403.3.4.4
Boiler Turndown

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

C403.3.4.5 Buildings with high-capacity space-heating gas boiler systems. New buildings with gas hot water boiler systems for space heating with a total system input of at least 1,000,000 Btu/h but not more than 10,000,000 Btu/h shall comply with this section.

EXCEPTIONS:

1. Where 25 percent of the annual space heating requirement is provided by site-recovered energy, or heat recovery chillers.
2. Space heating boilers installed in individual dwelling units.
3. Where 50 percent or more of the design heat load is served using perimeter convective heating, radiant ceiling panels, or both.
4. Individual gas boilers with input capacity less than 300,000 Btu/h shall not be included in the calculations of the total system input or total system efficiency.

C403.3.4.5.1 Boiler efficiency. Gas hot water boilers shall have a minimum thermal efficiency (Et) of 90 percent when rated in accordance with the test procedures in Table C403.3.2(6). Systems with multiple boilers are allowed to meet this requirement if the space-heating input provided by equipment with thermal efficiency (Et) above and below 90 percent provides an input capacity-weighted average thermal efficiency of at least 90 percent. For boilers rated only for combustion efficiency, the calculation for the input capacity-weighted average thermal efficiency shall use the combustion efficiency value.

C403.3.4.5.2 Hot water distribution system design. The hot water distribution system shall be designed to meet all of the following:

1. Coils and other heat exchangers shall be selected so that at design conditions the hot water return temperature entering the boilers is 120°F (48.9°C) or less.
2. Under all operating conditions, the water temperature entering the boiler is 120°F (48.9°C) or less, or the flow rate of supply hot water that recirculates directly into the return system, such as three-way valves or minimum flow bypass controls, shall be no greater than 20 percent of the design flow of the operating boilers.

C403.3.5 Dedicated outdoor air systems (DOAS). For buildings with occupancies as shown in Table C403.3.5, outdoor air shall be provided to each occupied space by a dedicated outdoor air system (DOAS) which delivers 100 percent outdoor air without requiring operation of the heating and cooling system fans for ventilation air delivery.

EXCEPTIONS:

1. Occupied spaces that are not ventilated by a mechanical ventilation system and are only ventilated by a natural ventilation system in accordance with Section 402 of the *International Mechanical Code*.
2. High efficiency variable air volume (VAV) systems complying with Section C403.6.10 for occupancy classifications other than Groups A-1, A-2 and A-3 as specified in Table C403.3.5, and high efficiency VAV systems complying with Section C403.12 for occupancy classification Groups A-1, A-2 and A-3 as specified in Table C403.3.5. This exception shall not be used as a substitution for a DOAS per Section C406.6.

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3. Spaces that are within building types not subject to the requirements of Section C403.3.5, and that qualify as accessory occupancies according to Section 508.2 of the International Building Code, are not required to comply with this section.

**Table C403.3.5
Occupancy Classifications Requiring DOAS**

Occupancy Classification ^a	Inclusions	Exempted
A-1	All occupancies not specifically exempted	Television and radio studios
A-2	Casinos (gaming area)	All other A-2 occupancies
A-3	Lecture halls, community halls, exhibition halls, gymnasiums, courtrooms, libraries, places of religious worship	All other A-3 occupancies
A-4, A-5		All occupancies excluded
B	All occupancies not specifically exempted	Food processing establishments including commercial kitchens, restaurants, cafeterias; laboratories for testing and research; data processing facilities and telephone exchanges; air traffic control towers; animal hospitals, kennels, pounds; ambulatory care facilities
F, H, I, R, S, U		All occupancies excluded
E, M	All occupancies included	

a. Occupancy classification from the *International Building Code* Chapter 3.

C403.3.5.1 DOAS with energy recovery ventilation. The DOAS shall include energy recovery. The *energy recovery ventilation* system shall have a ~~((68))~~ 67 percent minimum sensible recovery effectiveness of the energy recovery device as calculated in accordance with Equation 4-9 or provide an enthalpy recovery ratio of not less than 60 percent at design conditions in accordance with Section C403.7.6. The airflow rate thresholds in Section C403.7.6 that define when the energy recovery requirements in that section do not apply, are not applicable to this section. The return/exhaust air stream temperature for heat recovery device selection shall be 70°F (21°C) at 30 percent relative humidity, or as calculated by the registered design professional.

$$\text{Sensible Recovery Effectiveness} = \frac{T_{OA} - T_{SA}}{T_{OA} - T_{RA}} \quad \text{(Equation 4-9)}$$

Where:

T_{OA} = Design outdoor air dry bulb temperature entering the energy recovery device.

T_{SA} = Supply air dry bulb temperature leaving the energy recovery device at design temperatures and airflow conditions, as selected for the proposed DOAS unit(s).

T_{RA} = Design return air dry bulb temperature.

EXCEPTIONS:

1. Systems installed for the sole purpose of providing makeup air for systems exhausting toxic, flammable, paint, or corrosive fumes or dust, dryer exhaust, or commercial kitchen hoods used for collecting and removing grease vapors and smoke.
2. Heat recovery and energy recovery ventilators (H/ERV) that are rated and *listed* in accordance with HVI 920 can demonstrate compliance with the sensible recovery effectiveness requirement using the adjusted sensible recovery effectiveness (ASRE) rating of the equipment at 32°F test conditions. Applied flow rate for ASRE rating shall be no less than the design flow rate or the closest value interpolated between two listed flow rates.
- ~~((3. The energy recovery systems for Group R-2 occupancies are permitted to provide 50 percent minimum sensible heat recovery effectiveness in lieu of 68 percent sensible recovery effectiveness in accordance with Section C403.7.6. The return/exhaust air stream temperature for heat recovery device selection shall be 70°F (21°C) or as determined by an approved calculation procedure.))~~

C403.3.5.2 DOAS fan power. For a DOAS that does not have at least one fan or fan array with fan electrical input power ≥ 1 kW, the total combined fan power shall not exceed ~~((1-watt))~~ 0.8 watts per cfm of outdoor air as calculated in accordance with Equation 4-10 using design maximum airflows and external static pressures. For a DOAS with at least one fan or fan array with fan electrical input power ≤ 1 kW, the DOAS shall comply with the fan power limitations of Section C403.8.1. DOAS total combined fan power shall include all supply, exhaust and other fans utilized for the

purpose of ventilation. This fan power restriction applies to each DOAS in the permitted project, but does not include the fan power associated with the zonal heating and cooling equipment.

$$\text{DOAS Total Combined Fan Power} \left(\frac{\text{Watts}}{\text{CFM}} \right) = \sum \left(\frac{\text{Fan bhp}}{\eta_m} \right) \times \frac{746}{\text{CFM}_{\text{supply}}} \quad \text{(Equation 4-10)}$$

Where:

- Fan bhp = Brake horsepower for each supply, exhaust and other fan in the system at design maximum airflow rate.
 η_m = Fan motor efficiency including all motor, drive and other losses for each fan in the system.
 $\text{CFM}_{\text{supply}}$ = Design maximum airflow rate of outdoor (supply) air.

C403.3.5.3 Heating and cooling system fan controls. Heating and cooling equipment fans, heating and cooling circulation pumps, and terminal unit fans shall cycle off and terminal unit primary cooling air shall be shut off when there is no call for heating or cooling in the *zone*.

EXCEPTION: Fans used for heating and cooling using less than 0.12 watts per cfm may operate when space temperatures are within the setpoint deadband (Section C403.4.1.2) to provide destratification and air mixing in the space.

C403.3.5.4 Decoupled DOAS supply air. The DOAS supply air shall be delivered directly to the occupied space or downstream of the terminal heating and/or cooling coils.

EXCEPTIONS:

1. Active chilled beam systems.
2. Sensible only cooling terminal units with pressure independent variable airflow regulating devices limiting the DOAS supply air to the greater of latent load or minimum ventilation requirements.
3. Terminal heating and/or cooling units that comply with the low fan power allowance requirements in the exception of Section C403.3.5.3.

C403.3.5.5 Supplemental heating and cooling. Supply air stream heating in the DOAS system shall comply with Section C403.7.3. Cooling is permitted for dehumidification only. Cooling coil shall be sized to meet peak dehumidification requirement at design outdoor temperatures, and no larger. Cooling coil shall be controlled to maintain supply air relative humidity or *zone* relative humidity.

EXCEPTIONS:

1. Heating permitted for defrost control shall be locked out when outside air temperatures are above 35°F (2°C). Supplemental heating for defrost shall modulate to 10 percent of the peak capacity, and shall be sized to prevent (~~frost/damage/dam~~) frost damage to the unit at design temperatures and provide supply air less than or equal to 55°F (13°C).
2. A DOAS serving Group R-1 or R-2 occupancy spaces that are served by zonal heating systems, but not by zonal heat pumps, air conditioners, or other zonal mechanical cooling systems, is permitted to be provided with a supplemental heating and cooling system in compliance with Section C403.1.4.

C403.3.5.6 DOAS Energy Recovery Ventilator Temperature Control. Where DOAS includes energy or heat recovery and the design outdoor airflow is greater than 500 cfm (250 L/s), the DOAS shall be equipped with an air economizer bypass damper, energy recovery media bypass damper, or energy recovery wheel speed control that is controlled to prevent overheating of the supply air between the outdoor air temperatures of 55°F (18°C) and 75°F (24°C). Controls must be configured to minimize energy recovery operation or maintain an appropriate DOAS leaving air temperature to prevent zonal heating when the building is in cooling, based either on outdoor air temperature, return air temperature, or a DDC zone-based cooling system demand status reset, based on one of the following:

1. Outdoor air temperature;
2. Return air temperature; or
3. A DDC zone-based cooling system demand status reset.

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~~((C403.3.5.6))~~ **C403.3.5.7 Impracticality.** Where the *code official* determines that full compliance with one or more of the requirements in Sections C403.3.5.1 through C403.3.5.5 is impractical, it is permissible to provide an approved alternate means of compliance that achieves a comparable level of energy efficiency as the requirement(s) deemed impractical. For the purposes of this section, impractical means that an HVAC system complying with all requirements in Section C403.3.5 cannot effectively be utilized due to an unusual use or configuration of the building.

C403.3.6 (Reserved) (~~Ventilation for Group R-2 occupancy.~~ For all Group R-2 dwelling and sleeping units, a balanced ventilation system with a heat recovery system shall provide outdoor air directly to all habitable spaces. The heat recovery system shall have a 60 percent minimum sensible recovery effectiveness as calculated in accordance with Section C403.3.5.1. The ventilation system shall allow for the design flow rates to be tested and verified at each habitable space as part of the commissioning process in accordance with Section C408.2.2.

EXCEPTION: Heat recovery and energy recovery ventilators (H/ERV) that are rated and listed in accordance with HVI 920 can demonstrate compliance with the sensible recovery effectiveness requirement using the adjusted sensible recovery effectiveness (ASRE) rating of the equipment at 32°F test conditions. Applied flow rate for ASRE rating shall be no less than the design flow rate or the closest value interpolated between two listed flow rates.)

SDCI Informative Note: See Section C403.7.6.1 for Ventilation for Group R-2 occupancies.

C403.3.7 Hydronic system flow rate. 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 C403.3.7 for the appropriate total annual hours of operation. Pipe sizes 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 permitted to be selected from the “Variable Flow/Variable Speed” columns. All others shall be selected from the “Other” columns.

EXCEPTION: Design flow rates exceeding the values in Table C403.3.7 are permitted in specific sections of pipe if the pipe is not in the critical circuit at design conditions and is not predicted to be in the critical circuit during more than 30 percent of operating hours.

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

Table C403.3.7
Piping System Design Maximum Flow Rate in GPM^a

Pipe Size (in)	≤ 2000 hours/year		> 2000 and ≤ 4400 hours/year		> 4400 hours/year	
	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	1100	570	860	440	680
8	1200	1800	900	1400	700	1100
10	1800	2700	1300	2000	1000	1600
12	2500	3800	1900	2900	1500	2300
Maximum velocity for pipes over 14 to 24 in. in size	8.5 ft/s	13.0 ft/s	6.5 ft/s	9.5 ft/s	5.0 ft/s	7.5 ft/s

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

C403.3.8 Hydronic coil selection. Hydronic coils shall comply with Sections C403.3.8.1 and C403.3.8.2.

EXCEPTION: Replacement coils within existing equipment.

C403.3.8.1 Chilled-water coil selection. Chilled-water cooling coils shall be selected to provide a 15°F or higher temperature difference between leaving and entering water temperatures and a minimum of 57°F leaving water temperature at design conditions.

EXCEPTIONS:

1. Chilled-water cooling coils that have an airside pressure drop exceeding 0.70 in. of water when rated at 500 fpm face velocity and dry conditions (no condensation).
2. Individual fan-cooling units with a design supply airflow rate ≤ 5000 cfm.
3. Constant-air-volume systems.
4. Coils selected at the maximum temperature difference allowed by the cooling plant equipment manufacturer’s approved operating conditions.
5. Passive coils (no mechanically supplied airflow).
6. Coils with design entering chilled-water temperature ≥ 50°F (10°C).
7. Coils with design entering air dry-bulb temperature ≤ 65°F (18°C).

C403.3.8.2 Hot-water coil selection. Hot-water heating coils shall be selected to provide a maximum 20°F temperature difference between leaving and entering water temperatures and a maximum of 118°F (48°C) entering water temperature at design conditions.

EXCEPTIONS:

1. Hot-water heating systems which utilize heat pumps as the primary source.
2. Individual terminal fan units with a design supply airflow rate ≤ 1500 cfm are exempt from the 20°F maximum temperature difference between leaving and entering water temperature requirement.
3. Passive coils (no mechanically supplied airflow).
4. Coils with design leaving air temperature ≥ 95°F (35°C).

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C403.4 HVAC system controls. HVAC systems shall be provided with controls in accordance with Sections C403.4.1 through C403.4.12 and shall be capable of and configured to implement all required control functions in this code.

C403.4.1 Thermostatic controls. The supply of heating and cooling energy to each *zone* shall be controlled by individual thermostatic controls capable of responding to temperature within the *zone*. Controls in the same *zone* or in neighboring *zones* connected by openings larger than 10 percent of the floor area of either *zone* shall not allow for simultaneous heating and cooling. At a minimum, each floor of a building shall be considered as a separate *zone*. Controls on systems required to have economizers and serving single *zones* shall have multiple cooling stage capability and activate the economizer when appropriate as the first stage of cooling. See Section C403.5 for further economizer requirements. Where humidification or dehumidification or both is provided, at least one humidity control device shall be provided for each humidity control system.

EXCEPTIONS:

1. Independent perimeter systems that are designed to offset only building envelope heat losses or gains or both serving one or more perimeter *zones* also served by an interior system provided:
 - 1.1. The perimeter system includes at least one thermostatic control *zone* for each building exposure having exterior walls facing only one orientation (within +/-45 degrees) (0.8 rad) for more than 50 contiguous feet (15,240 mm);
 - 1.2. The perimeter system heating and cooling supply is controlled by a thermostat located within the *zones* served by the system; and
 - 1.3. Controls are configured to prevent the perimeter system from operating in a different heating or cooling mode from the other equipment within the *zones* or from neighboring *zones* connected by openings larger than 10 percent of the floor area of either *zone*.
2. Where an interior *zone* and a perimeter *zone* are open to each other with permanent openings larger than 10 percent of the floor area of either *zone*, cooling in the interior *zone* is permitted to operate at times when the perimeter *zone* is in heating and the interior *zone* temperature is at least 5°F (2.8°C) higher than the perimeter *zone* temperature. For the purposes of this exception, a permanent opening is an opening without doors or other operable closures.
3. Dedicated outdoor air units that provide ventilation air, make-up air or replacement air for exhaust systems are permitted to be controlled based on supply air temperature. The supply air temperature shall be controlled to a maximum of 65°F (18.3°C) in heating and a minimum of 72°F (22°C) in cooling unless the supply air temperature is being reset based on the status of cooling or heating in the *zones* served or it being reset based on outdoor air temperature.

~~((C403.4.1.1 Heat pump supplementary heat control. 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 (4.4°C). Heat pumps equipped with internal electric resistance heaters shall have controls that prevent supplemental heater operation when the heating load can be met by the heat pump alone during both steady-state operation and setback recovery. Supplemental heater operation is permitted during outdoor coil defrost cycles. Heat pumps equipped with supplementary heaters shall comply with all conditions of Section C403.1.4.~~

EXCEPTIONS:

1. ~~Packaged terminal heat pumps (PTHPs) of less than 2 tons (24,000 Btu/hr) cooling capacity that have reverse-cycle demand defrost and are configured to operate in heat pump mode whenever the outdoor air temperatures are above 25°F (-3.9°C) and the unit is not in defrost.~~
2. ~~Heat pumps whose minimum efficiency is regulated by NAECA and whose ratings meet the requirements shown in Table C403.3.2(2) and include all usage of internal electric resistance heating.~~

C403.4.1.1 Heat pump supplementary heat control. Heat pumps equipped with internal electric resistance heaters shall have controls that prevent supplemental heater operation when the heating load can be met by the heat pump alone during both steady-state operation and setback recovery. Supplemental heater operation is permitted during outdoor coil defrost cycles. Heat pumps equipped with supplementary heaters shall comply with all conditions of Section C403.1.4.

EXCEPTIONS:

1. Packaged terminal heat pumps (PTHPs) of less than 2 tons (24,000 Btu/hr) cooling capacity that have reverse-cycle demand defrost and are configured to operate in heat pump mode whenever the outdoor air temperatures are above 25°F (-3.9°C) and the unit is not in defrost.
2. Heat pumps whose minimum efficiency is regulated by NAECA and whose ratings meet the requirements shown in Table C403.3.2(2) and include all usage of internal electric resistance heating.

C403.4.1.2 Deadband. Where used to control both heating and cooling, zone thermostatic controls shall be configured

to 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 shut off or reduced to a minimum.

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EXCEPTIONS:

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

C403.4.1.3 Setpoint overlap restriction. Where a *zone* has a separate heating and a separate cooling thermostatic control located within the zone, a limit switch, mechanical stop or direct digital control system with software programming shall be configured to prevent the heating setpoint from exceeding the cooling setpoint and to maintain a deadband in accordance with Section C403.4.1.2.

C403.4.1.4 Heated or cooled vestibules and air curtains. The heating system for heated vestibules and air curtains with integral heating shall be provided with controls configured to shut off the source of heating when the outdoor air temperature is greater than 45°F (7°C). Vestibule heating and cooling systems shall be controlled by a thermostat located in the vestibule configured to limit heating to a temperature not greater than 60°F (16°C) and cooling to a temperature not less than 85°F (29°C).

EXCEPTIONS:

1. Control of heating or cooling provided by transfer air that would otherwise be exhausted.
2. Vestibule heating only systems are permitted to be controlled without an outdoor air temperature lockout when controlled by a thermostat located in the vestibule configured to limit heating to a temperature not greater than 45°F (7°C) where required for freeze protection of piping and sprinkler heads located in the vestibule.

C403.4.1.5 Hot water boiler outdoor temperature setback control. Hot water boilers that supply heat to the building through one- or two-pipe heating systems shall have an outdoor setback control that lowers the boiler water temperature based on the outdoor temperature.

C403.4.1.6 Operable opening switches for HVAC system thermostatic control. Operable openings meeting the minimum size criteria of Section C402.5.11 and that open to the outdoors from a conditioned space must have controls configured to do the following once doors have been open for 5 minutes:

1. Disable the mechanical heating to the zone or reset the space heating temperature setpoint to 55°F or less within 5 minutes of the door open enable signal.
2. Disable the mechanical cooling to the zone or reset the space cooling temperature setpoint to 85°F or more within 5 minutes of the door open enable signal.

EXCEPTION: Hydronic radiant heating and cooling systems.

C403.4.1.7 Demand responsive controls. Thermostatic controls for heating or cooling systems shall be provided with *demand responsive controls* capable of increasing the cooling setpoint and decreasing the heating setpoint by no less than 4°F (2.2°C). The thermostatic controls shall be capable of performing all other functions provided by the control when the *demand responsive controls* are not available. Systems with *direct digital control* of individual *zones* report to a central control panel shall be capable of remotely increasing the cooling setpoint and decreasing the heating setpoint for each *zone* by no less than 4°F (2.2°C).

EXCEPTIONS:

1. Health care and assisted living facilities.
2. Group R-2 occupancy dwelling and sleeping units.

C403.4.2 Off-hour controls. For all occupancies other than Group R, and for conditioned spaces other than dwelling units and sleeping units within Group R occupancies, each *zone* shall be provided with thermostatic setback controls that are controlled by either an automatic time clock or programmable control system.

EXCEPTIONS:

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

C403.4.2.1 Thermostatic setback. Thermostatic setback controls shall be configured 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).

C403.4.2.2 Automatic setback and shutdown. 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 configured to operate the system for up to 2 hours; or an occupancy sensor.

C403.4.2.3 Automatic start and stop. Automatic start and stop controls shall be provided for each HVAC system. The automatic start controls shall be configured to automatically adjust the daily start time of the HVAC system in order to bring each space to the desired occupied temperature immediately prior to scheduled occupancy. Automatic stop controls shall be provided for each HVAC system with direct digital control of individual zones. The automatic stop controls shall be configured to reduce the HVAC system's heating temperature setpoint and increase the cooling temperature setpoint by at least 2°F (1.1°C) before scheduled unoccupied periods based upon the thermal lag and acceptable drift in space temperature that is within comfort limits.

C403.4.2.4 Exhaust system off-hour controls. For all occupancies other than Group R, exhaust systems serving spaces within the conditioned envelope shall be controlled by either an automatic time clock, thermostatic controls or programmable control system to operate on the same schedule as the HVAC systems providing their make-up air.

EXCEPTIONS:

1. Exhaust systems requiring continuous operation.
2. Exhaust systems that are controlled by occupancy sensor control configured with automatic on and automatic shutoff within 15 minutes after occupants have left the space.

C403.4.2.5 Transfer and destratification fan system off-hour controls. For all occupancies other than Group R, transfer fan or mixing fan systems serving spaces within the conditioned envelope shall be controlled by either an automatic time clock, thermostatic controls or programmable control system to operate on the same schedule as the associated HVAC systems.

EXCEPTION: Transfer fan and destratification fan systems that are controlled by occupancy sensor control configured with manual on and automatic shutoff within 15 minutes after occupants have left the space.

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 configured to sequence operation of the boilers. Hydronic heating systems comprised of a single boiler and greater than 500,000 Btu/h (146,550 W) input design capacity shall include either a multi-staged or modulating burner.

403.4.3.1 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 configured to provide a heat pump water supply temperature dead band of at least 20°F (11.1°C) between initiation of heat rejection and heat addition by the central devices.

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

C403.4.3.3.2 Heat rejection. The following shall apply to hydronic water loop heat pump systems:

1. Where a closed-circuit cooling tower is used directly in the heat pump loop, either an *automatic* valve shall be installed to bypass the flow of water around the closed-circuit cooling tower, except for the minimum flow necessary for freeze protection. Flow controls for freeze protection shall not allow water through the closed-circuit cooling tower when outdoor temperatures are above the freezing point of the glycol/water solution, i.e. 32°F (0°C) for 100 percent water applications, and 18°F (-7.8°C) for 20 percent by mass propylene glycol solution.
2. Where an open-circuit cooling tower is used directly in the heat pump loop, an *automatic* valve shall be installed to bypass all heat pump water flow around the open-circuit cooling tower.
3. Where an open-circuit cooling tower is used in conjunction with a separate heat exchanger to isolate the open-circuit cooling tower from the heat pump loop, heat loss shall be controlled by shutting down the circulation pump on the cooling tower loop.

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

C403.4.3.3 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 C403.4.6.

C403.4.4 Part load controls. Hydronic systems greater than or equal to 300,000 Btu/h (88 kW) in design output capacity supplying heated or chilled water to comfort conditioning systems shall include controls that are configured to:

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

EXCEPTIONS:

1. Hydronic systems serving hydronic heat pumps.
 2. Hydronic systems with thermal energy storage where resetting the supply-water temperature would reduce the capacity of the storage.
2. Automatically vary fluid flow for hydronic systems with a combined pump motor capacity of 2 hp or larger with three or more control valves or other devices by reducing the system design flow rate by not less than 50 percent or the maximum reduction allowed by the equipment manufacturer for proper operation of equipment by valves that modulate or step open and close, or pumps that modulate or turn on and off as a function of load.
3. Automatically vary pump flow on heating water systems, chilled-water systems and heat rejection loops serving water-cooled unitary air conditioners as follows:
 - 3.1. Where pumps operate continuously or operate based on a time schedule, pumps with nominal output motor power of 2 hp or more shall have a variable speed drive.
 - 3.2. Where pumps have automatic direct digital control configured to operate pumps only when zone heating or cooling is required, a variable speed drive shall be provided for pumps with motors having the same or greater nominal output power indicated in Table C403.4.4 based on the climate zone and system served.
4. Where variable speed drive is required by Item 3 of this section, pump motor power input shall be not more than 30 percent of design wattage at 50 percent of the design water flow. Pump flow shall be controlled to maintain one control valve nearly wide open or to satisfy the minimum differential pressure.

EXCEPTIONS:

1. Supply-water temperature reset is not required for chilled-water systems supplied by off-site district chilled water or chilled water from ice storage systems.
2. Variable pump flow is not required on dedicated coil circulation pumps where needed for freeze protection.
3. Variable pump flow is not required on dedicated equipment circulation pumps where configured in primary/secondary design to provide the minimum flow requirements of the equipment manufacturer for proper operation of equipment.
4. Variable speed drives are not required on heating water pumps where more than 50 percent of annual heat is generated by an electric boiler.

**Table C403.4.4
Variable Speed Drive (VSD) Requirements for Demand-Controlled Pumps**

Climate Zones 4c, 5b	VSD Required for Motors with Rated Output of at Least
Heating water pumps	≥ ((7.5) <u>5.0</u>) hp
Chilled water and heat rejection loop pumps	≥ ((7.5) <u>5.0</u>) hp

C403.4.5 Pump isolation. Chilled water plants including more than one chiller shall be capable of and configured to reduce flow automatically through the chiller plant when a chiller is shut down and automatically shut off flow to chillers that are shut down. Chillers piped in series for the purpose of increased temperature differential shall be considered as one chiller.

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

C403.4.6 Variable flow controls. Individual pumps required by this code to have variable speed control shall be controlled in one of the following manners:

1. For systems having a combined pump motor horsepower less than or equal to 20 hp (15 kW) and without direct digital control of individual coils, pump speed shall be a function of either:
 - 1.1. Required differential pressure; or
 - 1.2. Reset directly based on zone hydronic demand, or other zone load indicators; or
 - 1.3. Reset directly based on pump power and pump differential pressure; or
 - 1.4. Reset directly by an integral controller based on the relationship between variable speed controller frequency and power.
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; or
 - 2.3. Reset directly by an integral controller based on the relationship between variable speed controller frequency and power.

C403.4.7 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.

C403.4.7.1 Combustion decorative vented appliance, combustion 2 and fire pit controls. Combustion decorative vented appliances, combustion fireplaces and fire pits shall be equipped with local controls to limit operation to a maximum duration of one hour without override hold capability or shall be controlled by occupancy sensor control configured with manual on and *automatic* shutoff within 15 minutes after occupants have left the space.

C403.4.8 Group R-1 hotel/motel guestrooms. See Section C403.7.4.

C403.4.9 Group R-2 and R-3 dwelling units. The primary space conditioning system within each *dwelling unit* shall be provided with at least one programmable thermostat for the regulation of space temperature. The thermostat shall allow for, at a minimum, a 5-2 programmable schedule (weekdays/weekends) and be capable of providing at least two programmable setback periods per day.

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

EXCEPTIONS:

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

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

1. When used to control heating only: 55°F to 75°F.
2. When used to control cooling only: 70°F to 85°F.
3. All other: 55°F to 85°F with an adjustable dead band configured to at least 5°F in accordance with Section C403.4.1.2.

C403.4.10 Group R-2 sleeping units. The primary space conditioning system within each sleeping unit shall be provided with at least one programmable thermostat for the regulation of space temperature. The thermostat shall allow for, at a minimum, a 5-2 programmable schedule (weekdays/weekends) and be capable of providing at least two programmable setback periods per day.

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

EXCEPTIONS:

1. Systems controlled by an occupant sensor that is configured to shut the system off when no occupant is sensed for a period of up to 30 minutes.

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2. Systems controlled solely by a manually operated timer configured to operate the system for no more than two hours.
3. *Zones* with a full HVAC load demand not exceeding 3,400 Btu/h (1 kW) and having a manual shutoff switch located with ready access.
4. Ductless heat pumps.

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

1. When used to control heating only: 55°F to 75°F;
2. When used to control cooling only: 70°F to 85°F;
3. All other: 55°F to 85°F with an adjustable dead band configured to at least 5°F in accordance with Section C403.4.1.2.

C403.4.11 Direct digital control systems. Direct digital control (DDC) shall be required as specified in Sections C403.4.11.1 through C403.4.11.4.

C403.4.11.1 DDC applications. DDC shall be provided in the applications and qualifications listed in Table C403.4.11.1 and for load management measures where installed to meet the requirements of Section C406.3.

C403.4.11.2 DDC controls. Where DDC is required by Section C403.4.11.1, the DDC system shall be configured to perform all of the following functions, as required to provide the system and zone control logic required in Sections C403.2, C403.5, C403.6.8 and C403.4.3:

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

C403.4.11.3 DDC display. Where DDC is required by Section C403.4.11.1 for new buildings, the DDC system shall be configured to gather and provide trending data and graphically displaying input and output points.

C403.4.11.4 DDC demand response setpoint adjustment. Where DDC is required by Section C403.4.11.1 for new buildings and serve mechanical systems with a cooling capacity exceeding 780,000 Btu/h (2,662 kW), the *DDC system* shall be capable of demand response setpoint adjustment. The *DDC system* shall be configured with control logic to increase the cooling zone setpoints by at least 2°F (1°C) and reduce the heating zone setpoints 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.

**Table C403.4.11.1
DDC Applications and Qualifications**

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

C403.4.12 Pressure independent control valves. Where design flow rate of heating water and chiller water coils is 5 gpm or higher, modulating pressure independent control valves shall be provided.

C403.5 Economizers. Air economizers shall be provided on all new cooling systems including those serving computer server rooms, electronic equipment, radio equipment, and telephone switchgear. Economizers shall comply with Sections C403.5.1 through C403.5.5.

EXCEPTIONS:

- 1a. For other than Group R-2 occupancies, cooling system where the supply fan is not installed outside the *building thermal envelope* nor in a *mechanical room* adjacent to outdoors, and is installed in conjunction with DOAS complying with Section C403.3.5 and serving only spaces with year-round cooling loads from lights and equipment of less than 5 watts per square foot.
- 1b. For Group R-2 occupancies, cooling system where the supply fan is not installed outside the *building thermal envelope* nor in a *mechanical room* adjacent to outdoors, and is installed in conjunction with DOAS complying with Section C403.3.5, where the ERV/HRV has a minimum ~~((68))~~ 67 percent sensible recovery or 60 percent enthalpy recovery heating effectiveness, ~~((Exception 3 of Section C403.3.5.1 is not utilized;))~~ and serving only spaces with year-round cooling loads from lights and equipment of less than 5 watts per square foot.
2. Unitary or packaged systems serving one zone with dehumidification ~~((that affect other systems so as to))~~ where an air economizer would increase the overall building energy consumption. New humidification equipment shall comply with Section C403.3.2.7.
3. Unitary or packaged systems serving one zone where the cooling efficiency meets or exceeds the efficiency requirements in Table C403.5(3).
4. Equipment serving chilled beams and chilled ceiling space cooling systems only which are provided with a water economizer meeting the requirements of Section C403.5.4.
5. For Group R occupancies, cooling unit where the supply fan is not installed outside the *building thermal envelope* or in a *mechanical room* adjacent to outdoors with a total cooling capacity less than 20,000 Btu/h and other cooling units with a total cooling capacity less than 54,000 Btu/h provided that these are high-efficiency cooling equipment with IEER, CEER, SEER, and EER values more than 15 percent higher than minimum efficiencies listed in Tables C403.3.2(1), C403.3.2(2), C403.3.2(4), C403.3.2(8) and C403.3.2(9) or an IPLV kW/ton that is at least 15 percent lower than the minimum efficiencies listed in Table C403.3.2(3) or C403.3.2(15), 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.
6. Equipment used to cool *Controlled Plant Growth Environments* provided these are high-efficiency cooling equipment with SEER, EER and IEER values a minimum of 20 percent greater than the values listed in Tables C403.3.2(1), (3), (4), and (15).
7. Equipment serving a space with year-round cooling loads from lights and equipment of 5 watts per square foot or greater complying with the following criteria:
 - 7.1. Equipment serving the space utilizes chilled water as the cooling source; and
 - 7.2. The chilled water plant includes a condenser heat recovery system that meets the requirements of Section ~~((C403.9.5))~~ C403.9.2.1 or the building and water-cooled system meets the following requirements:
 - 7.2.1. A minimum of 90 percent (capacity-weighted) of the building space heat is provided by hydronic heating water.
 - 7.2.2. Chilled water plant includes a heat recovery chiller or water-to-water heat pump capable of rejecting heat from the chilled water system to the hydronic heating equipment capacity.
 - 7.2.3. Heat recovery chillers shall have a minimum COP of 7.0 when providing heating and cooling water simultaneously.
8. Water-cooled equipment served by systems meeting the requirements of Section C403.9.2.4 Condenser heat recovery.
9. Dedicated outdoor air systems that include energy recovery as required by Section C403.7.6 but that do not include mechanical cooling.
10. Dedicated outdoor air systems not required by Section C403.7.6 to include energy recovery that modulate the supply airflow to provide only the minimum outdoor air required by Section C403.2.2.1 for ventilation, exhaust air make-up, or other process air delivery.
- ~~((9))~~ 11. Equipment used to cool any dedicated server room, electronic equipment room, elevator machine room or telecom switch room provided the system complies with Option a, b, ~~((or))~~ c, d or e in ~~((the table))~~ Table C403.5(9) below. The total cooling capacity of all fan systems qualifying under this exception without economizers shall not exceed 240,000 Btu/h per building or 10 percent of its *air economizer* capacity, whichever is greater. This exception shall not be used for Total Building Performance or Target Performance Path compliance.
- ~~((10. Dedicated outdoor air systems that include energy recovery as required by Section C403.7.6 but do not include mechanical cooling.~~

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- 11. ~~Dedicated outdoor air systems not required by Section C403.7.6 to include energy recovery that modulate the supply airflow to provide only the minimum outdoor air required by Section C403.2.2.1 for ventilation, exhaust air make-up, or other process air delivery.)~~
- 12. Medical and laboratory equipment that is directly water-cooled and is not dependent upon space air temperature.

**Table C403.5(9)
Server room, electronic equipment room or telecom room cooling equipment**

	Equipment Type	Higher Equipment Efficiency	Part-Load Control	Economizer
Option a	Tables C403.3.2(1), C403.3.2(2) and C403.3.2(14) ^a	+15% ^b	Required over 85,000 Btu/h ^c	None Required
Option b	Tables C403.3.2(1), C403.3.2(2) and C403.3.2(14) ^a	+5% ^d	Required over 85,000 Btu/h ^c	Waterside Economizer ^e
Option c	ASHRAE Standard 127 ^f	+0% ^g	Required over 85,000 Btu/h ^c	Waterside Economizer ^e
<u>Option d</u>	<u>Table C403.3.2(7)^h</u>	<u>+ 25%ⁱ</u>	<u>Required for all chillers^j</u>	<u>None Required</u>
<u>Option e</u>	<u>Table C403.3.2(7)^h</u>	<u>+ 10/15%^k</u>	<u>Required over 85,000 Btu/h^c</u>	<u>Dedicated waterside Economizer^e</u>

Footnotes for Table C403.5(9):

- a For a system where all of the cooling equipment is subject to the AHRI standards listed in Tables C403.3.2(1), C403.3.2(2), and C403.3.2 (14), the system shall comply with ~~((all of the following))~~ the higher equipment efficiency, part-load control and economizer requirements of the row in which this footnote is located, including the associated footnotes (note that if the system contains any cooling equipment that exceeds the capacity limits in Table C403.3.2(1), C403.3.2(2), or C403.3.2 (14), or if the system contains any cooling equipment that is not included in Table C403.3.2(1), C403.3.2(2), or C403.3.2 (14), then the system is not allowed to use this option).
- b The cooling equipment shall have a SEER/EER value and an IEER/IPLV value that each is a minimum of 15 percent greater than the value listed in Tables C403.3.2(1), C403.3.2(2), and C403.3.2 (14).
- 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 a SEER/EER value and an IEER/IPLV value that each is a minimum of 5 percent greater than the value listed in Tables C403.3.2(1), C403.3.2(2), and C403.3.2 (14).
- e The system shall include a water economizer in lieu of air economizer. Water economizers shall meet the requirements of C403.5.1 and C403.5.2 and be capable of providing the total concurrent cooling load served by the connected terminal equipment lacking airside economizer, at outside air temperatures of 50°F dry-bulb/45°F wet-bulb and below. For this calculation, all factors including solar and internal load shall be the same as those used for peak load calculations, except for the outside temperatures. The equipment shall be served by a dedicated condenser water system unless a nondedicated condenser water system exists that can provide appropriate water temperatures during hours when waterside economizer cooling is available.
- f For a system where all cooling equipment is subject to ASHRAE Standard 127, the system shall comply with the higher equipment efficiency, part-load control, and economizer requirements of the row in which this footnote is located, including the associated footnotes.
- g The cooling equipment subject to the ASHRAE Standard 127 shall have an ~~((EER value and an IPLV))~~ SCOP value that is ~~((equal or))~~ a minimum of 10 percent greater than the value listed in Tables C403.3.2(1), C403.3.2(2), and C403.3.2 (14) (1.10 × values in these tables) when determined in accordance with the rating conditions 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 C403.3.2(7) (as an example, a chilled water system with fan coil units), the system shall comply with the higher equipment efficiency, part-load control and economizer requirements of the row in which this footnote is located, including the associated footnotes.
- i The cooling equipment shall have an full-load EER value and an IPLV value that is a minimum of 25 percent greater than the value listed in Table C403.3.2(7) (1.25 × value in Table C403.3.2(7) or a full-load and IPLV kW/ton that is at least 25 percent lower than the value listed in Table C403.3.2(7) (0.75 × value in Table C403.3.2(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 C403.3.2(7) (1.10 × values in Table C403.3.2(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 C403.3.2(7) (0.85 × values in Table C403.3.2(7)).

**Table C403.5(3)
Equipment Efficiency Performance**

Climate Zones	Efficiency Improvement ^a
4C	64%
5B	59%

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

C403.5.1 Integrated economizer control. Economizer systems shall be integrated with the mechanical cooling system and be configured to provide partial cooling even where additional mechanical cooling is required to provide the remainder of the cooling load. Controls shall not be capable of creating a false load in the mechanical cooling system by limiting or disabling the economizer or any other means, such as hot gas bypass, except at the lowest stage of mechanical cooling.

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

1. Unit controls shall have the mechanical cooling capacity control interlocked with the *air economizer* controls such that the outdoor air damper is at the 100 percent open position when mechanical cooling is on and the outdoor air damper does not begin to close to prevent coil freezing due to minimum compressor run time until the leaving air temperature is less than 45°F (7°C).
2. Direct expansion (DX) units with cooling capacity 65,000 Btu/H (19 kW) or greater of rated capacity shall comply with the following:
 - 2.1. DX units that control the capacity of the mechanical cooling directly based on occupied space temperature shall have not fewer than two stages of mechanical cooling capacity.
 - 2.2. Other DX units, including those that control space temperature by modulating the airflow to the space, shall be in accordance with Table C403.5.1.

**TABLE C403.5.1
DX COOLING STAGE REQUIREMENTS FOR MODULATING AIRFLOW UNITS**

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

For SI: 1 Btu/h = 0.2931 W

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

C403.5.2 Economizer heating system impact. HVAC system design and economizer controls shall be such that economizer operation does not increase building heating energy use during normal operation.

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

C403.5.3. Air economizers. *Air economizers* shall comply with Sections C403.5.3.1 through C403.5.3.5.

C403.5.3.1 Design capacity. *Air economizer* systems shall be configured to modulate *outdoor air* and return air dampers to provide up to 100 percent of the design supply air quantity as *outdoor air* for cooling.

C403.5.3.2 Control signal. Economizer controls and dampers shall be configured to sequence the dampers with mechanical cooling equipment and shall not be controlled by only mixed air temperature. *Air economizers* on systems with cooling capacity greater than 65,000 Btu/h shall be configured to provide partial cooling even when additional mechanical cooling is required to meet the remainder of the cooling load.

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

C403.5.3.3 High-limit shutoff. *Air economizers* shall be configured to automatically reduce *outdoor air* intake to the design minimum outdoor air quantity when outdoor air intake will no longer reduce cooling energy usage. High-limit shutoff control types shall be chosen from Table C403.5.3.3. High-limit shutoff control settings for these control types shall be those specified in Table C403.5.3.3.

**TABLE C403.5.3.3
HIGH-LIMIT SHUTOFF CONTROL SETTING FOR AIR ECONOMIZERS^b**

DEVICE TYPE	REQUIRED HIGH LIMIT (Economizer Off When):		REQUIRED HIGH LIMIT FOR CYCLING FANS ^c (Economizer Off When):	
	EQUATION	DESCRIPTION	EQUATION	DESCRIPTION
Fixed dry bulb	$T_{OA} > 75^{\circ}\text{F}$	Outdoor air temperature exceeds 75°F	$T_{OA} > 70^{\circ}\text{F}$	Outdoor air temperature exceeds 70°F
Differential dry bulb	$T_{OA} > T_{RA}$	Outdoor air temperature exceeds return air temperature	$T_{OA} > (T_{RA} - 5)$	Outdoor air temperature exceeds return air temperature - 5°F
Fixed enthalpy with fixed dry-bulb temperatures	$h_{OA} > 28 \text{ Btu/lb}^a$ or $T_{OA} > 75^{\circ}\text{F}$	Outdoor air enthalpy exceeds 28 Btu/lb of dry air ^a or outdoor temperature exceeds 75°F	$h_{OA} > 26 \text{ Btu/lb}^a$ or $T_{OA} > 70^{\circ}\text{F}$	Outdoor air enthalpy exceeds 26 Btu/lb of dry air ^d or outdoor temperature exceeds 70°F
Differential enthalpy with fixed dry-bulb temperatures	$h_{OA} > h_{RA}$ or $T_{OA} > 75^{\circ}\text{F}$	Outdoor air enthalpy exceeds return air enthalpy or outdoor temperature exceeds 75°F	$h_{OA} > (h_{RA} - 2)$ or $T_{OA} > 70^{\circ}\text{F}$	Outdoor air enthalpy exceeds return air enthalpy or outdoor temperature exceeds 70°F

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. Devices with selectable set point shall be capable of being set to within 2°F and 2 Btu/lb of the set point listed.
- c. Where fans cycle on only to provide heating and cooling, limits are adjusted lower to compensate for fan energy use in economizer mode.
- d. For cycling fans, at altitudes substantially different than sea level, the fixed enthalpy limit shall be set to the enthalpy value at 70°F and 50% relative humidity.

C403.5.3.4 Relief of excess outdoor air. Systems shall be capable of relieving excess *outdoor air* during *air economizer* operation to prevent over-pressurizing the building. The relief air outlet shall be located to avoid recirculation into the building.

C403.5.3.5 Economizer dampers. Return, exhaust/relief and outdoor air dampers used in economizers shall comply with Section C403.7.8.

C403.5.4 Water-side economizers. Water-side economizers shall comply with Sections C403.5.4.1 and C403.5.4.2.

C403.5.4.1 Design capacity. *Water economizer* systems shall be configured to cool supply air by indirect evaporation and providing up to 100 percent of the expected system cooling load at *outdoor air* temperatures of not greater than 50°F dry-bulb (10°C dry-bulb)/45°F wet-bulb (7.2°C wet-bulb).

EXCEPTION: Systems 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) and where 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) is met with evaporative *water economizers*.

C403.5.4.2 Maximum pressure drop. Precooling coils and water-to-water heat exchangers used as part of a *water economizer* system shall either have a water-side pressure drop of less than 15 feet (4572 mm) of water or a secondary loop shall be created so that the coil or heat exchanger pressure drop is not seen by the circulating pumps when the system is in the normal cooling (noneconomizer) mode.

C403.5.5 Economizer fault detection and diagnostics (FDD). Air-cooled unitary direct-expansion units with a cooling capacity of 54,000 Btu/h or greater listed in the tables in Section C403.3.2 that are equipped with an economizer in accordance with Section C403.5 shall include a fault detection and diagnostics (FDD) system complying with the following:

1. The following temperature sensors shall be permanently installed to monitor system operation:
 - 1.1. Outside air.
 - 1.2. Supply air.
 - 1.3. Return air.
2. Temperature sensors shall have an accuracy of ±2°F (1.1°C) over the range of 40°F to 80°F (4°C to 26.7°C).
3. Refrigerant pressure sensors, where used, shall have an accuracy of ±3 percent of full scale.
4. The unit controller shall be configured to provide system status by indicating the following:
 - 4.1. Free cooling available.
 - 4.2. Economizer enabled.
 - 4.3. Compressor enabled.
 - 4.4. Heating enabled.

- 4.5. Mixed air low limit cycle active.
- 4.6. The current value of each sensor.
5. The unit controller shall be capable of manually initiating each operating mode so that the operation of compressors, economizers, fans and the heating system can be independently tested and verified.
6. The unit shall be configured to report faults to a fault management application available for access by day-to-day operating or service personnel or annunciated locally on zone thermostats.
7. The FDD system shall be configured to detect the following faults:
 - 7.1. Air temperature sensor failure/fault.
 - 7.2. Not economizing when the unit should be economizing.
 - 7.3. Economizing when the unit should not be economizing.
 - 7.4. Damper not modulating.
 - 7.5. Excess outdoor air.

C403.6 Requirements for mechanical systems serving multiple zones. Sections C403.6.1 through C403.6.10 shall apply to mechanical systems serving multiple zones.

C403.6.1 Variable air volume (VAV) and multiple zone systems. Supply air systems serving multiple zones shall be VAV systems that have zone controls configured to reduce the volume of air that is reheated, recooled or mixed in each *zone* to one of the following:

1. Twenty percent of the zone design peak supply for systems with *direct digital control* (DDC) and 30 percent of the maximum supply air for other systems.
2. Systems with DDC where items 2.1 through 2.3 apply.
 - 2.1. The airflow rate in the deadband between heating and cooling does not exceed 20 percent of the zone design peak supply rate or higher allowed rates under Items 3, 4, or 5 of this section.
 - 2.2. The first stage of heating modulates the zone supply air temperature setpoint up to a maximum setpoint while the airflow is maintained at the deadband flow rate.
 - 2.3. The second stage of heating modulates the airflow rate from the deadband flow rate up to the heating maximum flow rate that is less than 50 percent of the zone design peak supply rate.
3. The outdoor airflow rate required to meet the minimum ventilation requirements of Chapter 4 of the *International Mechanical Code*.
4. Any higher rate that can be demonstrated to reduce overall system annual energy use by offsetting reheat/recool energy losses through a reduction in outdoor air intake for the system, as *approved* by the code official.
5. The airflow rates to comply with applicable codes or accreditation standards such as pressure relationships or minimum air change rates.

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

1. *Zones* or supply air systems where not less than 75 percent of the energy for reheating or for providing warm air in mixing systems is provided from a site-recovered source, including condenser heat.
2. Systems that prevent reheating, recooling, mixing or simultaneous supply of air that has been previously cooled, either mechanically or through the use of economizer systems, and air that has been previously mechanically heated.
3. Ventilation systems complying with Section C403.3.5, DOAS, with ventilation rates comply with Section C403.2.2.

C403.6.2 Single duct variable air volume (VAV) systems, terminal devices. Single duct VAV systems shall use terminal devices capable of and configured to reduce the supply of primary supply air before reheating or recooling takes place.

C403.6.3 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 and configured to reduce the flow from one duct to a minimum before mixing of air from the other duct takes place.

C403.6.4 Supply-air temperature reset controls. Multiple *zone* HVAC systems shall include controls that are capable of and configured to automatically reset the supply-air temperature in response to representative building loads, or to outdoor air temperature. The controls shall be configured to reset the supply air temperature at least 25 percent of the difference between the design supply-air temperature and the design room air temperature. Controls that adjust the reset based on zone humidity are allowed. HVAC zones that are expected to experience relatively constant loads shall have maximum airflow designed to accommodate the fully reset supply air temperature.

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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 a site-recovered source.

C403.6.5 Multiple-zone VAV system ventilation optimization control. Multiple-zone VAV systems with direct digital control of individual zone boxes reporting to a central control panel shall have automatic controls configured to reduce outdoor air intake flow below design rates in response to changes in system ventilation efficiency (E_v) as defined by the *International Mechanical Code*.

EXCEPTIONS:

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

C403.6.6 Parallel-flow fan-powered VAV air terminal control. Parallel-flow fan-powered VAV air terminals shall have automatic controls configured to:

1. Turn off the terminal fan except when space heating is required or where required for ventilation.
2. Turn on the terminal fan as the first stage of heating before the heating coil is activated.
3. During heating for warmup or setback temperature control, either:
 - 3.1. Operate the terminal fan and heating coil without primary air.
 - 3.2. Reverse the terminal damper logic and provide heating from the central air handler by primary air.

C403.6.7 Reserved.

C403.6.8 Set points for direct digital control. For systems with direct digital control of individual *zones* reporting to the central control panel, the static pressure setpoint shall be reset based on the *zone* requiring the most pressure. In such cases, the set point is reset lower until one zone damper is nearly wide open. The direct digital controls shall be capable of monitoring zone damper positions or shall have an alternative method of indicating the need for static pressure that is configured to provide all of the following:

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

C403.6.9 Static pressure sensor location. Static pressure sensors used to control VAV fans shall be located such that the controller setpoint is no greater than 1.2 inches w.c. (299 Pa). Where this results in one or more sensors being located downstream of major duct splits, not less than one sensor shall be located on each major branch to ensure that static pressure can be maintained in each branch.

EXCEPTION: Systems complying with Section C403.6.8.

C403.6.10 High efficiency variable air volume (VAV) systems. For HVAC systems subject to the requirements of Section C403.3.5 but utilizing Exception 2 of that section, a high efficiency multiple-zone VAV system may be provided without a separate parallel DOAS when the system is designed, installed, and configured to comply with all of the following criteria (this exception shall not be used as a substitution for a DOAS per Section C406.6):

1. Each VAV system must serve a minimum of 3,000 square feet (278.7 m²) and have a minimum of five VAV zones.
2. The VAV systems are provided with airside economizer per Section C403.5 without exceptions.
3. A direct-digital control (DDC) system is provided to control the VAV air handling units and associated terminal units per Section C403.4.11 regardless of sizing thresholds of Table C403.4.11.1.
4. Multiple-zone VAV systems with a minimum outdoor air requirement of 2,500 cfm (1180 L/s) or greater shall be equipped with a device capable of measuring outdoor airflow intake under all load conditions. The system shall be capable of increasing or reducing the outdoor airflow intake based on feedback from the VAV terminal units as required by Section C403.6.5, without exceptions, and Section C403.7.1 demand controlled ventilation.
5. Multiple-zone VAV systems with a minimum outdoor air requirement of 2,500 cfm (1180 L/s) or greater shall be equipped with a device capable of measuring supply airflow to the VAV terminal units under all load conditions.
6. In addition to meeting the zone isolation requirements of C403.2.1 a single VAV air handling unit shall not serve more than 50,000 square feet (4645 m²) unless a single floor is greater than 50,000 square feet (4645 m²) in which case the air handler is permitted to serve the entire floor.

7. The primary maximum cooling air for the VAV terminal units serving interior cooling load driven zones shall be sized for a supply air temperature that is a minimum of 5°F greater than the supply air temperature for the exterior zones in cooling.
8. Air terminal units with a minimum primary airflow setpoint of 50 percent or greater of the maximum primary airflow setpoint shall be sized with an inlet velocity of no greater than 900 feet per minute. ~~((Allowable fan motor horsepower shall not exceed 90 percent of the allowable HVAC fan system bhp (Option 2) as defined by Section C403.8.1.1.))~~
9. ~~((Allowable fan power shall not exceed 90 percent of the allowable fan power budget as defined by Section C403.8.1.1.))~~ Fan system electrical input power (Fan kW_{design,system}) shall not exceed 90 percent of the fan power budget (Fan kW_{budget}) as defined by Section C403.8.1.
10. All fan powered VAV terminal units (series or parallel) shall be provided with electronically commutated motors. The DDC system shall be configured to vary the speed of the motor as a function of the heating and cooling load in the space. Minimum speed shall not be greater than 66 percent of design airflow required for the greater of heating or cooling operation. Minimum speed shall be used during periods of low heating and cooling operation and ventilation-only operation.

EXCEPTION: For series fan powered terminal units where the volume of primary air required to deliver the ventilation requirements at minimum speed exceeds the air that would be delivered at the speed defined above, the minimum speed setpoint shall be configured to exceed the value required to provide the required ventilation air.

11. Fan-powered VAV terminal units shall only be permitted at perimeter zones with an envelope heating load requirement. All other VAV terminal units shall be single duct terminal units.

EXCEPTION: Fan powered VAV terminal units are allowed at interior spaces with an occupant load greater than or equal to 25 people per 1000 square feet of floor area (as established in Table 403.3.1.1 of the *International Mechanical Code*) with demand control ventilation in accordance with Section C403.7.1.

12. When in occupied heating or in occupied deadband between heating and cooling all fan powered VAV terminal units shall be configured to reset the primary air supply setpoint, based on the VAV air handling unit outdoor air vent fraction, to the minimum ventilation airflow required per *International Mechanical Code*.
13. Spaces that are larger than 150 square feet (14 m²) and with an occupant load greater than or equal to ~~((25))~~ 15 people per 1000 square feet (93 m²) of floor area (as established in Table 403.3.1.1 of the *International Mechanical Code*) shall be provided with all of the following features:
 - 13.1. A dedicated VAV terminal unit capable of controlling the space temperature and minimum ventilation shall be provided.
 - 13.2. Demand control ventilation (DCV) shall be provided that utilizes a carbon dioxide sensor to reset the ventilation setpoint of the VAV terminal unit from the design minimum to design maximum ventilation rate as required by Chapter 4 of the *International Mechanical Code*.
 - 13.3. Occupancy sensors shall be provided that are configured to reduce the minimum ventilation rate to zero and setback room temperature setpoints by a minimum of 5°F, for both cooling and heating, when the space is unoccupied.
14. Dedicated data centers, computer rooms, electronic equipment rooms, telecom rooms, or other similar spaces with cooling loads greater than 5 watts/sf shall be provided with separate cooling systems to allow the VAV air handlers to turn off during unoccupied hours in the office space and to allow the supply air temperature reset to occur.

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

Additionally, computer rooms, electronic equipment rooms, telecom rooms, or other similar spaces shall be provided with airside economizer in accordance with Section 403.5 without using the exceptions to Section C403.5.

EXCEPTION: Heat recovery per Exception 9 of Section C403.5 may be in lieu of airside economizer for the separate, independent HVAC system.

15. HVAC system central heating or cooling plant will include a minimum of one of the following options:
 - 15.1. VAV terminal units with hydronic heating coils connected to systems with hot water generation equipment limited to the following types of equipment: ~~((Gas-fired hydronic boilers with a thermal efficiency, E_t, of not less than 92 percent.))~~ air-to-water heat pumps, ground-source water-to-water heat pumps, wastewater heat recovery water-to-water heat pumps, or heat recovery chillers. Hydronic heating coils shall be sized for a maximum entering hot water temperature of 120°F (48.9°C) for peak anticipated heating load conditions.
 - 15.2. Chilled water VAV air handling units connected to systems with chilled water generation equipment with IPLV values more than 25 percent higher than the minimum part load efficiencies listed in Table C403.3.2(3), in the appropriate size category, using the same test procedures. Equipment shall be listed in

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the appropriate certification program to qualify. The smallest chiller or compressor in the central plant shall not exceed 20 percent of the total central plant cooling capacity or the chilled water system shall include thermal storage sized for a minimum of 20 percent of the total central cooling plant capacity.

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

C403.7 Ventilation and exhaust systems. In addition to other requirements of Section C403 applicable to the provisions of ventilation air or the exhaust of air, ventilation and exhaust systems shall be in accordance with Sections C403.7.1 through C403.7.8.

C403.7.1 Demand control ventilation.

C403.7.1.1 Spaces requiring demand control ventilation. Demand control ventilation (DCV) shall be provided for the following:

1. Spaces with ventilation provided by single-zone systems where an air economizer is provided to comply with Section C403.5.
2. Spaces with an occupant load greater than or equal to 15 people per 1000 square feet (93 m²) of floor area (as established in Table 403.3.1.1 of the *International Mechanical Code*) or with an occupant outdoor airflow rate greater than or equal to 15 cfm/person, as established in Table 403.3.1.1 of the *International Mechanical Code*.

EXCEPTIONS:

1. Spaces including, but not limited to, dining areas, where more than 75 percent of the space design outdoor airflow is transfer air required for makeup air supplying an adjacent commercial kitchen.
2. Spaces with one of the following occupancy classifications as defined in Table 403.3.1.1 of the *International Mechanical Code*: Correctional cells, educational laboratories, barbers, beauty and nail salons, and bowling alley seating.
3. Dormitory sleeping areas with fewer than five occupants per space.
4. Spaces with ventilation not provided by a single-zone system where the design occupant component outdoor airflow is less than 100 cfm (23.6 L/s), or 200 cfm (47.2 L/s) with system having energy recovery with minimum 60 percent sensible effectiveness. Design occupant component outdoor airflow shall be calculated as the product of the design number of occupants in the space and the people outdoor airflow rate per occupant (R_p) as established in Table 403.3.1.1 of the *International Mechanical Code*.
5. Spaces with ventilation not provided by a single-zone system where the total system design outdoor airflow is less than 750 cfm (354 L/s), or 1500 cfm (708 L/s) with system having energy recovery with minimum 60 percent sensible effectiveness.

C403.7.1.2 Demand control ventilation design. Each space required to have demand control ventilation shall have equipment and controls capable of and configured to automatically change the quantity of outdoor air supplied to the space based upon the output of a CO₂ sensor. System outdoor air intake shall be adjusted from peak design levels in response to changes in outdoor air required in the spaces served by the system. This adjustment shall be accomplished by variable speed fan control.

EXCEPTION: These system types may use other means of adjusting outdoor air:

1. Single zone systems designed to recirculate return air.
2. Systems with total supply air less than 1500 cfm (708 L/s).

C403.7.2 Occupancy sensors. Classrooms, gyms, auditoriums, conference rooms, and other spaces with an occupant load greater than or equal to 25 people per 1000 square feet (93 m²) of floor area (as established in Table 403.3.1.1 of the *International Mechanical Code*) that are larger than 500 square feet (46 m²) of floor area shall have occupancy sensor control that will either close outside air dampers, close ventilation supply dampers or turn off ventilation 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.

EXCEPTIONS:

1. Spaces with one of the following occupancy categories (as defined by the *International Mechanical Code*):
 - 1.1. Correctional cells.
 - 1.2. Daycare sickrooms.
 - 1.3. Science labs.
 - 1.4. Barbers.
 - 1.5. Beauty and nail salons.
 - 1.6. Bowling alley seating.
2. When the space is unoccupied during occupied building hours, a ventilation rate equal to or less than the zone outdoor airflow as defined in Section 403.3.1.1.1 of the *International Mechanical Code* with a zone population of zero.

C403.7.3 Ventilation air heating control. For ventilation air units with supplemental heating capacity that operate in conjunction with zone heating and cooling systems, supplemental heating shall not warm ventilation supply air to a temperature greater than 55°F (13°C).

C403.7.4 Automatic control of HVAC systems serving guestrooms. In Group R-1 buildings containing more than 50 guestrooms, each guestroom shall be provided with controls complying with the provisions of Sections C403.7.4.1 and C403.7.4.2. Card key controls comply with these requirements.

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C403.7.4.1 Temperature setpoint controls. Controls shall be provided on each HVAC system that are capable of and configured with three modes of temperature control.

1. When the guestroom is rented but unoccupied, the controls shall automatically raise the cooling setpoint and lower the heating setpoint by not less than 4°F (2°C) from the occupant setpoint within 30 minutes after the occupants have left the guestroom.
2. When the guestroom is unrented and unoccupied, the controls shall automatically raise the cooling setpoint to not lower than 80°F (27°C) and lower the heating setpoint to not higher than 60°F (16°C). Unrented and unoccupied guestroom mode shall be initiated within 16 hours of the guestroom being continuously occupied or where a *networked guestroom control system* indicates that the guestroom is unrented and the guestroom is unoccupied for more than 20 minutes. A *networked guestroom control system* that is capable of returning the thermostat setpoints to default occupied setpoints 60 minutes prior to the time a guestroom is scheduled to be occupied is not precluded by this section. Cooling that is capable of limiting relative humidity with a setpoint not lower than 65 percent relative humidity during unoccupied periods is not precluded by this section.
3. When the guestroom is occupied, HVAC set points shall return to their occupied set point once occupancy is sensed.

C403.7.4.2 Ventilation controls. Controls shall be provided on each HVAC system that are capable of and configured to automatically turn off the ventilation and exhaust fans within 20 minutes of the occupants leaving the guestroom or isolation devices shall be provided to each guestroom that are capable of automatically shutting off the supply of outdoor air to and exhaust air from the guestroom.

EXCEPTION: Guestroom ventilation systems are not precluded from having an automatic daily preoccupancy purge cycle that provides daily outdoor air ventilation during unrented periods at the design ventilation rate for 60 minutes, or at a rate and duration equivalent to one air change.

C403.7.5 Loading dock, motor vehicle repair garage, and parking garage ventilation system controls. Mechanical ventilation systems for loading docks, motor vehicle repair garages, and parking garages shall be designed to exhaust the airflow rates (maximum and minimum) determined in accordance with the *International Mechanical Code*.

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

Ventilation systems with total ventilation system motor nameplate horsepower exceeding 5 hp (3.7 kW) at fan system design conditions and those with heating and/or cooling shall have controls and devices that modulate fan speed and result in fan motor demand of no more than 30 percent of design wattage at 50 percent of the design airflow.

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. Parking garages, repair garages, and loading docks shall be equipped with a controller and a full array of carbon monoxide (CO) sensors set to maintain levels of carbon monoxide below 35 parts per million (ppm). Additionally, a full array of nitrogen dioxide detectors shall be connected to the controller set to maintain the nitrogen dioxide level below the OSHA standard for eight hour exposure.

Spacing and location of the sensors shall be installed in accordance with manufacturer recommendations.

C403.7.5.1 System activation devices for loading docks. Ventilation systems for enclosed loading docks shall operate continuously during unoccupied hours at 50 percent or less of design capacity 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*, [Section 404](#); or
2. Occupant detection sensors used to activate the system that detects entry into the loading area along both the vehicle and pedestrian pathways.

C403.7.5.2 System activation devices for parking garages. Ventilation systems for enclosed parking garages shall be activated by gas sensors [to activate the full required ventilation rate in accordance with the *International Mechanical Code*, Section 404.](#)

C403.7.6 Energy recovery ventilation systems. Energy recovery ventilation systems shall be provided as specified in Sections C403.7.6.1 and C403.7.6.2.

C403.7.6.1 Ventilation for Group R-2 occupancy. For all Group R-2 dwelling and sleeping units, a balanced ventilation system with heat recovery system with minimum 60 percent sensible recovery effectiveness shall provide outdoor air directly to each habitable space in accordance with the *International Mechanical Code*. The ventilation system shall allow for the design flow rates to be tested and verified at each habitable space as part of the commissioning process in

accordance with Section C408.2.2. The return/exhaust air stream temperature for heat recovery device selection shall be 70°F (21°C), or as calculated by the *registered design professional*.

EXCEPTION: Heat recovery and energy recovery ventilators (H/ERVs) that are rated and listed in accordance with HVI 920 can demonstrate compliance with the sensible recovery effectiveness requirement using the sensible recovery effectiveness (ASRE) rating of the equipment at 32°F test conditions. Applied flow rate for ASRE rating shall be no less than the design flow rate or the closest value interpolated between two listed flow rates.

C403.7.6.2 Spaces other than Group R-2 dwelling or sleeping units. Any system serving a space other than a Group R-2 dwelling or sleeping unit with minimum ((outside)) outdoor air requirements at design conditions greater than 5,000 cfm or any system where the system's supply airflow rate exceeds the value listed in Tables C403.7.6(1) and C403.7.6(2), based on the climate zone and percentage of outdoor airflow rate at design conditions, shall include an energy recovery system. Table C403.7.6(1) shall be used for all ventilation systems that operate less than 8,000 hours per year, and Table C403.7.6(2) shall be used for all ventilation systems that operate 8,000 hours or more per year. The energy recovery system shall provide a ~~((68))~~ 67 percent minimum sensible recovery effectiveness or have an *enthalpy recovery ratio* of not less than 60 percent at design conditions. Where an air economizer is required, the energy recovery system shall include a bypass of the energy recovery media for both the outdoor air and exhaust air, bypass of the energy recovery media for only the outdoor air controlled in accordance with Section C403.3.5.6, or return air dampers and controls which permit operation of the air economizer as required by Section C403.5. Where a single room or space is supplied by multiple units, the aggregate ventilation (cfm) of those units shall be used in applying this requirement. The return/exhaust air stream temperature for heat recovery device selection shall be 70°F (21°C) at 30 percent relative humidity, or as calculated by the registered design professional.

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

1. In Seattle, the winter outdoor design air temperature is 24°F as specified in Appendix C. The registered design professional shall determine the coincident winter wet bulb temperature or percent relative humidity at the anticipated design conditions. Based on these conditions the outdoor design air enthalpy is determined from a psychrometric chart.
2. Determine the return/exhaust air stream enthalpy from a psychrometric chart based on the 70°F (21°C) at 30 percent relative humidity.
3. Calculate the 60% difference between the outside air and return air enthalpies at design winter conditions.
4. See example below:
 - a. OA Enthalpy at 24°F/23°F (drybulb/wetbulb) = 8.2 BTU/LB
 - b. RA/EA Enthalpy at 70°F and 30% RH = 21.9 BTU/LB
 - c. SA Enthalpy Minimum Leaving Energy Recovery Media

$$= (8.2 + (21.9 - 8.2) * 60\%)$$

$$= 16.42 \text{ BTU/LB}$$

(Note that this example represents 60% enthalpy recovery. For an equivalent sensible-only recovery system, it would take 73.9% effectiveness (increasing from 24°F DB to 58°F DB) to achieve the same enthalpy recovery.)

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

1. Where energy recovery systems are restricted per Section 514 of the *International Mechanical Code* to sensible energy recovery, the system shall comply with one of the following:
 - 1.1. Kitchen exhaust systems where they comply with Section C403.7.7.1.
 - 1.2. Laboratory fume ~~((hood))~~ exhaust systems where they comply with ~~((Exception 2 of Section C403.7.6))~~ Section C403.7.7.2.
 - 1.3. Other sensible energy recovery systems with the capability to provide a change in dry-bulb temperature of the outdoor air supply of not less than 50 percent of the difference between the outdoor air and the return air dry-bulb temperatures, at design conditions. Where an air economizer is required, the energy recovery system shall include a bypass of the energy recovery media for both the outdoor air and exhaust air or bypass of the energy recovery media for only the outdoor air controlled in accordance with Section C403.3.5.6.
2. Buildings with laboratory fume ~~((hood))~~ exhaust systems having a total exhaust rate less than or equal to 5,000 cfm (2360 L/s) ((that)) shall include at least one of the following features ~~((and also))~~ or shall comply with Section C403.7.7.2:
 - 2.1. Variable-air-volume hood exhaust and room supply systems configured to reduce exhaust and makeup air volume to 50 percent or less of design values.

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- 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 air heating energy is provided from site-recovered energy.
- 5. Systems exhausting hazardous, toxic, flammable, paint or corrosive fumes or dust. This exception may not be used for laboratory fume exhaust systems required to comply with Exception 2 of Section C403.7.6 or Section C403.7.7.2 without approval of the code official.
- 6. Cooling energy recovery.
- 7. Systems requiring dehumidification that employ energy recovery in series with the cooling coil.
- 8. Multiple-zone systems where the supply airflow rate is less than the values specified in Tables C403.7.6 (1) and (2), for the corresponding percent of outdoor air. Where a value of NR is listed, energy recovery shall not be required.
- 9. Equipment which meets the requirements of Section C403.9.2.4.
- 10. Systems serving Group R-1 dwelling or sleeping units where the largest source of air exhausted at a single location at the building exterior is less than 25 percent of the design outdoor air flow rate.
- 11. Systems serving Ambulatory Care Facilities and Group I-2 Occupancies ventilated in accordance with Section 407 of the International Mechanical Code, systems exhausting environmental exhaust air in research or education laboratory spaces complying with the Seattle Director’s Rule alternate of Section 510 of the International Mechanical Code, and systems exhausting environmental exhaust air in spaces that have Hazardous Exhaust Systems complying with Section 510 of the International Mechanical Code, are permitted to provide a 60 percent minimum sensible heat recovery effectiveness or have an enthalpy heat recovery ratio of not less than 50 percent at design conditions. Where an air economizer is required, the energy or heat recovery system shall include a bypass of the energy or heat recovery media for both the outdoor air and exhaust air or bypass of the energy recovery media for only the outdoor air controlled in accordance with Section C403.3.5.6.

**Table C403.7.6(1)
Energy Recovery Requirement**

Climate zone	Percent (%) Outdoor Air at Full Design Airflow Rate							
	≥ 10% and < 20%	≥ 20% and < 30%	≥ 30% and < 40%	≥ 40% and < 50%	≥ 50% and < 60%	≥ 60% and < 70%	≥ 70% and < 80%	≥ 80%
Design Supply Fan Airflow Rate (cfm)								
4C, 5B	NR	NR	NR	NR	NR	NR	≥ 5000	≥ 5000

NR = Not required.

**Table C403.7.6(2)
Energy Recovery Requirement**

Climate zone	Percent (%) Outdoor Air at Full Design Airflow Rate							
	≥ 10% and < 20%	≥ 20% and < 30%	≥ 30% and < 40%	≥ 40% and < 50%	≥ 50% and < 60%	≥ 60% and < 70%	≥ 70% and < 80%	≥ 80%
Design Supply Fan Airflow Rate (cfm)								
4C	NR	≥ 19500	≥ 9000	≥ 5000	≥ 4000	≥ 3000	≥ 1500	≥ 120
5B	≥ 2500	≥ 2000	≥ 1000	≥ 500	≥ 140	≥ 120	≥ 100	≥ 80

NR = Not required.

C403.7.7 Exhaust systems.

C403.7.7.1 Kitchen exhaust systems.

C403.7.7.1.1 Replacement air. Replacement air introduced directly into the exhaust hood cavity shall not be greater than 10 percent of the hood exhaust airflow rate.

C403.7.7.1.2 Kitchen exhaust hood certification and maximum airflow. Where a kitchen or kitchen/dining facility has a total kitchen hood exhaust airflow rate that is greater than 2,000 cfm, each hood shall be a factory built commercial exhaust hood listed by a nationally recognized testing laboratory in compliance with UL 710 and each hood shall have a maximum exhaust rate as specified in Table C403.7.7.1.2. Where a single hood, or hood section, is installed over appliances with different duty ratings, the maximum allowable flow rate for the hood or hood section shall be based on the requirements for the highest appliance duty rating under the hood or hood section.

EXCEPTION: Type II dishwasher exhaust hoods that have an exhaust airflow of 1000 cfm or less.

Table C403.7.7.1.2
Maximum Net Exhaust Flow Rate, CFM Per Linear Foot of Hood Length

Type of Hood	Light-duty Equipment	Medium-duty Equipment	Heavy-duty Equipment	Extra-heavy-duty Equipment
Wall-mounted canopy	140	210	280	385
Single island	280	350	420	490
Double island (per side)	175	210	280	385
Eyebrow	175	175	NA	NA
Backshelf/pass-over	210	210++++	280	NA

For SI: 1 cfm = 0.4719 L/s; 1 foot = 305 mm

NA = Not allowed

C403.7.7.1.3 Kitchen exhaust hood system. Kitchen exhaust hood systems serving Type I exhaust hoods shall be provided with *demand control kitchen ventilation* (DCKV) controls where a kitchen or kitchen/dining facility has a total kitchen hood exhaust airflow rate greater than 2000 cfm. DCKV systems shall be configured to provide a minimum of 50 percent reduction in exhaust and replacement air system airflows in response to appliance operation and to maintain full capture and containment of smoke, effluent and combustion products during cooking and idle operation.

EXCEPTIONS:

1. UL 710 listed exhaust hoods that have a design maximum exhaust airflow rate no greater than 250 cfm per linear foot of hood that serve kitchen or kitchen/dining facilities with a total kitchen hood exhaust airflow rate less than 5000 cfm.
2. An energy recovery device is installed on the kitchen exhaust with a sensible heat recovery effectiveness of not less than 40 percent or not less than 50 percent of the total exhaust hood airflow.

C403.7.7.2 Laboratory fume exhaust systems. Buildings with laboratory **fume** exhaust systems having a total exhaust rate greater than 5,000 cfm (2360 L/s) shall include heat recovery systems to precondition replacement air from laboratory **fume** exhaust. The heat recovery system shall be capable of increasing the outside air supply temperature at design heating conditions by 25°F (13.9°C). A provision shall be made to bypass or control the heat recovery system to permit air economizer operation as required by Section C403.5.

EXCEPTIONS:

1. Variable air volume laboratory **fume** exhaust and room supply systems configured to reduce 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 **fume** exhaust rate, heated no warmer than 2°F (1.1°C) below room setpoint, cooled to no cooler than 3°F (1.7°C) above room setpoint, no humidification added, and no simultaneous heating and cooling used for dehumidification control; or
3. Combined energy reduction method: VAV **fume** exhaust and room supply system configured to reduce **fume** exhaust and makeup air volumes and a heat recovery system to precondition makeup air from laboratory **fume** 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:

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

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

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

Where:

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

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

CFMs = 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

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C403.7.7.3 Transfer air. Conditioned supply air delivered to any space with mechanical exhaust shall not exceed the greater of:

1. The supply flow required to meet the space heating or cooling load;
2. The ventilation rate required by the authority having jurisdiction, the facility environmental health and safety department, or Section C403.2.2; or
3. The mechanical exhaust flow minus the available transfer air from conditioned spaces or return air plenums that at their closest point are within 15 feet of each other on the same floor that are not in different smoke or fire compartments. Available transfer air is that portion of outdoor ventilation air that:
 - 3.1. Is not required to satisfy other exhaust needs;
 - 3.2. Is not required to maintain pressurization of other spaces; and
 - 3.3. Is transferable according to applicable codes and standards and per the *International Mechanical Code*.

EXCEPTIONS:

1. Laboratories classified as biosafety level 3 or higher.
2. Vivarium spaces.
3. Spaces that are required by applicable codes and standards to be maintained at positive pressure relative to adjacent spaces. For spaces taking this exception, any transferable air that is not directly transferred shall be made available to the associated air-handling unit and shall be used whenever economizer or other options do not save more energy.
4. Spaces where the demand for transfer air may exceed the available transfer airflow rate and where the spaces have a required negative pressure relationship. For spaces taking this exception, any transferable air that is not directly transferred shall be made available to the associated air-handling unit and shall be used whenever economizer or other options do not save more energy.

C403.7.8 Shutoff dampers. Mechanical openings shall be provided with shutoff dampers in accordance with Sections C403.7.8.1 through C403.7.8.4.

C403.7.8.1 Shutoff dampers for building isolation. Outdoor air supply, exhaust openings and relief outlets and stairway and elevator hoistway shaft vents shall be provided with Class I motorized dampers. See Sections C403.10.1 and C403.10.2 for ductwork insulation requirements upstream and downstream of the shutoff damper.

EXCEPTIONS:

1. Gravity (nonmotorized) dampers shall be permitted in lieu of motorized dampers as follows:
 - 1.1. Relief dampers serving systems less than ~~((5,000))~~ 300 cfm total supply shall be permitted (~~((# buildings less than three stories in height.))~~)
 - 1.2. Gravity (nonmotorized) dampers where the design outdoor air intake or exhaust capacity does not exceed 300 cfm (142 L/s).
 - 1.3. Systems serving areas which require continuous operation for 24/7 occupancy schedules.
2. Shutoff dampers are not required in:
 - 2.1. Combustion air intakes.
 - 2.2. Systems serving areas which require continuous operation in animal hospitals, kennels and pounds, laboratories, and Group H, I and R occupancies.
 - 2.3. Subduct exhaust systems or other systems that are required to operate continuously by the *International Mechanical Code*.
 - 2.4. Type I grease exhaust systems or other systems where dampers are prohibited by the *International Mechanical Code* to be in the airstream.
 - 2.5. Unconditioned stairwells or unconditioned elevator hoistway shafts that are only connected to unconditioned spaces.

C403.7.8.2 Shutoff dampers for return air. Return air openings used for airside economizer operation shall be equipped with Class I motorized dampers.

C403.7.8.3 Damper leakage rating. Class 1 dampers shall have a maximum leakage rate of 4 cfm/ft² (20.3 L/s × m²) at 1.0 inch water gauge (w.g.) (249 Pa) when tested in accordance with AMCA 500D and shall be labeled by an approved agency for such purpose. Gravity (nonmotorized) dampers shall have an air leakage rate not greater than 20 cfm/ft² where not less than 24 inches (610 mm) in either dimension and 40 cfm/ft² where less than 24 inches in either dimension. The rate of air leakage shall be determined at 1.0 inch w.g. (249 Pa) when tested in accordance with AMCA 500D

for such purpose. The dampers shall be labeled by an approved agency. Gravity dampers for ventilation air intakes shall be protected from direct exposure to wind.

EXCEPTIONS:

1. Gravity (nonmotorized) dampers are not required to be tested to verify the air leakage rating when installed in exhaust systems where the exhaust capacity does not exceed 400 cfm and the gravity damper is provided with a gasketed seal.
2. Motorized dampers on return air openings in unitary packaged equipment that have the minimum leakage rate available from the manufacturer.

C403.7.8.4 Damper actuation. Outdoor air intake, relief and exhaust shutoff dampers shall be installed with automatic controls configured to close when the systems or spaces served are not in use or during unoccupied period warm-up and setback operation, unless the systems served require outdoor or exhaust air in accordance with the *International Mechanical Code* or the dampers are opened to provide intentional economizer cooling. Stairway and elevator hoistway shaft vent dampers shall be installed with automatic controls configured to open upon the activation of any fire alarm initiating device of the building's fire alarm system or the interruption of power to the damper.

C403.8 Fan and fan controls. Fans in HVAC systems shall comply with Sections C403.8.1 through C403.8.5.1. The airflow requirements of Section C403.8.5.1 shall apply to all fan motors. Low capacity ventilation fans shall also comply with Section C403.8.4.

C403.8.1 Fan System. Each *fan system* that includes at least one fan or fan array with *fan electrical input power* ≥ 1 kW, moving air into, out of, or between conditioned spaces or circulating air for the purpose of conditioning air within a space shall comply with Sections C403.8.1.1 through C403.8.1.2.

C403.8.1.1 Determining fan power budget. For each *fan system*, the *fan system electrical input power* (Fan kW_{design,system}) determined in accordance with Section C403.8.1.2 at the *fan system airflow* shall not exceed Fan kW_{budget}. Calculate fan power budget (Fan kW_{budget}) for each fan system as follows:

1. Determine the *fan system airflow* and choose the appropriate table(s) for fan power allowance.
 - 1.1. For *single-cabinet fan systems*, use the *fan system airflow* and the power allowances in both Table C403.8.1.1(1) and Table C403.8.1.1(2).
 - 1.2. For *supply-only fan systems*, use the *fan system airflow* and power allowances in Table C403.8.1.1(1).
 - 1.3. For *relief fan systems*, use the design relief airflow and the power allowances in Table C403.8.1.1(2).
 - 1.4. For exhaust, return and transfer *fan systems*, use the *fan system airflow* and the power allowances in Table C403.8.1.1(2).
 - 1.5. For complex and DOAS with energy recovery *fan systems*, separately calculate the *fan power* allowance for the supply and return/exhaust systems and sum them. For the supply airflow, use supply airflow at the *fan system* design conditions, and the power allowances in Table C403.8.1.1(1). For the return/exhaust airflow, use return/exhaust airflow at the *fan system* design conditions, and the power allowances in Table C403.8.1.1(2).
2. For each *fan system*, determine the components included in the fan system and sum the fan power allowances of those components. All fan systems shall include the system base allowance. If, for a given component, only a portion of the fan system airflow passes through the component, calculate the fan power allowance for that component in accordance with Equation 4-11:

$$FPA_{adj} = (Q_{comp}/Q_{sys}) \times FPA_{comp} \quad \text{(Equation 4-11)}$$

Where:

- FPA_{adj} = The corrected fan power allowance for the component in W/cfm.
 Q_{comp} = The airflow through component in cfm.
 Q_{sys} = The *fan system airflow* in cfm.
 FPA_{comp} = The fan power allowance of the component from Table C403.8.1.1(1) or Table C403.8.1.1(2).

3. Multiply the *fan system airflow* by the sum of the fan power allowances for the *fan system*.
4. Divide by 1,000 to convert to Fan kW_{budget}.
5. For building sites at elevations greater than 3,000 feet, multiply Fan kW_{budget} by 0.896.

GENERAL REQUIREMENTS

**Table C403.8.1.1(1)
Supply Fan Power Allowances (W/CFM)**

Airflow	Multi-Zone VAV Systems^a ≤ 5,000 cfm	Multi-Zone VAV Systems^a > 5,000 and ≤ 10,000 cfm	Multi-Zone VAV Systems^a > 10,000 cfm	All Other Fan Systems ≤ 5,000 cfm	All Other Fan Systems > 5,000 and ≤ 10,000 cfm	All Other Fan Systems > 10,000 cfm
Supply system base allowance for AHU serving spaces ≤ 6 floors away	0.395	0.453	0.413	0.232	0.256	0.236
Supply system base allowance for AHU serving spaces > 6 floors away	0.508	0.548	0.501	0.349	0.356	0.325
MERV 13 to MERV 16 Filter upstream of thermal conditioning equipment (two-times the clean filter pressure drop) ^b	0.136	0.114	0.105	0.139	0.120	0.107
MERV 13 to MERV 16 Final filter downstream of thermal conditioning equipment (two-times the clean filter pressure drop) ^b	0.225	0.188	0.176	0.231	0.197	0.177
Filtration allowance for > MERV 16 or HEPA Filter (two-times the clean filter pressure drop) ^b	0.335	0.280	0.265	0.342	0.292	0.264
Central hydronic heating coil allowance	0.046	0.048	0.052	0.046	0.050	0.054
Electric heat allowance	0.046	0.038	0.035	0.046	0.040	0.036
Gas heat allowance	0.069	0.057	0.070	0.058	0.060	0.072
Hydronic/DX cooling coil or heat pump coil (wet) allowance ^c	0.135	0.114	0.105	0.139	0.120	0.107
Solid or liquid desiccant system allowance	0.157	0.132	0.123	0.163	0.139	0.124
Reheat coil for dehumidification allowance	0.045	0.038	0.035	0.046	0.040	0.036
Allowance for evaporative humidifier/cooler in series with a cooling coil. Value shown is allowed W/cfm per 1.0 inches of water gauge (in. w.g.). Determine pressure loss (in. w.g.) at 400 fpm or maximum velocity allowed by the manufacturer, whichever is less ^d	0.224	0.188	0.176	0.231	0.197	0.177
Allowance for 100% Outdoor air system ^e	0.000	0.000	0.000	0.070	0.100	0.107

Table C403.8.1.1(1)—continued
Supply Fan Power Allowances (W/CFM)

Airflow	Multi-Zone VAV Systems ^a ≤ 5,000 cfm	Multi-Zone VAV Systems ^a > 5,000 and ≤ 10,000 cfm	Multi-Zone VAV Systems ^a > 10,000 cfm	All Other Fan Systems ≤ 5,000 cfm	All Other Fan Systems > 5,000 and ≤ 10,000 cfm	All Other Fan Systems > 10,000 cfm
Energy recovery allowance for 0.50 ≤ ERR < 0.55 ^f	0.135	0.114	0.105	0.139	0.120	0.107
Energy recovery allowance for 0.55 ≤ ERR < 0.60 ^f	0.160	0.134	0.124	0.165	0.141	0.126
Energy recovery allowance for 0.60 ≤ ERR < 0.65 ^f	0.184	0.155	0.144	0.190	0.163	0.146
Energy recovery allowance for 0.65 ≤ ERR < 0.70 ^f	0.208	0.175	0.163	0.215	0.184	0.165
Energy recovery allowance for 0.70 ≤ ERR < 0.75 ^f	0.232	0.196	0.183	0.240	0.205	0.184
Energy recovery allowance for 0.75 ≤ ERR < 0.80 ^f	0.257	0.216	0.202	0.264	0.226	0.203
Energy recovery allowance for ERR ≥ 0.80 ^f	0.281	0.236	0.222	0.289	0.247	0.222
Coil runaround loop	0.135	0.114	0.105	0.139	0.120	0.107
Allowance for Gas phase filtration required by code or accredited standard. Value shown is allowed W/cfm per 1.0 in. wg air pressure drop ^d	0.224	0.188	0.176	0.231	0.197	0.177
Economizer damper return	0.045	0.038	0.035	0.046	0.040	0.036
Air blender allowance	0.045	0.038	0.035	0.046	0.040	0.036
Sound attenuation section [fans serving spaces with design background noise goals below NC35]	0.034	0.029	0.026	0.035	0.030	0.027
Deduction for systems that feed a terminal unit with a fan with electrical input power < 1kW	-0.100	-0.100	-0.100	-0.100	-0.100	-0.100
Low-turndown single-zone VAV fan systems ^g	0.000	0.000	0.000	0.070	0.100	0.089

C403.8.1.2 Determining Fan System Electrical Input Power (Fan kW_{design,system}). Fan kW_{design,system} is the sum of Fan kW_{design} for each fan or fan array included in the fan system. If variable speed drives are used, their efficiency losses shall be included. Fan input power shall be calculated with two-times the clean filter pressure drop. The Fan kW_{design} for each fan or fan array shall be determined using one of the following methods. There is no requirement to use the same method for all fans in a fan system:

GENERAL REQUIREMENTS

1. Use the default $Fan kW_{design}$ in Table C403.8.1.2 for one or more of the fans. This method cannot be used for *complex fan systems*.
2. Use the $Fan kW_{design}$ at *fan system design conditions* provided by the manufacturer of the fan, fan array, or equipment that includes the fan or fan array calculated per a test procedure included in 10 C.F.R. Part 430, 10 C.F.R. Part 431, ANSI/AMCA 208, ANSI/AMCA S210, AHRI 430, AHRI 440, or ISO 5801.
3. Use the $Fan kW_{design}$ provided by the manufacturer, calculated at *fan system design conditions* per one of the methods listed in Section 5.3 of ANSI/AMCA 208.
4. Determine the $Fan kW_{design}$ by using the maximum electrical input power provided on the motor nameplate.

Table C403.8.1.2
Default Values for Fan kW_{design} Based on Motor Nameplate HP^{a,b}

Motor Nameplate HP	Default $Fan kW_{design}$ with variable speed drive ($Fan kW_{design}$)	Default $Fan kW_{design}$ without variable speed drive ($Fan kW_{design}$)
<1	0.96	0.89
≥1 and <1.5	1.38	1.29
≥1.5 and <2	1.84	1.72
≥2 and <3	2.73	2.57
≥3 and <5	4.38	4.17
≥5 and <7.5	6.43	6.15
≥7.5 and <10	8.46	8.13
≥10 and <15	12.4	12.0
≥15 and <20	16.5	16.0
≥20 and <25	20.5	19.9
≥25 and <30	24.5	23.7
≥30 and <40	32.7	31.7
≥40 and <50	40.7	39.4
≥50 and <60	48.5	47.1
≥60 and <75	60.4	58.8
≥75 and ≤100	80.4	78.1

C403.8.2 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 (4476 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 (4476 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.
4. Fans with motor nameplate horsepower less than 1 hp or fans with a fan motor nameplate electrical input power of less than 0.89 kW.
5. Fans equipped with electronic speed control devices to vary the fan airflow as a function of load.

C403.8.3 Fan efficiency. Each fan and *fan array* shall have a *fan energy index (FEI)* of not less than 1.00 at the design point of operation, as determined in accordance with AMCA 208 by an *approved*, independent testing laboratory and labeled by the manufacturer. Each fan and *fan array* used for a variable-air volume system shall have an *FEI* of not less than 0.95 at the design point of operation as determined in accordance with AMCA 208 by an *approved*, independent testing laboratory and labeled by the manufacturer. The *FEI* for *fan arrays* shall be calculated in accordance with AMCA 208 Annex C.

EXCEPTION: The following fans are not required to have a fan energy index:

1. Fans that are not *embedded* (~~(fans)~~) *fans* with motor nameplate horsepower of less than 1.0 hp (0.75 kW) or with a nameplate electrical input power of less than 0.89 kW.
2. *Embedded fans* that have a motor nameplate horsepower of 5 hp (3.7 kW) or less or with a fan system electrical input power of 4.1 kW or less.

3. Multiple fans operated in series or parallel as the functional equivalent of a single fan that have a combined motor nameplate horsepower of 5 hp (3.7 kW) or less or with a fan system electrical input power of 4.1 kW or less.
4. Fans that are part of equipment covered under Section C403.3.2.
5. Fans included in an equipment package certified by an *approved agency* for air or energy performance.
6. *Ceiling fans.*
7. Fans used for moving gases at temperatures above 425°F (250°C).
8. Fans used for operation in explosive atmospheres.
9. Reversible fans used for tunnel ventilation.
10. Fans that are intended to operate only during emergency conditions.
11. Fans outside the scope of AMCA 208.

C403.8.4 Low-capacity ventilation fans. Mechanical ventilation system fans with motors less than 1/12 hp (0.062 kW) in capacity shall meet the efficacy requirements of Table C403.8.4 (~~(at one or more rating points)~~). Airflow shall be tested in accordance with the test procedure referenced in Table C403.8.4 and listed. The efficacy, airflow divided by power, shall be reported in the product listing or shall be derived from the input power and airflow values reported in the product listing or on the label. The efficacy shall be determined using the input power at a listed airflow that is not less than the design airflow or shall be determined by interpolating between the input power at the two nearest listed airflow rates. Design airflow, power, and efficacy shall be reported on the mechanical equipment schedule submitted in the permit documents.

EXCEPTIONS:

1. Where ventilation fans are a component of a listed heating or cooling appliance.
2. Dryer exhaust duct power ventilators and domestic range booster fans that operate intermittently.
3. Fans in radon mitigation systems.
4. Fans not covered within the scope of the test methods referenced in Table C403.8.5.
5. Ceiling fans regulated under 10 CFR 430 Appendix U.
6. Mechanical ventilation system types with an input power greater than 62 watts having electronically commutated motors or motors with a minimum efficiency of 70 percent when rated in accordance with DOE 10 CFR 431. Such systems shall also have the means to adjust motor speed for either balancing or remote control. Belt-driven fans may use sheave adjustment for airflow balancing in lieu of a varying motor speed. The efficiency shall be verified through certification under an approved certification program, or, where no certification program exists, the equipment efficiency rating shall be supported by data furnished by the motor manufacturer.

The efficacy shall be determined at a listed airflow that is not less than the design airflow or shall be determined by interpolating between the efficacies determined at the two nearest listed airflow rates.

~~((Table C403.8.4—
Low-Capacity Ventilation Fan Efficacy^a~~

Fan Location	Airflow Rate Minimum (cfm)	Minimum Efficacy (cfm/watt)	Airflow Rate Maximum (cfm)
HRV or ERV	Any	1.2 cfm/watt	Any
Range hood	Any	2.8 cfm/watt	Any
In-line fan	Any	3.8 cfm/watt	Any
Bathroom, utility room	10	2.8 cfm/watt	< 90
Bathroom, utility room	90	3.5 cfm/watt	Any

For SI: 1 cfm/ft = 47.82 W.

a. Airflow shall be tested in accordance with HVI 916 and listed. Efficacy shall be listed or shall be derived from listed power and airflow. Fan efficacy for fully ducted HRV, ERV, balanced and in-line fans shall be determined at a static pressure not less than 0.2 inch w.e. Fan efficacy for ducted range hoods, bathroom, and utility room fans shall be determined at a static pressure not less than 0.1 inch w.e.)

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**Table C403.8.4
Low-Capacity Ventilation Fan Efficacy^a**

System Type	Airflow Rate (cfm)	Minimum Efficacy (cfm/watt)	Minimum Static Pressure for Testing	Test Procedure
Balanced ventilation system without heat or energy recovery	Any	1.2 ^a	0.2 inch w.c.	ASHRAE Standard 51 (ANSI/AMCA Standard 210)
HRV or ERV	Any	1.2 ^a	0.2 inch w.c. ^b	CAN/CSA 439-18
Range hood	Any	2.8	0.1 inch w.c.	ASHRAE 51 (ANSI/AMCA Standard 210)
In-line supply or exhaust fan	Any	3.8	0.2 inch w.c.	
Other exhaust fan	<90	2.8	0.1 inch w.c.	
	>90 and <200	3.5	0.1 inch w.c.	
	>200	4.0	0.1 inch w.c.	

For SI: 1 cfm/ft = 47.82 W.

a. For balanced systems, HRVs, and ERVs, the efficacy shall be determined as the outdoor airflow divided by the total fan power of the system.

b. The minimum static pressure for determining HRV or ERV fan efficacy shall be 0.4 inch w.c. for airflows greater than or equal to 100 L/s.

C403.8.5 Fan controls. Controls shall be provided for fans in accordance with Section C403.8.5.1 and as required for specific systems provided in Section C403.

C403.8.5.1 Fan airflow control. Each cooling system listed in Table C403.8.5.1 shall be designed to vary the indoor fan airflow as a function of load and shall comply with the following requirements:

1. Direct expansion (DX) and chilled water cooling units that control the capacity of the mechanical cooling directly based on space temperature shall have not fewer than two stages of fan control. Low or minimum speed shall not be greater than 66 percent of full speed. At low or minimum speed, the fan system shall draw not more than 40 percent of the fan power at full fan speed. Low or minimum speed shall be used during periods of low cooling load and ventilation-only operation.
2. Other units including DX cooling units and chilled water units that control the space temperature by modulating the airflow to the space shall have modulating fan control. Minimum speed shall be not greater than 50 percent of full speed. At minimum speed, the fan system shall draw no more than 30 percent of the power at full fan speed. Low or minimum speed shall be used during periods of low cooling load and ventilation-only operation.
3. Units that include an airside economizer in accordance with Section C403.5 shall have not fewer than two speeds of fan control during economizer operation.

EXCEPTIONS:

1. Modulating fan control is not required for chilled water and evaporative cooling units with fan motors of less than 1 hp (0.746 kW) where the units are not used to provide ventilation air and the indoor fan cycles with the load.
2. Where the volume of outdoor air required to comply with the ventilation requirements of the *International Mechanical Code* at low speed exceeds the air that would be delivered at the minimum speed defined in Section C403.8.5, the minimum speed shall be selected to provide the required ventilation air.

**Table C403.8.5.1
Fan Control**

Cooling System Type	Fan Motor Size	Mechanical Cooling Capacity
DX cooling	Any	≥ 42,000 Btu/h
Chilled water and evaporative cooling	≥ 1/4 hp	Any

C403.8.6 Large-diameter ceiling fans. Where provided, *large-diameter ceiling fans* shall be tested and labeled in accordance with AMCA 230.

C403.9 Heat rejection and heat recovery equipment.

C403.9.1 Heat rejection equipment. Heat rejection equipment, including air-cooled condensers, dry coolers, open-circuit cooling towers, closed-circuit cooling towers and evaporative condensers, shall comply with this section.

EXCEPTION: Heat rejection devices where energy usage is included in the equipment efficiency ratings listed in Tables C403.3.2(1), C403.3.2(2), C403.3.2(3), C403.3.2(4), C403.3.2(8), C403.3.2(9), C403.3.2(10) and C403.3.2(16).

Heat rejection equipment shall have a minimum efficiency performance not less than values specified in Table C403.3.2(7).

C403.9.1.1 Fan speed control. Each fan powered by an individual motor or array of motors with a connected power, including the motor and devices configured to automatically modulate the fan speed to control the leaving fluid temperature or condensing temperature and pressure of the heat rejection device. Fan motor power input shall be not more than 30 percent of design wattage at 50 percent of the design airflow.

EXCEPTIONS:

1. Fans serving multiple refrigerant or fluid cooling circuits.
2. Condenser fans serving flooded condensers.

C403.9.1.2 Multiple-cell heat rejection equipment. Multiple-cell heat rejection equipment with variable speed fan drives shall be controlled to operate the maximum number of fans allowed that comply with the manufacturer's requirements for all system components and so that all fans can operate at the same fan speed required for the instantaneous cooling duty, as opposed to staged (on/off) operation. The minimum fan speed shall be the minimum allowable speed of the fan drive system in accordance with the manufacturer's recommendations.

C403.9.1.3 Limitation on centrifugal fan open-circuit cooling towers. Centrifugal fan open-circuit cooling towers with a combined rated capacity of 1,100 gpm (4164 L/m) or greater at 95°F (35°C) condenser water return, 85°F (29°C) condenser water supply, and 75°F (24°C) outdoor air wet-bulb temperature shall meet the energy efficiency requirement for axial fan open-circuit cooling towers listed in Table C403.3.2(7).

C403.9.1.4 Tower flow turndown. Open-circuit cooling towers used on water-cooled chiller systems that are configured with multiple- or variable-speed condenser water pumps shall be designed so that all open circuit cooling tower cells can be run in parallel with the larger of the flow that is produced by the smallest pump at its minimum expected flow rate or at 50 percent of the design flow for the cell.

C403.9.2 Heat recovery.

C403.9.2.1 Condenser heat recovery for service water heating. Condenser heat recovery shall be installed for heating or reheating of service hot water provided the facility operates 24 hours a day, the total installed heat capacity of water cooled systems exceeds 1,500,000 Btu/hr of heat rejection, and the design service water heating load exceeds 250,000 Btu/hr.

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

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

EXCEPTIONS:

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

C403.9.2.2 Steam 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 off-site generated steam where the condensate is not returned to the source, shall have an on-site condensate water heat recovery system.

C403.9.2.3 Refrigeration condenser heat recovery. Facilities having food service, meat or deli departments and having 500,000 Btu/h or greater of remote refrigeration condensers shall have condenser waste heat recovery from freezers and coolers and shall use the waste heat for service water heating, space heating or for dehumidification reheat. Facilities having a gross conditioned floor area of 40,000 ft² or greater and 1,000,000 Btu/h or greater of remote refrigeration shall have condenser waste heat recovery from freezers and coolers and shall use the waste heat for service water heating, and either for space heating or for dehumidification reheat for maintaining low space humidity.

C403.9.2.4 Condenser heat recovery for space heating. A water-source condenser heat recovery system meeting the requirements of Sections C403.9.2.4.1 through C403.9.2.4.4 shall be installed to serve space and ventilation heating systems in new buildings and additions meeting the following criteria:

1. The facility operates greater than 70 hours per week.
2. The sum of all heat rejection equipment capacity serving the new building or addition exceeds 1,500,000 Btu/hr.
3. The sum of zone minimum airflows in all zones with zone reheat coils divided by the conditioned floor area served by those systems is at least 0.45 cfm per square foot.

EXCEPTION: Systems complying with Section C403.3.5, Dedicated outdoor air systems.

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C403.9.2.4.1 Water-to-water heat recovery. Ninety percent (90%) of the total building space and ventilation heating system design load shall be served by systems that include heat recovery chiller or water-to-water heat pump equipment capable of rejecting heat from the cooling loop to the space and ventilation heating loop as the first stage of heating.

C403.9.2.4.2 Exhaust heat recovery. Heat shall be recovered by the heat recovery system from 90 percent of the total building exhaust airflow. The maximum leaving air temperature of exhaust air after heat recovery shall be 55°F dry-bulb when operating at full capacity in heat recovery mode.

EXCEPTIONS:

1. Where energy recovery systems are restricted by Section 514 of the International Mechanical Code to sensible energy, those systems shall not be included in the calculation of total building exhaust airflow.
2. Exhaust air systems handling contaminated airstreams that are regulated by applicable codes or accreditation standards and pose a health risk to maintenance personnel to maintain heat recovery devices, those systems shall not be included in the calculation of total building exhaust airflow.

C403.9.2.4.3 Process heat recovery. Spaces with year-round cooling loads from lights and equipment of 5 watts and greater per square foot shall be served by water-cooled equipment. Cooling loops serving the water-cooled equipment shall be served by water source heat recovery systems meeting the requirements of Section C403.9.2.4.1. If such spaces are provided with an air or water economizer, the economizer controls shall be configured with an override signal from the building automation system to disable economizer operation during heat recovery mode.

C403.9.2.4.4 Water-to-water heat recovery sizing. The minimum total combined capacity of heat recovery chillers or water-to-water heat pumps shall match the total combined capacity of installed equipment sized to meet the requirements of Sections C403.9.2.4.2 and C403.9.2.4.3.

C403.10 Construction of HVAC system elements. Ducts, plenums, piping and other elements that are part of an HVAC system shall be constructed and insulated in accordance with Sections C403.10.1 through C403.10.3.1.

C403.10.1 Duct and plenum insulation and sealing.

C403.10.1.1 Ducts, shafts, and plenums conveying outdoor air. Shafts and plenums conveying outdoor 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*.

Ducts conveying outdoor air shall be insulated continuously from the building exterior to an automatic shutoff damper or heating or cooling equipment. Duct surfaces shall be insulated with the minimum insulation values in Table C403.10.1.1. Duct surfaces included as part of the building envelope shall not be used in the calculation of maximum glazing area as described in Section C402.4.1.

EXCEPTION: Outdoor air ducts serving individual supply air units with less than 2,800 cfm of total supply air capacity, provided these are insulated to the minimum insulation values in Table C403.10.1.1.

**Table C403.10.1.1
Outdoor Air Ductwork Insulation**

Duct system	Duct Location and Use	Climate Zone	Airflow	Minimum Installed Duct Insulation R-value ^{a,b}	Notes
Outdoor Air	Inside conditioned space and upstream of automatic shutoff damper	4C and 5B	≥ 2800 CFM	R-16	See Section C403.10.1.1 for additional requirements
Outdoor Air	Inside conditioned space and downstream of automatic shutoff damper to HVAC unit or room	4C	≥ 2800 CFM	R-8	
Outdoor Air	Inside conditioned space and downstream of automatic shutoff damper to HVAC unit or room	5B	≥ 2800 CFM	R-12	
Outdoor Air	Inside conditioned space	4C and 5B	≤ 2800 CFM	R-7	See Exception 1 to Section C403.10.1.1 for additional details

a. Insulation R-values, measured in $h \cdot ft^2 \cdot ^\circ F/Btu$, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a mean temperature of 75°F at the installed thickness.

b. See *International Mechanical Code* Sections 603.12 and 604 for further details on duct insulation requirements.

C403.10.1.2 Other supply and return ducts. All other supply and return air ducts and plenums shall be insulated with a minimum of R-6 insulation where located in unconditioned spaces, and where located outside the building with a minimum of R-8 insulation in Climate Zone 4 and R-12 insulation in Climate Zone 5. Ducts located underground beneath buildings shall be insulated as required in this section or have an equivalent *thermal distribution efficiency*. Underground ducts utilizing the *thermal distribution efficiency* method shall be listed and labeled to indicate the R-value equivalency. Where located within a building envelope assembly, the duct or plenum shall be separated from the building exterior or unconditioned or exempt spaces by minimum insulation value as required for exterior walls by Section C402.1.3.

EXCEPTIONS:

1. Where located within equipment.
2. Supply and return ductwork located in unconditioned spaces where the design temperature difference between the interior and exterior of the duct or plenum does not exceed 15°F (8°C) and are insulated in accordance with Table C403.10.1.2.

Where located within conditioned space, supply ducts which convey supply air at temperatures less than 55°F or greater than 105°F shall be insulated with a minimum insulation R-value in accordance with Table C403.10.1.2.

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

Where located within conditioned space, return or exhaust air ducts that convey return or exhaust air downstream of an energy recovery media shall be insulated with a minimum insulation R-value in accordance with Table C403.10.1.2.

Where located within conditioned space, ducts that convey air from outside the conditioned space shall be insulated with a minimum insulation R-value in accordance with Table C403.10.1.2.

Where located within conditioned space, ducts that convey ambient air to and from outside for the condenser section of HVAC heat pumps, service hot water heat pumps, or air conditioning units shall be insulated with a minimum insulation R-value in accordance with Table C403.10.1.2.

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

**Table C403.10.1.2
Supply, Return, Exhaust and Relief Air Ductwork Insulation**

Duct System	Duct Location and Use	Climate Zone	Minimum Installed Duct Insulation R-value ^{a,b}	Notes
Supply air or return air	Outside the building (outdoors and exposed to weather) ^c	4C	R-8	See Section C403.10.1.2 for details
Supply air or return air	Outside the building (outdoors and exposed to weather) ^c	5B	R-12	See Section C403.10.1.2 for details
Supply air or return air	Unconditioned space (enclosed but not in the building conditioned envelope)	4C and 5B	R-6	See Section C403.10.1.2 for details
Supply air or return air	Unconditioned space where the duct conveys air that is within 15°F of the air temperature of the surrounding unconditioned space	4C and 5B	R-3.3	See IMC Section 603.12 for additional requirements for condensation control at ductwork
Supply air or return air	Where located in a building envelope assembly	4C and 5B	R-16	Duct or plenum is separated from building envelope assembly with the minimum insulation value
Supply air	Within conditioned space where the supply duct conveys air that is less than 55°F or greater than 105°F	4C and 5B	R-3.3	See Section C403.10.1.2 for details
Supply air	Within conditioned space that the duct directly serves where the supply duct conveys air that is less than 55°F or greater than 105°F	4C and 5B	None	See Section C403.10.1.2 for details
Supply air	Within conditioned space where the supply duct conveys air that is 55°F or greater and 105°F or less	4C and 5B	None	
Return or exhaust air	Within conditioned space, downstream of an energy recovery media, upstream of an automatic shutoff damper	4C	R-8	

Table C403.10.1.2—continued
Supply, Return, Exhaust and Relief Air Ductwork Insulation

Duct System	Duct Location and Use	Climate Zone	Minimum Installed Duct Insulation R-value ^{a,b}	Notes
Return or exhaust air	Within conditioned space, downstream of an energy recovery media, upstream of an automatic shutoff damper	5B	R-12	
Relief or exhaust air	Conditioned space and downstream of an automatic shutoff damper	4C and 5B	R-16	
<u>Exhaust or other air duct</u>	<u>Duct conveying air from unconditioned space through conditioned space</u>	<u>4C and 5B</u>	<u>R-16</u>	
<u>Condenser air intake and outlet</u>	<u>Conditioned space and conveys ambient air to or from the outdoors to heat pump or AC unit condenser</u>	<u>4C and 5B</u>	<u>< 2800 CFM = R-8</u> <u>> 2800 CFM = R-16</u>	

a Insulation R-values, measured in h•ft²•°F/Btu, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a mean temperature of 75°F at the installed thickness.

b See *International Mechanical Code* Sections 603.12 and 604 for further details on duct insulation requirements.

c Includes attics above insulated ceilings, parking garages and crawl spaces.

C403.10.2 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. Ducts shall be leak-tested where required by Section C403.10.2.4.

C403.10.2.1 Low-pressure duct systems. 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.

C403.10.2.2 Medium-pressure duct systems. 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 C403.10.1. Pressure classifications specific to the duct system shall be clearly indicated on the construction documents in accordance with the *International Mechanical Code*.

C403.10.2.3 High-pressure duct systems. Ducts designed to operate at static pressures equal to or greater than 3 inches water gauge (w.g.) (750 Pa) shall be insulated and sealed in accordance with Section C403.10.1.

C403.10.2.4 Duct leak testing. ~~((In addition, ducts))~~ Ducts and plenums designed to operate at static pressures equal to or greater than 3 inches water gauge (w.g.) (750 Pa) and all supply and return ductwork that is located outside the building thermal envelope and that serves conditioned space, shall be leak-tested in accordance with the SMACNA *HVAC Air Duct Leakage Test Manual* and shown to have a rate of air leakage (CL) less than or equal to 4.0, as determined in accordance with Equation 4-12. Ducts shall be tested using a pressure equal to the average operating pressure or the design Duct Construction Pressure Class level in accordance with the SMACNA HVAC Air Duct Leakage Test Manual.

$$CL = F/P^{0.65} \tag{Equation 4-12}$$

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 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.

C403.10.3 Piping insulation. All piping, other than field installed HVAC system refrigerant piping, serving as part of a heating or cooling system shall be thermally insulated in accordance with Table C403.10.3.

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).
7. In radiant heating systems, sections of piping intended by design to radiate heat.

**Table C403.10.3
Minimum Pipe Insulation Thickness (thickness in inches)^a**

Fluid Operating Temperature Range and Usage (°F)	Insulation Conductivity		Nominal Pipe or Tube Size (inches)				
	Conductivity Btu • in. / (h • ft ² • °F) ^b	Mean Rating Temperature, °F	< 1	1 to < 1-1/2	1-1/2 to < 4	4 to < 8	≥ 8
> 350	0.32 - 0.34	250	4.5	5.0	5.0	5.0	5.0
251 - 350	0.29 - 0.32	200	3.0	4.0	4.5	4.5	4.5
201 - 250	0.27 - 0.30	150	2.5	2.5	2.5	3.0	3.0
141 - 200	0.25 - 0.29	125	1.5	1.5	2.0	2.0	2.0
105 - 140	0.21 - 0.28	100	1.0	1.0	1.5	1.5	1.5
40 - 60	0.21 - 0.27	75	0.5	0.5	1.0	1.0	1.0
< 40	0.20 - 0.26	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).
- k* = The upper value of the conductivity range listed in the table for the applicable fluid temperature.

- c For direct-buried heating and hot water system piping, reduction of these thicknesses by 1-1/2 inches (38 mm) shall be permitted (before thickness adjustment required in footnote b but not to thicknesses less than 1 inch (25 mm)).

C403.10.3.1 Protection of piping insulation. Piping insulation exposed to weather shall be protected from damage, including that due to sunlight, moisture, physical damage and wind, and shall provide shielding from solar radiation that can cause degradation of the material. Protection shall be removable for no less than six feet from the equipment for maintenance. Adhesive tape shall not be permitted.

C403.10.4 Insulation of HVAC system refrigerant piping. Field installed HVAC refrigerant piping, other than piping factory installed in HVAC equipment, shall have insulation as listed below, at a conductivity rating of 0.21 to 0.26 Btu × in/(h × ft² × °F) with a mean temperature rating of 75°F. Piping insulation exposed to weather shall be protected from damage, including that due to sunlight, moisture, physical damage and wind, and shall provide shielding from solar radiation that can cause degradation of the material. Adhesive tape shall not be permitted. Manufacturer’s required minimum pipe insulation shall be maintained.

1. For lines that convey hot gas for space heating:
 - 1.1. Minimum 1-inch insulation on the portions outside the building thermal envelope.
 - 1.2. Minimum 1/2-inch insulation on the portions within the building thermal envelope.
2. Minimum 1/2-inch insulation on the liquid line for mini-split systems and other systems for which insulation is required by the manufacturer, or where the metering device is located in the outdoor unit.
3. No insulation is required on the liquid line for other heat pump types or for cooling-only units where insulation is not required by the manufacturer.

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C403.11 Mechanical systems located outside of the building thermal envelope. Mechanical systems providing heat outside of the thermal envelope of a building shall be configured to comply with Section C403.11.1 through C403.11.3, and shall be provided with an electric heat pump or electric resistance heating system in accordance with Section C403.1.4.

C403.11.1 Heating outside a building or in unheated spaces. Systems installed to provide heat outside a building or in unheated spaces 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 20 minutes.

C403.11.2 Snow- and ice-melt system controls. Snow- and ice-melting systems, supplied through energy service to the building, shall include automatic controls configured to shut off the system when the pavement temperature is above 50°F (10°C) and no precipitation is falling and an automatic control that is configured to shut off when the outdoor temperature is above 40°F (4°C) so that the potential for snow or ice accumulation is negligible.

C403.11.3 Freeze protection system controls. Freeze protection systems, such as heat tracing of outdoor piping and heat exchangers, including self-regulating heat tracing, shall include automatic controls configured to shut off the systems when outdoor air temperatures are above 40°F (4°C) or when the conditions of the protected fluid will prevent freezing.

C403.12 High efficiency single-zone variable air volume (VAV) systems.

1. The single-zone VAV system is provided with airside economizer in accordance with Section C403.3 without exceptions.
2. A direct-digital control (DDC) system is provided to control the system as a single zone in accordance with Section C403.4.11 regardless of sizing thresholds of Table C403.4.11.1.
3. Single-zone VAV systems with a minimum outdoor air requirement of 1,000 cfm (472 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 Section C403.7.1, Demand controlled ventilation.
4. Allowable fan power shall not exceed 90 percent of the allowable fan power budget as defined by Section C403.8.1.1.
5. Each single-zone VAV system shall be designed to vary the supply fan airflow as a function of heating and cooling load and minimum fan speed shall not be more than the greater of:
 - 5.1. 30 percent of peak design airflow; or
 - 5.2. The required ventilation flow assuming no occupants.
6. Spaces that are larger than 150 square feet (14 m²) and with an occupant load greater than or equal to 25 people per 1000 square feet (93 m²) of floor area (as established in Table 403.3.1.1 of the *International Mechanical Code*) shall be provided with all of the following features:
 - 6.1. Demand control ventilation (DCV) shall be provided that utilizes a carbon dioxide sensor to reset the ventilation setpoint of the single-zone VAV system from the design minimum to design maximum ventilation rate as required by Chapter 4 of the *International Mechanical Code*.
 - 6.2. Occupancy sensors shall be provided that are configured to reduce the minimum ventilation rate to zero and setback room temperature setpoints by a minimum of 5°F, for both cooling and heating, when the space is unoccupied.
7. Single-zone VAV systems shall comply with one of the following options:
 - 7.1. Single-zone VAV air handling units with a hydronic heating coil connected to systems with hot water generation equipment limited to the following types of equipment: (~~Gas-fired hydronic boilers with a thermal efficiency, E_t, of not less than 92 percent,~~) air-to-water heat pumps or heat recovery chillers. Hydronic heating coils shall be sized for a maximum entering hot water temperature of 120°F for peak anticipated heating load conditions.
 - 7.2. Single-zone VAV air handling units with a chilled water coil connected to systems with chilled water generation equipment with IPLV values more than 25 percent higher than the minimum part load efficiencies listed in Table C403.3.2(3), in the appropriate size category, using the same test procedures. Equipment shall be listed in the appropriate certification program to qualify. The smallest chiller or compressor in the central plant shall not exceed 20 percent of the total central plant cooling capacity or the chilled water system shall include thermal storage sized for a minimum of 20 percent of the total central cooling plant capacity.
 - 7.3. Single-zone VAV air handling units with DX cooling, heat pump heating or gas-fired furnace shall comply with the following requirements as applicable:
 - 7.3.1. Have a DX cooling coil with cooling part load efficiency that is a minimum of 15 percent higher than the minimum SEER or IEER listed in Tables C403.3.2(1), C403.3.2(2), and C403.3.2 (14).

- 7.3.2. Have a gas-fired furnace with a thermal efficiency, E_t , of not less than 90 percent or heat pump with a minimum heating HSPF or COP efficiency that are a minimum of 10 percent higher than the minimum heating efficiency in Tables C403.3.2(1), C403.3.2(2), and C403.3.2(14).
- 7.3.3. Heating coils or burner output shall be modulating or have a minimum of 2 stages with the first stage being less than 50 percent of total heating capacity. Cooling coils shall be modulating or have a minimum of 2 stages with the first stage being less than 50 percent of the total cooling capacity.
- 8. The DDC system shall include a fault detection and diagnostics (FDD) system complying with the following:
 - 8.1. The following temperature sensors shall be permanently installed to monitor system operation:
 - 8.1.1. Outside air.
 - 8.1.2. Supply air.
 - 8.1.3. Return air.
 - 8.2. Temperature sensors shall have an accuracy of $\pm 2^\circ\text{F}$ (1.1°C) over the range of 40°F to 80°F (4°C to 26.7°C).
 - 8.3. The single-zone VAV air handling unit controller shall be configured to provide system status by indicating the following:
 - 8.3.1. Free cooling available.
 - 8.3.2. Economizer enabled.
 - 8.3.3. Compressor enabled.
 - 8.3.4. Heating enabled.
 - 8.3.5. Mixed air low limit cycle active.
 - 8.3.6. The current value of each sensor.
 - 8.4. The single-zone VAV air handling unit controller shall be capable of manually initiating each operating mode so that the operation of compressors, economizers, fans and the heating system can be independently tested and verified.
 - 8.5. The single-zone VAV air handling unit shall be configured to report faults to a fault management application able to be accessed by day-to-day operating or service personnel or annunciated locally on zone thermostats.
 - 8.6. The FDD system shall be configured to detect the following faults:
 - 8.6.1. Air temperature sensor failure/fault.
 - 8.6.2. Not economizing when the unit should be economizing.
 - 8.6.3. Economizing when the unit should not be economizing.
 - 8.6.4. Outdoor air or return air damper not modulating.
 - 8.6.5. Excess outdoor air.

C403.13 Dehumidification in spaces for plant growth and maintenance. Equipment that dehumidifies building spaces used for plant growth and maintenance shall be one of the following:

- 1. *Stand-alone dehumidifiers* that meet the following minimum integrated energy factors as measured by the test conditions in Appendix X1 to Subpart B of 10 C.F.R. Part 430:
 - 1.1. Minimum integrated energy factor of 1.77 L/kWh for product case volumes of 8.0 cubic feet or less;
 - 1.2. Minimum integrated energy factor of 2.41 L/kWh for product case volumes greater than 8.0 cubic feet;
- 2. *Integrated HVAC system* including, but not limited to, heat pump technology, with on-site heat recovery designed to fulfill at least 75 percent of the annual energy for dehumidification reheat;
- 3. Chilled water system including, but not limited to, heat pump technology, with on-site heat recovery designed to fulfill at least 75 percent of the annual energy for dehumidification reheat; or
- 4. Solid or liquid *desiccant dehumidification system* for system designs that require dewpoint of 50°F (10°C) or less.

C403.14 Commissioning. Mechanical systems shall be commissioned in accordance with Section C408.

SECTION C404 SERVICE WATER HEATING AND PRESSURE-BOOSTER SYSTEMS

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

GENERAL REQUIREMENTS

EXCEPTION: Energy using equipment used by a manufacturing, industrial or commercial process other than maintaining comfort and amenities for the occupants are exempt from all Section C404 subsections except Sections C404.2, C404.6 and C404.13. Laboratory sinks are considered to be process equipment for the purposes of this exception.

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

C404.2.1 Service water heating system type. Service hot water shall be provided by an electric air-source heat pump water heating (HPWH) system, or a ground-source heat pump water heating (GSHP) system. meeting the requirements of this section. Supplemental service water heating equipment is permitted to use electric resistance (~~or fossil fuel~~) in compliance with Section C404.2.1.4.

EXCEPTIONS:

1. 24 kW plus 0.1 watts per square foot of building area of electric resistance service water heating capacity is allowed per building.
2. Solar thermal, wastewater heat recovery, other *approved* waste heat recovery, (~~ground-source heat pumps,~~) water-source heat pump systems utilizing waste heat, and combinations thereof, are permitted to offset all or any portion of the required HPWH capacity where such systems comply with this code and the *Uniform Plumbing Code*, and are not claimed in Section C406.2.5, C407, or C411.
3. Systems that comply with the Northwest Energy Efficiency Alliance (NEEA) Commercial Electric Advanced Water Heating Specification.

SDCI Informative Note: To view the NEEA Advanced Water Heating Specification (AWHS) for central service water heating systems, see AWHS v8.0 (<http://www.neea.org>).

4. Service hot water systems served by a district energy system that serves multiple buildings and that was in service before the effective date of this code, including more energy-efficient upgrades to such existing systems, are permitted to serve as the primary heating energy source.
5. Commercial dishwashers, commercial food service equipment, and other *approved* process equipment are permitted to utilize electric booster heaters for supply water temperatures 120°F (49°C) or higher.
6. Systems connected to a *low-carbon district energy exchange system* or a *low-carbon district heating and cooling or heating only system*.
7. Essential facilities. Groups I-2 and I-3 occupancies that by regulation are required to have in place redundant emergency backup systems are permitted to use electric resistance or fossil fuel combustion equipment for those emergency backup systems.
8. Point of use instantaneous electric water heaters, serving fixtures no more than 8 feet of developed pipe length from the water heater, are permitted and do not contribute to the building combined water heating capacity calculation.
9. For other than Group R and Group I occupancies, unitary electric air-source heat pump water heaters are permitted to extract heat from the conditioned space where the primary source of space heating is electric heat pump or where heat recovery of waste heat is available, and where they are sized to meet all calculated service water heating demand using the heat pump compressor, and not supplementary heat.

SDCI Informative Note: For the purposes of this exception, “heat recovery of waste heat” can utilize heat from commercial cooking appliances, freezers, refrigerators, electronic equipment, machine rooms, and other internal heat sources. Such heat production must have sufficient magnitude and consistency to provide the majority of the heat energy required by operation of the heat pump water heater.

10. Standby service water heating equipment provided in addition to the primary heating system, and controlled such that it will only be used when the primary heating equipment is not available, is permitted to be electric resistance.

C404.2.1.1 Primary heat pump system sizing. The primary heat pump service water heating system shall be sized to deliver no less than ~~((59))~~ **100** percent of the calculated demand for service hot water production during the peak demand period. Demand shall be calculated using the equipment manufacturer’s selection criteria or another *approved* methodology with entering dry bulb or wet bulb outdoor air temperature at 40°F (4°C) for air source heat pumps or 44°F (7°C) ground temperature for ground-source heat pumps. Electric air source heat pumps shall also be sized to deliver no less than ~~((25))~~ **50** percent of the calculated demand for service hot water production during the peak demand period when entering dry bulb or wet bulb outdoor air temperature is 24°F (-4°C). The remaining primary service output may be met by ~~((fossil fuel,))~~ electric resistance, or heat pump water heating systems.

EXCEPTIONS:

1. ~~((Twenty-five))~~ **Fifty** percent sizing at entering dry bulb or wet bulb air temperature of 24°F (-4°C) is not required for air-source heat pumps located in a below-grade enclosed parking structure or other ventilated and unconditioned space that is not anticipated to fall below 40°F (4°C) at any time.
2. Any of the following system types are permitted to replace all or part of the primary heat pump service water heating system capacity:
 - a. Wastewater heat recovery systems that recover heat from wastewater of both cold and hot water plumbing fixtures and that utilize electric water-source heat pumps. The heat pumps shall be sized for incoming wastewater temperatures of no higher than 70°F (21°C) for Group R and Group I occupancies, and no higher than 60°F (16°C) for all other occupancies, unless an alternate wastewater temperature is approved by the code official.
 - b. Solar thermal systems.
 - c. Other electric water-source heat pump systems that utilize waste heat recovered from year-round mechanical cooling loads or other approved sources.

C404.2.1.2 Primary hot water storage sizing. The system shall provide sufficient hot water, as calculated using an approved methodology, to satisfy peak demand period requirements.

C404.2.1.3 System design. The service water heating system shall be configured to conform to one of the following provisions:

1. For *single-pass heat pump water heaters*, *temperature maintenance* heating provided for reheating return water from the building's heated water circulation system shall be physically decoupled from the primary service water heating system storage tank(s) in a manner that prevents destratification of the primary system storage tanks. *Temperature maintenance* heating is permitted to be provided by electric resistance, fossil fuel, or a separate dedicated heat pump system.
2. For *multi-pass heat pump water heaters*, *recirculated temperature maintenance* water is permitted to be returned to the primary water storage tanks for reheating.
3. ~~((For unitary))~~ **Unitary** heat pump water heaters, located in conditioned space, are permitted, where they are sized to meet all calculated service water heating demand using the heat pump compressor, and not supplementary heat.

C404.2.1.3.1 Mixing valve. A thermostatic **or electronic** mixing valve capable of supplying hot water to the building at the user temperature setpoint shall be provided, in compliance with requirements of the ~~((Uniform))~~ **Seattle Plumbing Code** and the HPWH manufacturer's installation guidelines. The mixing valve shall be sized and rated to deliver tempered water in a range from the minimum flow of the *temperature maintenance* recirculation system up to the maximum demand for the fixtures served.

C404.2.1.4 Supplemental water heating. Total supplemental water heating equipment shall not have an output capacity greater than the total summed capacity of all primary water heating equipment. For the purposes of determining this supplemental water heating allowance, the capacity of primary water heating equipment shall be evaluated at 40°F (4°C) entering dry bulb or wet bulb outdoor air temperature for air-source heat pumps, 44°F (7°C) ground temperature for ground-source heat pumps, and at the nameplate input rate for all other water heater system types. Supplemental heating is permitted for the following uses:

1. Temperature maintenance of heated-water circulation systems, physically separate from the primary service water heating system.
2. Defrost of compressor coils.
3. Heat tracing of piping for freeze protection or for temperature maintenance in lieu of recirculation of hot water.
4. Backup or low ambient temperature conditions, where all of the following are true:
 - 4.1. During normal operations, the supplemental heating is controlled to operate only when the entering air temperature at the air-source HPWH is below 40°F (4°C), and the primary HPWH compressor continues to operate together with the supplemental heating.
 - 4.2. The primary water heating equipment cannot satisfy the system load due to equipment failure or entering air temperature below 40°F (4°C).

GENERAL REQUIREMENTS

C404.2.1.5 System fault detection. The control system shall be capable of and configured to send automatic error alarms to building or maintenance personnel upon detection of equipment faults, low leaving water temperature from primary storage tanks, or low hot water supply delivery temperature to building distribution system.

**Table C404.2
Minimum Performance of Water-Heating Equipment**

Equipment Type	Size Category (input)	Subcategory or Rating Condition	Draw Pattern	Performance Required ^{aj}	Test Procedure ^b
Electric table-top water heaters ^k	≤ 12 kW ^c	≥ 20 gal ≤ 120 gal	Very small Low Medium High	UEF ≥ 0.6323 - (0.0058 × Vr) UEF ≥ 0.9188 - (0.0031 × Vr) UEF ≥ 0.9577 - (0.0023 × Vr) UEF ≥ 0.9884 - (0.0016 × Vr)	DOE 10 C.F.R. Part 430 App. E
Electric storage water heaters ^{g,i} resistance and heat pump	≤ 12 kW ^c	≥ 20 gal ≤ 55 gal	Very small Low Medium High	UEF ≥ 0.8808 - (0.0008 × Vr) UEF ≥ 0.9254 - (0.0003 × Vr) UEF ≥ 0.9307 - (0.0002 × Vr) UEF ≥ 0.9349 - (0.0001 × Vr)	DOE 10 C.F.R. Part 430 App. E
	≤ 12 kW	> 55 gal ≤ 120 gal	Very small Low Medium High	UEF ≥ 1.9236 - (0.0011 × Vr) UEF ≥ 2.0440 - (0.0011 × Vr) UEF ≥ 2.1171 - (0.0011 × Vr) UEF ≥ 2.2418 - (0.0011 × Vr)	DOE 10 C.F.R. Part 430 App. E
Electric storage water heaters ^g	> 12 kW			(0.3 + 27/Vm), %h	DOE 10 C.F.R. 431.106 App B.
Grid-enabled water heaters ^{g,l}		> 75 gal	Very small Low Medium High	UEF ≥ 1.0136 - (0.0028 × Vr) UEF ≥ 0.9984 - (0.0014 × Vr) UEF ≥ 0.9853 - (0.0010 × Vr) UEF ≥ 0.9720 - (0.0007 × Vr)	10 C.F.R. 430 Appendix E
Electric instantaneous water heater ^h	≤ 12 kW	< 2 gal	Very small Low Medium High	UEF ≥ 0.91 UEF ≥ 0.91 UEF ≥ 0.91 UEF ≥ 0.92	DOE 10 C.F.R. Part 430
	> 12 kW & ≤ 58.6 kW ^c	≤ 2 gal ≤ 180°F	All	UEF ≥ 0.80	DOE 10 C.F.R. Part 430
Gas storage water heaters ^g	≤ 75,000 Btu/h	≥ 20 gal & ≤ 55 gal ^f	Very small Low Medium High	UEF ≥ 0.3456 - (0.0020 × Vr) UEF ≥ 0.5982 - (0.0019 × Vr) UEF ≥ 0.6483 - (0.0017 × Vr) UEF ≥ 0.6920 - (0.0013 × Vr)	DOE 10 C.F.R. Part 430 App. E
	≤ 75,000 Btu/h	> 55 gal & ≤ 100 gal ^f	Very small Low Medium High	UEF ≥ 0.6470 - (0.0006 × Vr) UEF ≥ 0.7689 - (0.0005 × Vr) UEF ≥ 0.7897 - (0.0004 × Vr) UEF ≥ 0.8072 - (0.0003 × Vr)	DOE 10 C.F.R. Part 430 App. E
	> 75,000 Btu/h and ≤ 105,000 Btu/h ^d	≤ 120 gal ≤ 180°F	Very small Low Medium High	UEF ≥ 0.2674-0.0009 x Vr UEF ≥ 0.5362-0.0012 x Vr UEF ≥ 0.6002-0.0011 x Vr UEF ≥ 0.6597-0.0009 x Vr	DOE 10 C.F.R. Part 430 App. E
	> 105,000 Btu/h ^{d,f}			80% E _t SL ≤ (Q/800 + 110√V), Btu/h	DOE 10 C.F.R. 431.106
Gas instantaneous water heater ^h	> 50,000 Btu/h and < 200,000 Btu/h	< 2 gal	Very small Low Medium High	UEF ≥ 0.80 UEF ≥ 0.81 UEF ≥ 0.81 UEF ≥ 0.81	DOE 10 C.F.R. Part 430 App. E
	≥ 200,000 Btu/h ^{d,f}	< 10 gal		80% E _t	DOE 10 C.F.R. 431.106
	≥ 200,000 Btu/h ^f	≥ 10 gal		80% E _t SL ≤ (Q/800 + 110√V), Btu/h	

Table C404.2—continued
Minimum Performance of Water-Heating Equipment

Equipment Type	Size Category (input)	Subcategory or Rating Condition	Draw Pattern	Performance Required ^{a,j}	Test Procedure ^b
Oil storage water heaters ^g	≤ 105,000 Btu/h	≤ 50 gal	Very small Low Medium High	UEF = 0.2509 - (0.0012 × V _r) UEF = 0.5330 - (0.0016 × V _r) UEF = 0.6078 - (0.0016 × V _r) UEF = 0.6815 - (0.0014 × V _r)	DOE 10 C.F.R. Part 430
	> 105,000 Btu/h and ≤ 140,000 Btu/h ^c	≤ 120 gal ≤ 180°F	Very small Low Medium High	UEF ≥ 0.2932-0.0015 x V _r UEF ≥ 0.5596-0.0018 x V _r UEF ≥ 0.6194-0.0016 x V _r UEF ≥ 0.6740-0.0013 x V _r	DOE 10 C.F.R. Part 430 App. E
	> 140,000 Btu/h			80% E _t SL ≤ (Q/800 + 110√V), Btu/h	DOE 10 C.F.R. 431.106
Oil instantaneous water heater ^h	≤ 210,000 Btu/h	< 2 gal		80% E _t EF ≥ 0.59 - 0.0005 x V	DOE 10 C.F.R. Part 430 App. E
	> 210,000 Btu/h	< 10 gal		80% E _t	DOE 10 C.F.R. 431.106
	> 210,000 Btu/h	≥ 10 gal		78% E _t SL ≤ (Q/800 + 110√V), Btu/h	DOE 10 C.F.R. 431.106
Hot water supply boilers, gas and oil ^h	≥ 300,000 Btu/h and < 12,500,000 Btu/h	< 10 gal		80% E _t	DOE 10 C.F.R. 431.106
Hot water supply boilers, gas ^h	≥ 300,000 Btu/h and < 12,500,000 Btu/h	≥ 10 gal		80% E _t SL ≤ (Q/800 + 110√V), Btu/h	DOE 10 C.F.R. 431.106
Hot water supply boilers, oil ^h	≥ 300,000 Btu/h and < 12,500,000 Btu/h	≥ 10 gal		78% E _t SL ≤ (Q/800 + 110√V), Btu/h	DOE 10 C.F.R. 431.106
Pool heaters, gas	All			82% E _t	DOE 10 C.F.R. Part 430 App. P
Heat pump pool heaters	All	50°F db 44.2°F wb outdoor air 80.0°F entering water		4.0 COP	DOE 10 C.F.R. Part 430 App. P
Unfired storage tanks ^m	All			Minimum insulation requirement R-12.5 (h-ft ² -°F)/Btu	(none)

- a Thermal efficiency (E_t) is a minimum requirement, while standby loss is a maximum requirement. In the standby loss equation, V is the rated volume in gallons and Q is the nameplate input rate in Btu/h. V_m is the measured volume in the tank in gallons. Standby loss for electric water heaters is in terms of %/h and denoted by the term “S,” and standby loss for gas and oil water heaters is in terms of Btu/h and denoted by the term “SL” Draw pattern (DP) refers to the water draw profile in the Uniform Energy Factor (UEF) test. UEF and Energy Factor (EF) are minimum requirements. In the UEF standard equations, V_r refers to the rated volume in gallons.
- b Chapter 6 contains a complete specification, including the year version, of the referenced test procedure.
- c Electric instantaneous water heaters with input capacity ≤ 12 kW and ≤ 58.6 kW that have either (1) a storage volume ≤ 2 gal; or (2) is designed to provide outlet hot water at temperatures greater than 180°F; or (3) uses three-phase power has no efficiency standard.
- d Gas storage water heaters with input capacity ≤ 75,000 Btu/h and ≤ 105,000 Btu/h must comply with the requirements for the ≤ 105,000 Btu/h if the water heater either (1) has a storage volume ≤ 120 gal; (2) is designed to provide outlet hot water at temperatures greater than 180°F; or (3) uses three-phase power.
- e Oil storage water heaters with input capacity ≤ 105,000 Btu/h and ≤ 140,000 Btu/h must comply with the requirements for the ≤ 140,000 Btu/h if the water heater either (1) has a storage volume ≤ 120 gal; (2) is designed to provide outlet hot water at temperatures greater than 180°F; or (3) uses three-phase power.
- f Water heaters or gas pool heaters in this category are regulated as consumer products by the USDOE as defined in 10 C.F.R. Part 430.
- g Storage water heaters have a ratio of input capacity (Btu/h) to tank volume (gal) < 4000.
- h Instantaneous water heaters and hot water supply boilers have an input capacity (Btu/h) divided by storage volume (gal) ≥ 4000 Btu/h-gal.
- i There are no minimum efficiency requirements for electric heat pump water heaters greater than 12 kW or for gas heat pump water heaters.
- j Refer to Section C404.2.1 for additional requirements for service water heat system equipment.
- k A tabletop water heater is a storage water heater that is enclosed in a rectangular cabinet with a flat top surface not more than three feet (0.91 m) in height and have a ratio of input capacity (Btu/h) to tank volume (gal) < 4000.
- l A grid-enabled water heater is an electric resistance water heater that meets all of the following:
 1. Has a rated storage tank volume of more than 75 gallons.
 2. Is manufactured on or after April 16, 2015.
 3. Is equipped at the point of manufacture with an activation lock.
 4. Bears a permanent label applied by the manufacturer that complies with all of the following:
 - 4.1. Is made of material not adversely affected by water.

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- 4.2. Is attached by means of nonwater soluble adhesive.
- 4.3. Advises purchasers and end-users of the intended and appropriate use of the product with the following notice printed in 16.5 point Arial Narrow Bold font: "IMPORTANT INFORMATION: This water heater is intended only for use as a part of an electric thermal storage or demand response program. It will not provide adequate hot water unless enrolled in such a program and activated by your utility company or another program operator. Confirm the availability of a program in your local area before purchasing or installing this "Public

m [Unfired storage tanks shall be insulated with additional insulation beyond the minimum insulation required by Table C404.2, in accordance with Section C404.6.1.](#)

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

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

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

Table C404.3.1
Piping Volume and Maximum Piping Lengths

Nominal Pipe Size (inches)	Volume (liquid ounces per foot length)	Maximum Piping Length (feet)	
		Public lavatory faucets	Other fixtures and appliances
1/4	0.33	6	50
5/16	0.5	4	50
3/8	0.75	((3)) 8	50
1/2	1.5	((2)) 8	43
5/8	2	((1)) 8	32
3/4	3	0.5	21
7/8	4	0.5	16
1	5	0.5	13
1-1/4	8	0.5	8
1-1/2	11	0.5	6
2 or larger	18	0.5	4

C404.3.2 Maximum allowable pipe volume method. The water volume in the piping shall be calculated in accordance with Section C404.3.2.1.

The volume from the nearest source of heated water to the termination of the fixture supply pipe shall be as follows:

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

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

Table C404.3.2.1
Internal Volume of Various Water Distribution Tubing

Ounces of Water per Foot of Tube									
Nominal Size (inches)	Copper Type M	Copper Type L	Copper Type K	CPVC CTS SDR 11	CPVC SCH 40	CPVC SCH 80	PE-RT SDR	Composite ASTM F1281	PEX CTS SDR 9
3/8	1.06	0.97	0.84	N/A	1.17	—	0.64	0.63	0.64
1/2	1.69	1.55	1.45	1.25	1.89	1.46	1.18	1.31	1.18
3/4	3.43	3.22	2.90	2.67	3.38	2.74	2.35	3.39	2.35
1	5.81	5.49	5.17	4.43	5.53	4.57	3.91	5.56	3.91
1-1/4	8.70	8.36	8.09	6.61	9.66	8.24	5.81	8.49	5.81
1-1/2	12.18	11.83	11.45	9.22	13.20	11.38	8.09	13.88	8.09
2	21.08	20.58	20.04	15.79	21.88	19.11	13.86	21.48	13.86

C404.3.3 Demand load for Group R-2 occupancies. Demand load for water supply of dwelling units within Group R-2 occupancies shall be determined using Appendix M of the Seattle Plumbing Code. Piping shall be no more than one pipe size larger than the minimum size permitted when sized for maximum allowable velocity based upon the specified piping material in conjunction with the Appendix M demand load flow rate at any specific node within the water distribution system.

EXCEPTION: Existing buildings are not required to comply with this section if the existing plumbing fixtures have higher flow rates than those listed in Table M102.1 of the Seattle Plumbing Code.

C404.4 Heat traps for hot water storage tanks. Storage tank-type water heaters and hot water storage tanks that have vertical water pipes connecting to the inlet and outlet of the tank shall be provided with integral heat traps at the vertical inlets and outlets or shall have pipe-configured heat traps in the piping connected to those inlets and outlets. Tank inlets and outlets associated with solar water heating system circulation loops shall not be required to have heat traps.

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

C404.6 Insulation of piping. Piping from a water heater to the termination of the heated water fixture supply pipe shall be insulated in accordance with Table ((~~C403.10.3~~) **C404.6**). On both the inlet and outlet piping of a storage water heater or heated water storage tank, the piping to a heat trap or the first 8 feet (2438 mm) of piping, whichever is less, shall be insulated. Piping that is heat traced shall be insulated in accordance with Table ((~~C403.10.3~~) **C404.6**) or the heat trace manufacturer's instructions. Tubular pipe insulation shall be installed in accordance with the insulation manufacturer's instructions **or Table C404.6, whichever results in thicker insulation**. Pipe insulation shall be continuous, including through hangers and supports, such that thermal bridging is prevented, except where the piping passes through a framing member. The minimum insulation thickness requirements of this section shall not supersede any greater insulation thickness requirements necessary for the protection of piping from freezing temperatures or the protection of personnel against external surface temperatures on the insulation.

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

1. The tubing from the connection at the termination of the fixture supply piping to a plumbing fixture or plumbing appliance.
2. Valves, pumps, strainers and threaded unions in piping that is 1 inch (25 mm) or less in nominal diameter.
3. Piping from user-controlled shower and bath mixing valves to the water outlets.
4. ((~~Cold water piping of a demand recirculation water system.~~))
5. Tubing from a hot drinking-water heating unit to the water outlet.
6. ((~~Piping at~~) **Vertical pipe riser** locations where a vertical support of the piping is installed.
7. ((~~Piping surrounded by building insulation with a thermal resistance (R value) of not less than R-3.~~))
8. Hot water piping that is part of the final pipe run to the plumbing fixture and is not part of the heated-water circulation system circulation path is not required to meet the minimum insulation requirements of Section C404.6.

**Table C404.6
Required Pipe Insulation Thickness for Service Water Heating**

Location	Water Temp	Nominal Pipe or Tube Size					Insulation Conductivity	
		≤ 1"	1 to < 1-1/2"	1-1/2 to < 4"	4 to < 8"	8" or larger	Conductivity Btu · in./ (h · ft ² · °F) ^b	Mean Rating Temp, °F
Circulation Loop Piping not in-partition	105 - 140°F	2.0	2.0	2.5	2.5	2.5	0.21 - 0.28	100
	141 - 200°F	2.5	2.5	3.0	3.0	3.0	0.25 - 0.29	125
All other piping not in-partition	105 - 140°F	1.0	1.0	1.5	1.5	1.5	0.21 - 0.28	100
	141 - 200°F	1.5	1.5	2.0	2.0	2.0	0.25 - 0.29	125
In-partition ^a Circulation Loop Piping	105 - 140°F	1.0	1.0	2.5	2.5	2.5	0.21 - 0.28	100
	141 - 200°F	1.5	1.5	3.0	3.0	3.0	0.25 - 0.29	125
In-partition ^a All other piping	105 - 140°F	1.0	1.0	1.5	1.5	1.5	0.21 - 0.28	100
	141 - 200°F	1.5	1.5	2.0	2.0	2.0	0.25 - 0.29	125

a. In a partition within a conditioned space.

b. For insulation outside the stated conductivity range, conform to requirements of Table C403.10.1.

C404.6.1 Storage tank insulation. Unfired storage tanks used to store service hot water at temperatures above 130°F (54°C) shall be wrapped with an insulating product, installed in accordance with the insulation manufacturer’s instructions and providing a minimum of R-2 additional insulation for every 10°F (5°C) increase in stored water temperature above 130°F (54°C). Such additional insulation is also permitted to be integral to the tank. The insulation is permitted to be discontinuous at structural supports.

C404.7 Heated-water circulating and heat trace temperature maintenance systems. Heated-water circulation systems for *temperature maintenance* shall be in accordance with Section C404.7.1. Electric resistance heat trace systems for *temperature maintenance* shall be in accordance with Section C404.7.2. Controls for hot water storage shall be in accordance with Section C404.7.3. Automatic controls, temperature sensors and pumps shall be in a location with *access*. Manual controls shall be in a location with *ready access*.

C404.7.1 Circulation systems. Heated-water circulation systems shall be provided with a circulation pump. The pump shall have an electronically commutated motor with a means of adjusting motor speed for system balancing. The system return pipe shall be a dedicated return pipe. Gravity and thermo-syphon circulation systems are prohibited. Controls shall start the circulation pump based on the identification of a demand for hot water within the occupancy, according to the requirements of Sections C404.7.1.1 and C404.7.1.2.

C404.7.1.1 Single riser systems. Where the circulation system serves only a single domestic hot water riser or zone, the following controls shall be provided:

1. Controls shall be configured to automatically turn off the pump when the water in the circulation loop is at the design supply temperature and shall not turn the pump back on until the temperature is a minimum of 10°F (5°C) lower than the design supply temperature.
2. Controls shall be equipped with a manual switch or other control method that can be used to turn off the circulating pump during extended periods when hot water is not required.

C404.7.1.2 Multiple riser systems. Where the circulation system serves multiple domestic hot water risers or piping zones, the following equipment and controls shall be provided:

1. Controls shall be configured to automatically turn off the circulation pump during (~~extended~~) periods of time exceeding 4 hours when hot water is not required. Pump circulation is permitted to be automatically started a maximum of 4 hours before scheduled occupancy time to warm up the system or may be automatically started and stopped to run a maximum of 50% of each hour to maintain water circulation to reduce legionella or other biological growth in circulation water.
2. (~~Reserved~~) (~~System shall include means for balancing the flow rate through each individual hot water supply riser or piping zone.~~)
3. (~~For circulation systems that use a variable flow circulation pump, each riser and piping zone shall have a self-actuating thermostatic balancing valve.~~) At the end of each riser or piping zone before heated water is returned to the circulation pump, a thermostatic balancing valve or control valve that automatically controls the flow through the riser or piping zone to maintain the domestic hot water supply temperature in the riser at a maximum of 5°F (2.3°C) lower than the design supply water temperature.

EXCEPTION: Multiple riser systems serving Group R and Group I occupancies are not required to have controls that automatically turn off the circulation pump.

C404.7.1.3 Electronic thermostatic mixing valve (TMV). Where a heated water circulation system utilizes an electronic TMV to control the temperature of hot water supplied to the building, the TMV shall be configured so that it either reverts closed (fully COLD) or maintains its current valve position upon power failure or cessation of circulation flow.

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

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

C404.8 Demand recirculation controls. *Demand recirculation water systems are not permitted.* (~~shall have controls that comply with both of the following:~~

- ~~1. The controls shall start the pump upon receiving a signal from the action of a user of a fixture or appliance, sensing the presence of a user of a fixture or sensing the flow of hot or tempered water to a fixture fitting or appliance.~~
- ~~2. The controls shall limit the temperature of the water entering the cold water piping to not greater than 104°F (40°C))~~

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

EXCEPTION: *Dwelling units* in other than Group R-2 multi-family and live/work units are not required to provide domestic hot water metering at each *dwelling unit* where domestic hot water is metered separately for each of the following building end uses:

1. *Dwelling units.*
2. Sleeping units.
3. Commercial kitchens.
4. Central laundries.

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

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

C404.11.1 Heaters. Pool water heaters using electric resistance heating as the primary source of heat are prohibited for pools over 2,000 gallons. Heat pump pool heaters shall have a minimum COP of 4.0 at 50°F (10°C) db, 44.2°F (6.8°C) wb outdoor air and 80°F (27°C) entering water, determined in accordance with AHRI 1160. Other pool heating equipment shall comply with the applicable efficiencies in Section C404.2.

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

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

EXCEPTIONS:

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

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

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

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

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1. Solar water heating systems not claimed in Section ((~~C406.5~~) C406.2.5, C407, or C411;
2. Dehumidification heat recovery;
3. Waste heat recovery; or
4. A combination of these system sources capable of and configured to provide at least 70 percent of the heating energy required over an operating season.

C404.12 Portable spas. The energy consumption of electric-powered portable spas shall be controlled by the requirements of APSP 14.

C404.13 Service water pressure-booster systems. Service water pressure-booster systems shall be designed and configured such that the following apply:

1. One or more pressure sensors shall be used to vary pump speed and/or start and stop pumps. The sensors shall either be located near the critical fixtures that determine the pressure required, or logic shall be employed that adjusts the setpoint to simulate operations of remote sensors.
2. No devices 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. Booster system pumps shall not operate when there is no service water flow except to refill hydro-pneumatic tanks.
4. System pump motors 5.0 hp and greater shall be provided with variable flow capacity in accordance with Section C403.2.4.

C404.14 Demand responsive water heating. Electric storage water heaters with rated water storage volume between 40 and 120 gallons and a nameplate input rating equal to or less than 12kW shall be provided with *demand responsive controls* that comply with ANSI/CTA-2045-B Level 2 or another equivalent *approved demand responsive control*.

EXCEPTIONS:

1. Water heaters that provide a hot water delivery temperature of 180°F (82°C) or greater.
2. Water heaters that comply with Section IV, Part HLW or Section X of the ASME Boiler and Pressure Vessel Code.
3. Water heaters that use three-phase electric power.
4. Storage water heaters with *demand responsive controls* that comply with ANSI/CTA 2045-A or ANSI/CTA 2045-B Level 1, that are also capable of initiating water heating to meet the temperature setpoint in response to a *demand response signal*.

C404.15 Commissioning. Service water heating systems shall be commissioned in accordance with Section C408.

SECTION C405 ELECTRICAL POWER AND LIGHTING SYSTEMS

C405.1 General. Lighting system controls, the maximum lighting power for interior and exterior applications, electrical energy consumption, vertical and horizontal transportation systems, and minimum efficiencies for motors and transformers shall comply with this section. Receptacles shall be controlled according to Section C405.10. Controlled receptacles and light- ing systems shall be commissioned according to Section C405.12. Solar readiness shall be provided according to Section ((C411) C411.3 and renewable energy shall be provided according to Sections C411.1, C411.2, and C412.

Dwelling units shall comply with Sections C405.1.1 and C405.7.

Sleeping units shall comply with Section C405.2.6, item 2 and Section C405.1.1 or Section C405.4.

General lighting shall consist of all lighting included when calculating the total connected interior lighting power in accordance with Section C405.4.1 and which does not require specific application controls in accordance with Section C405.2.5.

Lighting installed in *walk-in coolers, walk-in freezers, refrigerated warehouse coolers* and *refrigerated warehouse freezers* shall comply with the lighting requirements of Section C410.2.

Transformers, uninterruptable power supplies, motors and electrical power processing equipment in *data center systems* shall comply with Section 8 of ASHRAE Standard 90.4 in addition to this code.

EXCEPTION: Energy using equipment used by a manufacturing, industrial or commercial process other than maintaining comfort and amenities for the occupants are exempt from all Section C405 subsections except Section C405.8. Data center and computer room HVAC equipment is not covered by this exemption.

C405.1.1 Lighting for dwelling and sleeping units. No less than 90 percent of the permanently installed lighting serving *dwelling units* or *sleeping units*, excluding kitchen appliance lighting, shall be provided by lamps with a minimum efficacy of 65 lumens per watt or luminaires with an efficacy of not less than 45 lumens per watt.

C405.2 Lighting controls. Lighting systems shall be provided with controls that comply with one of the following:

1. Lighting controls as specified in Sections C405.2.1 through C405.2.10.
2. *Luminaire-level* lighting controls (LLLC) as specified in Section C405.2.8.1.

EXCEPTION: Except for specific application controls required by Section C405.2.6, lighting controls are not required for the following:

1. Areas designated as security or emergency areas that are required to be continuously lighted.
2. Means of egress illumination serving the exit access that does not exceed 0.01 watts per square foot of building area.
3. Emergency egress lighting that is normally off.
4. Industrial or manufacturing process areas, as may be required for production and safety.

C405.2.1 Occupant sensor controls. Occupant sensor controls shall be installed to control luminaires in the space types listed in Table C405.2.1, and shall comply with the requirements listed in the table.

EXCEPTIONS:

1. Corridors in manufacturing facilities.
2. *General lighting* and task lighting in shop and laboratory classrooms.
3. Luminaires that are required to have specific application controls in accordance with Section C405.2.6 unless specifically required to comply with this section by Section C405.2.6.

**Table C405.2.1
Occupant sensor control locations**

<u>Space types^a</u>	<u>Comply with Section</u>
Classrooms/lecture/training rooms	C405.2.1.1
Conference/meeting/multipurpose rooms	C405.2.1.1
Copy/print rooms	C405.2.1.1
Lounge/breakrooms	C405.2.1.1
Enclosed offices	C405.2.1.1
Open plan office areas	C405.2.1.3
Restrooms	C405.2.1.1
Storage rooms	C405.2.1.1
Locker rooms	C405.2.1.1
Other spaces 300 square feet (28 m ²) or less that are enclosed by floor-to-ceiling height partitions	C405.2.1.1
Warehouse storage areas	C405.2.1.2
Library stacks	C405.2.1.2
Enclosed fire rated stairways	((C405.2.1.5)) C405.2.1.4
Corridors	((C405.2.1.6)) C405.2.1.5
<u>Covered parking</u>	<u>C405.2.10</u>

a. The space types listed include other spaces with substantially similar uses.

C405.2.1.1 Occupant sensor control function. Occupant sensor controls for the space types listed in Section C405.2.1 shall comply with all of the following:

1. They shall be configured to automatically turn off lights within 20 minutes of all occupants leaving the space.
2. They shall be manual on or configured to automatically turn the lighting on to not more than 50 percent power.

EXCEPTION: Full automatic-on controls with no manual control shall be permitted in corridors, interior parking areas, stairways, restrooms, locker rooms, library stacks, lobbies, and areas where manual operation would endanger occupant safety or security.

3. They shall incorporate a manual control to allow occupants to turn lights off.

~~((**EXCEPTION:** Full automatic-on controls with no manual control shall be permitted in corridors, interior parking areas, stairways, restrooms, locker rooms, library stacks, lobbies, and areas where manual operation would endanger occupant safety or security.~~

4. ~~They shall incorporate a manual control to allow occupants to turn lights off.))~~

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C405.2.1.2 Occupant sensor control function in warehouse storage areas and library stacks. Lighting in library stacks and warehouse storage areas shall be controlled as follows.

1. Lighting in each aisleway shall be controlled independently of lighting in all other aisleways and open areas.
2. Occupant sensors shall automatically reduce lighting power within each controlled area to an unoccupied setpoint of not more than 50 percent of full power within 20 minutes after all occupants have left the controlled area.
3. Lights which are not turned off by occupant sensors shall (~~(be turned off by time schedule sweep to turn lighting off within 20 minutes of all occupants leaving the space, or)~~) comply with Section C405.2.2 to turn lighting off when the building is vacant.
4. Restore lighting to full power or target light level when occupants enter the space.
5. A *manual* control shall be provided to allow occupants to turn off lights in the space.

C405.2.1.3 Occupant sensor control function in open plan office areas. Occupant sensor controls in open plan office spaces less than 300 square feet (28 m²) in area shall comply with Section C405.2.1.1. Occupant sensor controls in all other open plan office spaces shall be configured to comply with all of the following:

1. *General lighting* is controlled separately in control zones with floor areas not greater than 600 square feet (55 m²) within the open plan office space.
2. *General lighting* in each control zone shall be permitted to automatically turn on upon occupancy within the control zone. *General lighting* in other unoccupied zones within the open plan office space shall be permitted to turn on to not more than 20 percent of full power or remain unaffected.
3. Automatically turn off *general lighting* in all control zones within 20 minutes after all occupants have left the open plan office space.
4. *General lighting* in each control zone shall turn off or uniformly reduce lighting power to an unoccupied setpoint of not more than 20 percent of full power within 20 minutes after all occupants have left the control zone.
5. Lighting controls in open plan office areas larger than 5,000 square feet must also comply with Section C405.2.8.

C405.2.1.4 Occupant sensor control function in enclosed fire rated stairways. Occupant sensor controls shall be configured 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 20 minutes and restore lighting to full power when occupants enter the stairway. All portions of stairways shall remain illuminated to meet the requirements of (~~(Section 1009)~~) Sections 1008 and 1025 of the *International Building Code* when the lighting power is reduced.

C405.2.1.5 Occupant sensor control function in corridors. Occupant sensor controls in *corridors* shall uniformly reduce lighting power to an unoccupied setpoint of not more than 50 percent of full power within 20 minutes after all occupants have left the space.

EXCEPTION: *Corridors* provided with less than two foot-candles of illumination on the floor at the darkest point with all lights on.

C405.2.2 Time switch controls. Each area of the building that is not provided with *occupant sensor controls* complying with Section C405.2.1.1 through Section C405.2.1.5 shall be provided with time switch controls complying with Section C405.2.2.1.

EXCEPTIONS:

1. Luminaires which are required to have specific application controls in accordance with Section C405.2.6 unless specifically required to comply with this section by Section C405.2.6.
2. Spaces where patient care is directly provided.
3. Spaces where an automatic shutoff would endanger occupant safety or security.
4. Lighting intended for continuous operation.
5. Shop and laboratory classrooms.

C405.2.2.1 Time switch control function. Time switch controls shall provide programmed shutoff for lighting when building areas are unoccupied and shall comply with the following:

1. Have a minimum 7 day clock.
2. Be capable of being set for 7 different day types per week.
3. Incorporate an automatic holiday “shut-off” feature, which turns off all controlled lighting loads for at least 24 hours and then resumes normally scheduled operations.
4. Have program back-up capabilities, which prevent the loss of program and time settings for at least 10 hours, if power is interrupted.

5. Include an override switching device that complies with the following:
 - 5.1. The override switch shall be a *manual* control.
 - 5.2. The override switch, when initiated, shall permit the controlled lighting to remain on for not more than 2 hours.
 - 5.3. Any individual override switch shall control the lighting for an area not larger than ((~~5,000~~) 2,500 square feet ((~~465~~) 232 m²).
6. Time switch controls are allowed to automatically turn on lighting to full power in corridors, lobbies, restrooms, storage rooms less than 50 square feet, and medical areas of health care facilities. In all other spaces, time switch controls are allowed to automatically turn on the lighting to not more than 50 percent power.

EXCEPTION: Within mall concourses, auditoriums, sales areas, manufacturing facilities, pools, gymnasiums, skating rinks, and sports arenas:

1. The time limit shall be permitted to be greater than 2 hours provided the switch is a captive key device.
2. The area controlled by the override switch shall not be limited to 5,000 square feet (465 m²), provided that such area is less than 20,000 square feet (1860 m²).

C405.2.3 Manual controls. Stairwells and parking garages are not permitted to use manual switches. All other lighting shall have *manual* controls complying with the following:

1. They shall be in a location with *ready access* to occupants.
2. They shall be located where the controlled lights are visible, or shall identify the area served by the lights and indicate their status.
3. Each control device shall control an area no larger than a single room, or 2,500 square feet, whichever is less, if the room area is less than or equal to 10,000 square feet, or one-quarter of the room area or 10,000 square feet, whichever is less, if the room area is greater than 10,000 square feet.

EXCEPTIONS:

1. A *manual* control may be installed in a remote location for the purpose of safety or security provided each remote control device has an indicator pilot light as part of or next to the control device and the light is clearly labeled to identify the controlled lighting.
2. Restrooms.

C405.2.4 Light reduction controls. Where not provided with occupant sensor controls complying with Section C405.2.1.1, general lighting shall be provided with light-reduction controls complying with Section C405.2.4.1.

Exceptions:

1. Luminaires controlled by daylight responsive controls complying with Section C405.2.5.
2. Luminaires controlled by special application controls complying with Section C405.2.6.
3. Where provided with manual control, the following areas are not required to have light reduction control:
 - 3.1. Spaces that have only one luminaire with a rated power of less than 60 watts.
 - 3.2. Spaces that use less than 0.45 watts per square foot (4.9 W/m²)
 - 3.3. Corridors, lobbies, electrical rooms and/or mechanical rooms.

C405.2.4.1 Light reduction control function. Manual controls shall be configured to provide light reduction control that allows the occupant to reduce the connected lighting load by not less than 50 percent in a reasonable uniform illumination pattern with an intermediate step in addition to full on or off, or with continuous dimming control, by using one of the following or another approved method:

1. Continuous dimming of all luminaires from full output to less than 20 percent of full power.
2. Switching all luminaires to a reduced output of not less than 30 percent and not more than 70 percent of full power.
3. Switching alternate rows of luminaires or alternate luminaires to achieve a reduced output of not less than 30 percent and not more than 70 percent of full power.

C405.2.5 Daylight responsive controls. *Daylight responsive controls* complying with Section C405.2.5.1 shall be provided to control the *general lighting* within *daylight zones* in the following spaces:

1. Spaces with a total of more than 75 watts of *general lighting* within *primary sidelit daylight zones* complying with Section C405.2.5.2.
2. Spaces with a total of more than 150 watts of *general lighting* within the combined *primary* and *secondary daylight zones* complying with Section C405.2.5.2.

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3. Spaces with a total of more than 75 watts of *general lighting* within *toplit daylight zones* complying with Section C405.2.5.3.

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

1. Spaces in health care facilities where patient care is directly provided.
2. Sidelit daylight zones on the first floor above grade in Group A-2 and Group M occupancies where the fenestration adjoins a sidewalk or other outdoor pedestrian area, provided that the light fixtures are controlled separately from the general area lighting.

C405.2.5.1 Daylight responsive controls function. Where required, daylight responsive controls shall be provided within each space for control of lights in that space and shall comply with all of the following:

1. Lights in primary sidelit daylight zones shall be controlled independently of lights in secondary sidelit daylight zones in accordance with Section C405.2.5.2.
2. Lights in toplit daylight zones in accordance with Section C405.2.5.3 shall be controlled independently of lights in sidelit daylight zones in accordance with Section C405.2.5.2.
3. *Daylight responsive controls* within each space shall be configured so that they can be calibrated from within that space by authorized personnel.
4. Calibration mechanisms shall be in a location with *ready access*.
5. *Daylight responsive controls* shall dim lights continuously from full light output to 15 percent of full light output or lower.
6. *Daylight responsive controls* shall be configured to completely shut off all controlled lights in that zone.
7. When occupant sensor controls have reduced the lighting power to an unoccupied setpoint in accordance with Sections C405.2.1.2 through ~~((C405.2.1.4))~~ C405.2.1.5, *daylight responsive controls* shall continue to adjust electric light levels in response to available daylight but shall be configured to not increase the lighting power above the specified unoccupied setpoint.
8. Lights in sidelit daylight zones in accordance with Section C405.2.5.2 facing different cardinal orientations (i.e., within 45 degrees of due north, east, south, west) shall be controlled independently of each other.

EXCEPTION: Up to 75 watts of *general lighting* are permitted to be controlled together with lighting in a daylight zone facing a different cardinal orientation.

9. Incorporate time-delay circuits to prevent cycling of light level changes of less than three minutes.
10. The maximum area a single *daylight responsive control* device serves shall not exceed 2,500 square feet (232 m²) and no more than 60 lineal feet (18.3 m) of facade.
11. Occupant override capability of daylight dimming controls is not permitted, other than a reduction of light output from the level established by the daylighting controls.
12. Daylight responsive controls shall be set initially to activate at 30 footcandles (323 lux) or not more than 110 percent of the illuminance level specified on the construction documents.

C405.2.5.1.1 Dimming. *Daylight responsive controls* shall be configured to automatically reduce the power of *general lighting* in the *daylight zone* in response to available daylight, while maintaining *uniform illumination* in the space through ~~((one of the following methods:))~~

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

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

C405.2.5.2 Sidelit daylight zone. The sidelit daylight zone is the floor area adjacent to vertical *fenestration* which complies with the following:

1. Where the *fenestration* is located in a wall, the primary sidelit daylight zone shall extend laterally to the nearest full height wall, or up to 1.0 times the height from the floor to the top of the *fenestration*, and longitudinally from the edge of the *fenestration* to the nearest full height wall, or up to 0.5 times the height from the floor to the top of the *fenestration*, whichever is less, as indicated in Figure C405.2.5.2(1).
2. The secondary sidelit daylight zone is directly adjacent to the primary daylight zone and shall extend laterally to 2.0 times the height from the floor to the top of the *fenestration* or to the nearest full height wall, whichever is

less, and longitudinally from the edge of the *fenestration* to the nearest full height wall or up to ((2-feet)) 0.5 times the height from the floor to the top of the fenestration, whichever is less, as indicated in Figure C405.2.5.2(1).

3. Where *clerestory fenestration* is located in a wall, the sidelit daylight zone includes a lateral area twice the depth of the *clerestory fenestration* height, projected upon the floor at a 45 degree angle from the center of the *clerestory fenestration*. The longitudinal width of the sidelit daylight zone is calculated the same as for *fenestration* located in a wall. Where the 45 degree angle is interrupted by an obstruction greater than 0.7 times the ceiling height, the sidelit daylight zone shall remain the same lateral area but be located between the clerestory and the obstruction, as indicated in Figure C405.2.5.2(2).
4. Where the *fenestration* is located in a rooftop monitor, the sidelit daylight zone shall extend laterally to the nearest obstruction that is taller than 0.7 times the ceiling height, or up to 1.0 times the height from the floor to the bottom of the *fenestration*, whichever is less, and longitudinally from the edge of the *fenestration* to the nearest obstruction that is taller than 0.7 times the ceiling height, or up to 0.25 times the height from the floor to the bottom of the *fenestration*, whichever is less, as indicated in Figures C405.2.5.2(3) and C405.2.5.2(4).
5. If the rough opening area of a vertical fenestration assembly is less than 10 percent of the calculated primary sidelit daylight zone area for this fenestration, it does not qualify as a sidelit daylight zone.
6. The visible transmittance of the fenestration is no less than 0.20.
7. The projection factor (determined in accordance with Equation 4-5) for any overhanging projection which is shading the *fenestration* is not greater than 1.0 for fenestration oriented 45 degrees or less from true north, and not greater than 1.5 for all other orientations.

Figure C405.2.5.2(1)
Sidelit Daylight Zone Adjacent to Fenestration in a Wall

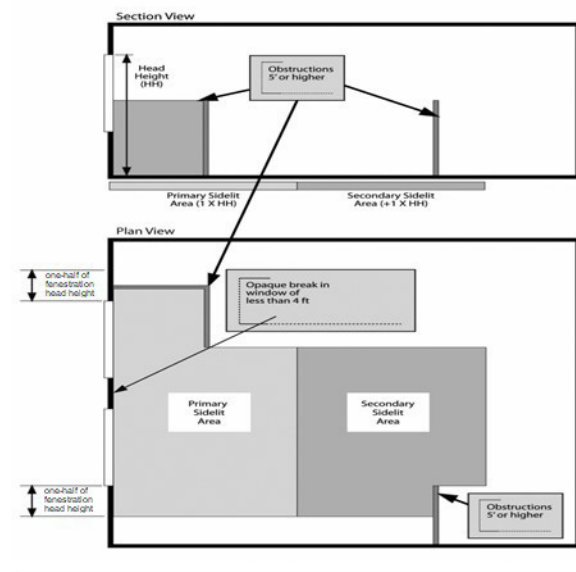


Figure C405.2.5.2(2)
Sidelit Daylight Zone Adjacent to Clerestory Fenestration in a Wall

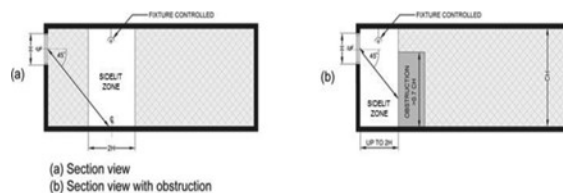
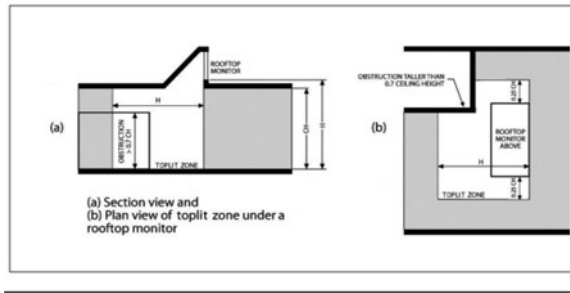


Figure C405.2.5.2(3)
Sidelit Daylight Zone Under a Sloped Rooftop Monitor



C405.2.5.3 Toplit daylight zone. The toplit daylight zone is the floor area underneath a roof fenestration assembly which complies with the following:

1. The toplit daylight zone shall extend laterally and longitudinally beyond the edge of the roof *fenestration* assembly to the nearest obstruction that is taller than 0.7 times the ceiling height, or up to 0.7 times the ceiling height, whichever is less, as indicated in Figure C405.2.5.3(1).
2. Where toplit daylight zones overlap with sidelit daylight zones, lights within the overlapping area shall be assigned to the toplit daylight zone.
3. The product of the *visible transmittance* of the roof *fenestration* assembly and the area of the rough opening of the roof fenestration assembly, divided by the area of the toplit daylight zone is no less than 0.008.
4. Where located under atrium fenestration, the toplit daylight zone shall include the bottom floor area directly beneath the atrium fenestration, and the top floor directly under the atrium fenestration, as indicated in Figure C405.2.5.3(4). The toplit daylight zone area at the top floor is calculated the same as for a toplit daylight zone. Intermediate levels below the top floor that are not directly beneath the atrium are not included.

Figure C405.2.5.3(1)
Toplit Daylight Zone Under a Rooftop Fenestration Assembly

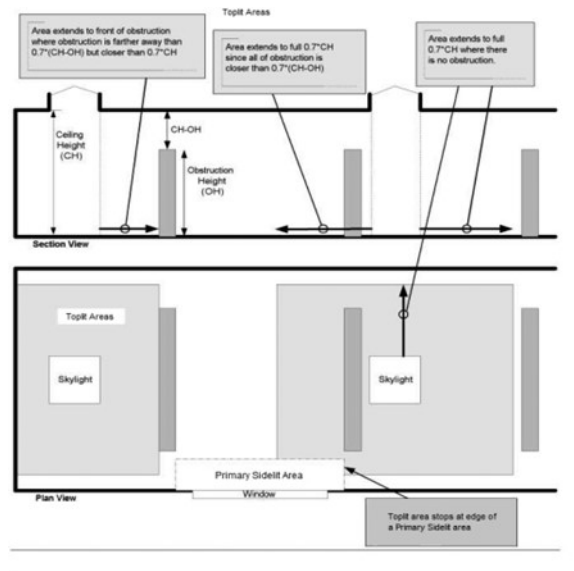


Figure C405.2.5.3(2)
Toplit Daylight Zone Under a Rooftop Monitor

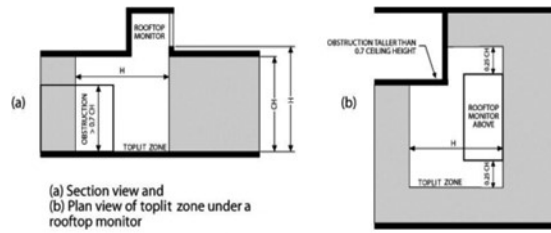
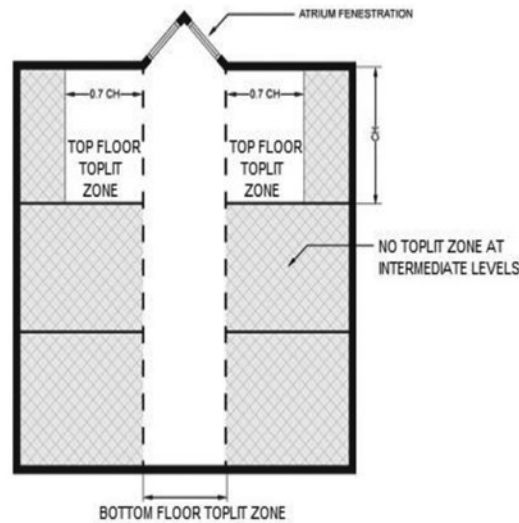


Figure C405.2.5.4
Toplit Daylight Zone Under Atrium Fenestration



C405.2.5.4 Atriums. Daylight zones at atrium spaces shall be established at the top floor surrounding the atrium and at the floor of the atrium space, and not on intermediate floors, as indicated in Figure C405.2.5.4.

C405.2.6 Additional lighting controls. Specific application lighting shall be provided with controls, in addition to controls required by other sections, for the following:

1. The following lighting shall be controlled by an occupant sensor complying with Section C405.2.1.1 or a time switch control complying with Section C405.2.2.1. In addition, a *manual* control shall be provided to control such lighting separately from the *general lighting* in the space:
 - 1.1. Luminaires for which additional lighting power is claimed in accordance with Section C405.4.2.2.1.
 - 1.2. Display and accent.
 - 1.3. Lighting in display cases.
 - 1.4. Supplemental task lighting, including permanently installed under-shelf or under-cabinet lighting.
 - 1.5. Lighting equipment that is for sale or demonstration in lighting education.
 - 1.6. Display lighting for exhibits in galleries, museums and monuments that is in addition to *general lighting*.
2. *Sleeping units* shall have control device(s) or systems configured to automatically switch off all permanently installed luminaires and switched receptacles, including those installed within furniture, within 20 minutes after all occupants have left the unit.

EXCEPTIONS:

1. Lighting and switched receptacles controlled by card key controls.
2. Spaces where patient care is directly provided.

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3. Lighting for life support of (~~nonhuman life forms~~) plants and animals and food warming, shall be controlled by a dedicated control that is independent of the controls for other lighting within the room or space. (~~Each control zone shall be no greater than the area served by a single luminaire or 4,000 square feet (372 m²), whichever is larger.~~)
4. Task lighting for medical and dental purposes that is in addition to *general lighting* shall be provided with a manual control.
5. Luminaires serving the exit access and providing means of egress illumination required by Section 1008.2 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 0.01 watts per square foot (0.108 W/m²) of building area is exempt from this requirement.

SDCI Informative Note: The term “exit access” is described in Chapter 10 of the International Building Code, and generally includes all portions of an egress pathway leading to an “exit,” which is typically an exterior door or a fire-rated stair enclosure.

C405.2.7 Area controls. The maximum lighting power that may be controlled from a single switch or automatic control device 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 ft².

C405.2.8 Advanced lighting controls. Any contiguous open office area larger than 5,000 square feet shall have its *general lighting* controlled by either:

1. *Luminaire-level lighting controls* (LLLC) conforming to the requirements of Section C405.2.8.1.
2. Networked lighting control (NLC) conforming to the requirements of Section C405.2.8.2.

C405.2.8.1 Luminaire-level lighting controls. Where *luminaire-level lighting controls* are required, they shall be configured to provide the controls or equivalent control function specified in Sections C405.2.1, C405.2.3, and C405.2.5. In addition, each LLLC luminaire shall be independently configured to:

1. Provide for continuous full range dimming.
2. Monitor occupant activity to brighten or dim lights when occupied or unoccupied, respectively.
3. Monitor ambient lighting, both electric and daylight, and brighten or dim artificial light to maintain desired light level. A maximum of 8 fixtures are permitted to be controlled together to maintain uniform light levels within a single daylight zone.
4. Allow configuration and reconfiguration of performance parameters for each control strategy including: High trim and low trim setpoints, timeouts, dimming fade rates, and sensor sensitivity adjustment.
5. Construction documents shall include a submittal of a sequence of operations including a specification outlining each of the functions required by this section.
6. Luminaires shall be configured with high end trim in accordance with Section C405.2.8.3.

C405.2.8.2 Networked lighting control (NLC). Where NLC are required, they shall be configured to provide controls and minimum function as specified in Section C405.2. In addition, each NLC luminaire shall be independently configured to:

1. Provide for continuous full range dimming.
2. Each luminaire shall be individually addressed.

EXCEPTIONS TO ITEM 2:

1. Multiple luminaires mounted on no more than 12 linear feet of a single lighting track and addressed as a single luminaire.
2. Multiple linear luminaires that are ganged together to create the appearance of a single longer fixture and addressed as a single luminaire, where the total length of the combined luminaires is not more than 12 feet.
3. Monitor occupant activity to brighten or dim lighting when occupied or unoccupied, respectively.
4. Monitor ambient lighting, both electric and daylight, and brighten or dim artificial light to maintain desired light level. A maximum of 8 fixtures are permitted to be controlled together to maintain uniform light levels within a single daylight zone.

5. Allow configuration and reconfiguration of performance parameters for each control strategy including: High trim and low trim setpoints, timeouts, dimming fade rates, and sensor sensitivity adjustment.
6. Allow for demand response load shed.
7. Construction documents shall include a submittal of a sequence of operations including a specification outlining each of the functions required by this section.
8. Luminaires shall be configured with high end trim in accordance with Section C405.2.8.3.

C405.2.8.3 High end trim. Luminaires subject to high end trim shall be initially configured with the following:

1. Programmed to limit the initial maximum lumen output or maximum lighting power to 85 percent or less of full light output or full power or to meet the target light level documented in project sequence of operations using the least amount of power.
2. High end trim power levels are allowed to automatically reset to accommodate lumen maintenance.
3. High end trim controls shall be accessible only to authorized personnel.

C405.2.9 Exterior lighting controls. Exterior lighting systems shall be provided with controls that comply with Sections C405.2.9.1 through C405.2.9.4.

EXCEPTIONS:

1. Lighting for covered vehicle entrances or exits from buildings or parking structures where required for safety, security or eye adaptation.
2. Lighting controlled from within dwelling units.

C405.2.9.1 Daylight shutoff. Lights shall be configured to automatically turn off when daylight is present and satisfies the lighting needs.

C405.2.9.2 Building façade and landscape lighting. Building façade and landscaping lighting shall be configured to automatically shutoff for a minimum of 6 hours per night or from not later than 1 hour after business closing to not earlier than 1 hour before business opening, whichever is less.

EXCEPTION: Areas where an automatic shutoff would endanger safety or security.

C405.2.9.3 Lighting setback. Lighting that is not controlled in accordance with Section C405.2.9.2 shall comply with the following:

1. Luminaires serving outdoor parking areas and having a rated input wattage of greater than 40 watts and a mounting height of 24 feet (7315 mm) or less above the ground shall also be controlled so that the total wattage of such lighting is automatically reduced by not less than 50 percent during any time where activity has not been detected for 15 minutes or more. Not more than 1,500 watts of lighting power shall be controlled together.
2. All other lighting shall be controlled so that the total wattage of such lighting is automatically reduced by not less than 50 percent by selectively switching off or dimming luminaires at one of the following times:
 - 2.1. From not later than 12 midnight to 6 a.m.
 - 2.2. From not later than 1 hour after business closing to not earlier than 1 hour before business opening.
 - 2.3. During any period when no activity has been detected for 15 minutes or more.

C405.2.9.4 Exterior time-switch control functions. Time-switch controls for exterior lighting shall comply with the following:

1. They shall have a clock capable of being programmed for not fewer than 7 days.
2. They shall be capable of being set for 7 different day types per week.
3. They shall incorporate an automatic holiday setback feature.
4. They shall have program backup capabilities that prevent the loss of program and time settings for a period of at least 10 hours in the event that power is interrupted.

C405.2.10 Parking garage lighting control. Parking garage lighting shall be controlled by an *occupant sensor* complying with Section C405.2.1.1 or a *time-switch control* complying with Section C405.2.2.1. Additional lighting controls shall be provided as follows:

1. Lighting power of each luminaire shall be automatically reduced by not less than 30 percent when there is no activity detected within a lighting zone for 20 minutes. Lighting zones for this requirement shall be not larger than 3,600 square feet (334.5 m²).
2. Where lighting for eye adaptation is provided at covered vehicle entrances and exits from buildings and parking structures, such lighting shall be separately controlled by a device that automatically reduces lighting power by at least 50 percent from sunset to sunrise.

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3. The power to luminaires within 20 feet (6096 mm) of perimeter wall openings shall automatically reduce in response to daylight by at least 50 percent.

EXCEPTIONS TO ITEM 3:

1. Daylight transition lighting for covered vehicle entrances and exits from buildings and parking structures; each transition zone shall not exceed a depth of 66 feet inside the structure and a width of 50 feet.
2. Where permanent screens or architectural elements obstruct more than 50 percent of the opening.
3. Where the top of any existing adjacent structure or natural object is at least twice as high above the openings as its horizontal distance from the opening.

C405.3 Lighting for plant growth and maintenance. ((All)) In Group F, Group U, and controlled plant growth environments, all permanently installed luminaires used for plant growth and maintenance shall have a *photosynthetic photon efficacy* measured at the lamp for luminaires with serviceable or removable lamps or at the luminaire for integrated, non-serviceable luminaires of not less than 1.7 $\mu\text{mol/J}$ for greenhouses and not less than 1.9 $\mu\text{mol/J}$ for all other indoor growing spaces as defined in accordance with ANSI/ASABE S640.

EXCEPTION: Buildings with no more than 10 kW of aggregate horticultural lighting load.

Luminaires used for the growth and maintenance of plants for decorative purposes, in spaces not primarily used for horticulture, shall have a *photosynthetic photon efficacy* measured at the luminaire of not less than 1.4 $\mu\text{mol/J}$.

C405.4 Interior lighting power requirements. A building complies with this section if its total connected interior lighting power calculated under Section C405.4.1 is no greater than the interior lighting power allowance calculated under Section C405.4.2.

C405.4.1 Total connected interior lighting power. The total connected interior lighting power shall be determined in accordance with Equation 4-13.

$$\text{TCLP} = [\text{LVL} + \text{BLL} + \text{TRK} + \text{POE} + \text{Other}] \quad \text{(Equation 4-13)}$$

Where:

TCLP = Total connected lighting power (watts).

LVL = For luminaires with lamps connected directly to building power, such as line voltage lamps, the rated wattage of the lamp, which must be minimum 60 lumens/watt.

BLL = For luminaires incorporating a ballast or transformer, the rated input wattage of the ballast or transformer when operating the lamp.

TRK = For lighting track, cable conductor, rail conductor and plug-in busway systems that allow the addition and relocation of luminaires without rewiring, the wattage shall be one of the following:

1. The specified wattage of the luminaires, but not less than 16 W/lin. ft. (52 W/lin. m).
2. The wattage limit of the permanent current limiting devices protecting the system.
3. The wattage limit of the transformer supplying the system.

POE = For other modular lighting systems served with power supplied by a driver, power supply for transformer including, but not limited to, low-voltage lighting systems, the wattage of the system shall be the maximum rated input wattage of the driver, power supply or transformed published in the manufacturer's catalogs, as specified by UL 2108 or 8750. For power-over-Ethernet lighting systems, power provided to installed nonlighting devices may be subtracted from the total power rating of the power-over-Ethernet systems.

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

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

1. Television broadcast lighting for playing areas in sports arenas.
2. Emergency lighting automatically off during normal building operation.
3. Lighting in spaces specifically designed for use by occupants with special lighting needs including those with visual impairment and other medical and age-related issues.
4. Casino gaming areas.
5. General area lighting power in industrial and manufacturing occupancies dedicated to the inspection or quality control of goods and products.
6. Mirror lighting in dressing rooms.
7. Task lighting for medical and dental purposes that is in addition to *general lighting*.
8. Display lighting for exhibits in galleries, museums and monuments that is in addition to *general lighting*.

9. Lighting for theatrical purposes, including performance, stage, film production and video production.
10. Lighting for photographic processes.
11. Lighting integral to equipment or instrumentation and installed by the manufacturer.
12. ~~((Task lighting for plant growth or maintenance where the lamp efficacy is not less than 90 lumens per watt.))~~ Lighting provided exclusively for plant growth and maintenance, in spaces other than Group F, Group U, or controlled plant growth environments, where controlled separately from general lighting using an automatic time clock system with rated fixture efficacy in compliance with Section C405.3.
13. Advertising signage or directional signage.
14. Lighting for food warming.
15. Lighting equipment that is for sale.
16. Lighting demonstration equipment in lighting education facilities.
17. Lighting *approved* because of safety considerations.
18. Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions.
19. Furniture mounted supplemental task lighting that is controlled by automatic shutoff.
20. Exit signs.
21. Lighting used for aircraft painting.
22. Antimicrobial lighting used for the sole purpose of disinfecting a space.

C405.4.2 Interior lighting power allowance. The total interior lighting power allowance (watts) for an entire building shall be determined according to Table C405.4.2(1) using the Building Area Method, or Table C405.4.2(2) using the Space-by-Space Method. The interior lighting power allowance for projects that involve only portions of a building shall be determined according to Table C405.4.2(2) using the Space-by-Space Method. Buildings with unfinished spaces shall use the Space-by-Space Method.

C405.4.2.1 Building area method. For the Building Area Method, the interior lighting power allowance is calculated as follows:

1. For each building area type inside the building, determine the applicable building area type and the allowed lighting power density for that type from Table C405.4.2(1). For building area types not listed, select the building area type that most closely represents the use of 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.
2. Determine the floor area for each building area type listed in Table C405.4.2(1) and multiply this area by the applicable value from Table C405.4.2(1) to determine the lighting power (watts) for each building area type.
3. The total interior lighting power allowance (watts) for the entire building is the sum of the lighting power from each building area type.

C405.4.2.2 Space-by-Space Method. Where a building has a space designated as unfinished, neither the area nor the lighting power in the space shall be calculated as part of the LPA. For the Space-by-Space Method, the interior lighting power allowance is calculated as follows:

1. For each area enclosed by partitions that are not less than 80 percent of the ceiling height determine the applicable space type from Table C405.4.2(2). For space types not listed, select the space type that most closely represents the proposed use of the space. Where a space has multiple functions, that space shall be broken up into smaller subspaces, each using their own space type. If an entire space has multiple functions that necessitate a higher lighting power allowance in order to serve one of the primary functions, the higher allowance is permitted to be used.
2. Determine the total floor area of all of the spaces of each space type and multiply by the value for the space type in Table C405.4.2(2) to determine the lighting power (watts) for each space type.
3. The total interior lighting power allowance (watts) shall be the sum of the lighting power allowances for all space types.

C405.4.2.2.1 Additional interior lighting power. Where using the Space-by-Space Method, an increase in the interior lighting power allowance is permitted for specific lighting functions. Additional power shall be permitted only where the specified lighting is installed in addition to and automatically controlled separately from *general lighting*, in accordance with Section C405.2.6. This additional power shall be used only for the specified luminaires and shall not be used for any other purpose.

An increase in the interior lighting power allowance is permitted for lighting equipment to be installed in sales areas specifically to highlight merchandise. The additional lighting power shall be determined in accordance with Equation 4-14.

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$$\begin{aligned} \text{Additional Interior Lighting Power Allowance} = & 500 \text{ watts} + (\text{Retail Area 1} \times 0.45 \text{ W/ft}^2) \\ & + (\text{Retail Area 2} \times 0.45 \text{ W/ft}^2) + (\text{Retail Area 3} \times 1.05 \text{ W/ft}^2) \\ & + (\text{Retail Area 4} \times 1.87 \text{ W/ft}^2) \end{aligned} \tag{Equation 4-14}$$

Where:

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

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

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

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

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

Table C405.4.2(1)
Interior Lighting Power Allowances—Building Area Method

Building Area Type	LPD (w/ft ²)
Automotive facility	0.64
Convention center	0.64
Court house	0.79
Dining: Bar lounge/leisure	0.79
Dining: Cafeteria/fast food	0.72
Dining: Family	0.71
Dormitory ^{a, b}	0.46
Exercise center	0.67
Fire station ^a	0.54
Gymnasium	0.75
Health care clinic	0.70
Hospital ^a	0.84
Hotel/motel ^{a,b}	0.56
Library	0.83
Manufacturing facility	0.82
Motion picture theater	0.44
Multifamily ^c	0.41
Museum	0.55
Office	0.64
Parking garage	0.14
Penitentiary	0.65
Performing arts theater	0.84
Police station	0.66
Post office	0.65
Religious building	0.67
Retail	0.84
School/university	0.70
Sports arena	0.62
Town hall	0.69
Transportation	0.50
Warehouse	0.40
Workshop	0.91

a. Where sleeping units are excluded from lighting power calculations by application of Section R404.1, neither the area of the sleeping units nor the wattage of lighting in the sleeping units is counted.

- b. Where *dwelling units* are excluded from lighting power calculations by application of Section R404.1, neither the area of the *dwelling units* nor the wattage of lighting in the *dwelling units* is counted.
- c. *Dwelling units* are excluded. Neither the area of the *dwelling units* nor the wattage of lighting in the *dwelling units* is counted.

Table C405.4.2(2)
Interior Lighting Power Allowances—Space-by-Space Method

Common Space-by-Space Types ^a	LPD (w/ft ²)
Atrium - Less than 20 feet in height	0.39
Atrium - 20 to 40 feet in height	0.48
Atrium - Above 40 feet in height	0.60
Audience/seating area - Permanent	
In an auditorium	0.61
In a gymnasium	0.23
In a motion picture theater	0.27
In a penitentiary	0.67
In a performing arts theater	1.16
In a religious building	0.72
In a sports arena	0.33
Otherwise	0.23
Banking activity area ⁿ	0.61
Breakroom (see lounge/breakroom)	
Classroom/lecture hall/training room	
In a penitentiary	0.89
Otherwise ^m	0.71 ^m
Computer room, data center	0.94
Conference/meeting/multipurpose	0.97
Copy/print room	0.31
Corridor	
In a facility for the visually impaired (and not used primarily by the staff) ^b	0.71
In a hospital	0.71
Otherwise ^{c,k}	0.41
Courtroom ^c	1.20
Dining area	
In a penitentiary	0.42
In a facility for the visually impaired (and not used primarily by the staff) ^b	1.27
In a bar/lounge or leisure dining ⁿ	0.86
In cafeteria or fast food dining	0.40
In a family dining area ⁿ	0.60
Otherwise	0.43
Electrical/mechanical	0.43
Emergency vehicle garage	0.52
Food preparation	1.09
Laboratory	
In or as a classroom	1.11
Otherwise	1.33
Laundry/washing area	0.53
Loading dock, interior	0.88

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**Table C405.4.2(2)—continued
Interior Lighting Power Allowances—Space-by-Space Method**

Common Space-by-Space Types ^a	LPD (w/ft ²)
Lobby ^c	
In a facility for the visually impaired (and not used primarily by the staff) ^b	1.69
For an elevator	0.65
In a hotel	0.51
In a motion picture theater	0.23
In a performing arts theater	1.25
Otherwise	0.84
Locker room	0.52
Lounge/breakroom ⁿ	
In a health care facility ⁿ	0.42
Otherwise ⁿ	0.59
Office	
Enclosed	0.74
Open plan	0.61
Parking area, interior	0.15
Pharmacy area	1.66
Restroom	
In a facility for the visually impaired (and not used primarily by the staff) ^b	1.26
Otherwise ⁿ	0.63
Sales area	1.05
Seating area, general	0.23
((Stairway (see space containing stairway)))	
Security screening general area	
Security screening in transportation facilities	
Security screening transportation waiting area	
Stairwell ⁿ	0.49
Storage room	
< 50 ft ²	
50-100 ft ²	
All other storage	0.38
Vehicular maintenance	0.60
Workshop	1.26
Building Specific Space-by-Space Types^a	LPD (w/ft²)
Automotive (see vehicular maintenance)	
Convention center - Exhibit space	0.61
Facility for the visually impaired ^b	
In a chapel (and not used primarily by the staff) ^b	0.70
In a recreation room (and not used primarily by the staff) ^b	1.77
Fire stations ^g	
Gaming establishments	
High limits game	
Slots	
Sportsbook	
Table games	

Table C405.4.2(2)—continued
Interior Lighting Power Allowances—Space-by-Space Method

Common Space-by-Space Types ^a	LPD (w/ft ²)
Gymnasium/fitness center	
In an exercise area	0.90
In a playing area	0.85
Health care facility	
In an exam/treatment room	1.40
In an imaging room	0.94
In a medical supply room	0.62
In a nursery	0.92
In a nurse's station	1.17
In an operating room	2.26
In a physical therapy room	0.91
In a recovery room	1.25
In a telemedicine room	
Library	
In a reading area ⁿ	0.96
In the stacks	1.10
Manufacturing facility	
In a detailed manufacturing area	0.80
In an equipment room	0.76
In an extra high bay area (greater than 50-foot floor-to-ceiling height)	1.42
In a high bay area (25 - 50-foot floor-to-ceiling height)	1.24
In a low bay (< 25-foot floor-to-ceiling height)	0.86
Museum	
In a general exhibition area	0.31
In a restoration room	1.10
Performing arts theater dressing/fitting room	0.41
Post office - Sorting area	0.76
Religious buildings	
In a fellowship hall ⁿ	0.54
In a worship/pulpit/choir area ⁿ	0.85
Retail facilities	
In a dressing/fitting room	0.51
Hair salon	
Nail salon	
In a mall concourse	0.82
Massage space	
Sports arena - Playing area	
For a Class 1 facility ⁱ	2.94
For a Class 2 facility ^j	2.01
For a Class 3 facility ^k	1.30
For a Class 4 facility ^l	0.86

GENERAL REQUIREMENTS

**Table C405.4.2(2)—continued
Interior Lighting Power Allowances—Space-by-Space Method**

Common Space-by-Space Types ^a	LPD (w/ft ²)
Sports arena - Pools	
For a Class 1 facility ⁱ	
For a Class 2 facility ^j	
For a Class 3 facility ^k	
For a Class 4 facility ^l	
Transportation	
Airport Hangar	
In a baggage/carousel area	0.39
In an airport concourse	0.25
At a terminal ticket counter ⁿ	0.51
Passenger loading area	
Warehouse - Storage area	
For medium to bulky palletized items	0.33
For smaller, hand-carried items	0.69

For SI: 1 foot = 304.8 mm, 1 watt per square foot = 10.76 w/m².

- a. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply.
- b. A ‘Facility for the Visually Impaired’ is a facility that is licensed or will be licensed by local or state authorities for senior long-term care, adult daycare, senior support or people with special visual needs.
- c. Additional lighting power allowance of 0.2 watts per square foot for the purpose of highlighting art or exhibits. This additional power shall be permitted only where the specified lighting is installed in addition to and controlled separately from general lighting in accordance with Section C405.2.6. This additional power shall be used only for the specified luminaires, shall not be used for any other purpose, and shall not be added to any other space or the interior power allowance.
- d. Reserved.
- e. Reserved.
- f. Reserved.
- g. Where sleeping units are excluded from lighting power calculations by application of Section R404.1, neither the area of the sleeping units nor the wattage of lighting in the sleeping units is counted.
- h. Where dwelling units are excluded from lighting power calculations by application of Section R404.1, neither the area of the dwelling units nor the wattage of lighting in the dwelling units is counted.
- i. Class I facilities consist of professional facilities; and semiprofessional, collegiate, or club facilities with seating for 5,000 or more spectators.
- j. Class II facilities consist of collegiate and semiprofessional facilities with seating for fewer than 5,000 spectators; club facilities with seating for between 2,000 and 5,000 spectators; and amateur league and high school facilities with seating for more than 2,000 spectators.
- k. Class III facilities consist of club, amateur league and high school facilities with seating for 2,000 or fewer spectators.
- l. Class IV facilities consist of elementary school and recreational facilities; and amateur league and high school facilities without provision for spectators.
- m. For classrooms, additional lighting power allowance of 4.50 W/ lineal foot of white or chalk boards for directional lighting dedicated to white or chalk boards.
- n. Additional lighting power allowance of 0.15 W/ft² for ornamental lighting. Qualifying ornamental lighting includes luminaires that are specifically used in a decorative manner. This additional power shall be permitted only where the specified lighting is installed in addition to and controlled separately from display or general lighting in accordance with Section C405.2.6. This additional power shall be used only for the specified luminaires and it shall not be added to any other space or the interior power allowance.
- o. For scientific laboratories, additional lighting power allowance of 0.35 Watts per square foot for specialized task work - lighting that provides for small-scale, cognitive or fast performance visual tasks; lighting required for operating specialized equipment associated with pharmaceutical/laboratorial activities.
- p. For offices, additional lighting power allowance of 0.20 W/square foot for portable lighting, which includes under shelf or furniture-mounted supplemental task lighting qualifies when controlled by a time clock or an occupancy sensor
- q. Where a space is designated as unfinished, neither the area nor the lighting power in the space shall be calculated as part of the LPA.
- r. For corridors, additional lighting power allowance of 0.25 W/square foot for display lighting and decorative lighting is permitted where provided for aesthetic purposes. Decorative lighting fixtures in corridors are also permitted to provide general lighting.

C405.5 Exterior lighting power requirements. The total connected exterior lighting power calculated in accordance with Section C405.5.2 shall not be greater than the exterior lighting power allowance calculated in accordance with Section C405.5.3.

C405.5.1 Exterior building grounds lighting. All exterior building grounds luminaires that operate at greater than 25 watts shall have a minimum efficacy of 100 lumens per watt.

EXCEPTIONS:

- 1. Luminaires controlled by a motion sensor.

- Luminaires that qualify for one of the exceptions under Section C405.5.2.

C405.5.2 Total connected exterior building lighting power. The total exterior connected lighting power shall be the total maximum rated wattage of all exterior lighting that is powered through the energy service for the building.

EXCEPTION: Lighting used for the following applications shall not be included:

- Lighting approved because of safety considerations;
- Emergency lighting automatically off during normal business operation;
- Exit signs;
- Specialized signal, directional and marker lighting associated with transportation;
- Advertising signage or directional signage;
- Integral to equipment or instrumentation and is installed by its manufacturer;
- Theatrical purposes, including performance, stage, film production and video production;
- Athletic playing areas;
- Temporary lighting;
- Industrial production, material handling, transportation sites and associated storage areas;
- Theme elements in theme/amusement parks;
- Lighting integrated within or used to highlight features of art, public monuments and the national flag;
- Lighting for water features and swimming pools; and
- Lighting that is controlled from within dwelling units, where the lighting complies with Section R404.1.

C405.5.3 Exterior lighting power allowance. The exterior lighting power allowance (watts) is calculated as follows:

- Determine the Lighting Zone (LZ) for the building according to Table C405.5.3(1), unless otherwise specified by the code official.
- For each exterior area that is to be illuminated by lighting that is powered through the energy service for the building, determine the applicable area type from Table C405.5.3(2). For area types not listed, select the area type that most closely represents the proposed use of the area. Covered parking garage lighting is not considered exterior lighting for the purposes of this calculation.
- Determine the total area or length of each area type and multiply by the value for the area type in Table C405.5.3(2) to determine the lighting power (watts) allowed for each area type.
- The total exterior lighting power allowance (watts) is the sum of the base site allowance determined according to Table C405.5.3(2), plus the watts from each area type.

C405.5.3.1 Additional exterior lighting power. Additional exterior lighting power allowances are available for the specific lighting applications listed in Table C405.5.3(3). These additional power allowances shall be used only for the luminaires serving these applications and shall not be used to increase any other lighting power allowance.

**TABLE C405.5.3(1)
EXTERIOR LIGHTING ZONES**

Lighting zone	Description
1	Developed areas of national parks, state parks, forest land, and rural areas
2	Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed use areas
3	All other areas not classified as lighting zone 1, 2 or 4
((4)) <u>Not used</u>	((High activity commercial districts in major metropolitan areas as designated by the local land use planning authority))

**TABLE C405.5.3(2)
LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS**

	Lighting Zones			
	Zone 1	Zone 2	Zone 3	((Zone 4
Base Site Allowance	160 W	280 W	400 W	560 W
Uncovered Parking Areas				
Parking areas and drives	0.015 W/ft ²	0.026 W/ft ²	0.037 W/ft ²	0.052 W/ft²
Building Grounds				
Walkways and ramps less than 10 feet wide	0.04 W/ft ²	0.07 W/ft ²	0.10 W/ft ²	0.14 W/ft²

GENERAL REQUIREMENTS

**TABLE C405.5.3(2)—continued
LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS**

	Lighting Zones			
	Zone 1	Zone 2	Zone 3	((Zone 4
Walkways and ramps 10 feet wide or greater, plaza areas, special feature areas	0.04 W/ft ²	0.07 W/ft ²	0.10 W/ft ²	0.14 W/ft²
Dining areas	0.156 W/ft ²	0.273 W/ft ²	0.390 W/ft ²	0.546 W/ft²
Stairways	Exempt	Exempt	Exempt	Exempt
Pedestrian tunnels	0.063 W/ft ²	0.110 W/ft ²	0.157 W/ft ²	0.220 W/ft²
Landscaping	0.014 W/ft ²	0.025 W/ft ²	0.036 W/ft ²	0.050 W/ft²
Building Entrances and Exits				
Pedestrian and vehicular entrances and exits	5.6 W/linear foot of opening	9.8 W/linear foot of opening	14.0 W/linear foot of opening	19.6 W/linear foot of opening
Entry canopies	0.072 W/ft ²	0.126 W/ft ²	0.180 W/ft ²	0.252 W/ft²
Loading docks	0.104 W/ft ²	0.182 W/ft ²	0.260 W/ft ²	0.364 W/ft²
Sales Canopies				
Free standing and attached	0.20 W/ft ²	0.35 W/ft ²	0.50 W/ft ²	0.70 W/ft²
Outdoor Sales				
Open areas (including vehicle sales lots)	0.072 W/ft ²	0.126 W/ft ²	0.180 W/ft ²	0.252 W/ft²
Street frontage for vehicle sales lots in addition to “open area” allowance	No Allowance	7 W/linear foot	10.3 W/linear foot	14.4 W/linear foot))

For SI: 1 foot = 304.8 mm, 1 watt per square foot = 10.76 W per m²

**TABLE C405.5.3(3)
INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS**

	Lighting Zones			
	Zone 1	Zone 2	Zone 3	((Zone 4
Building façade	No allowance	0.075 W/ft ² of gross above-grade wall area	0.113 W/ft ² of gross above-grade wall area	0.150 W/ft² of gross above-grade wall area
Automated teller machines (ATM) and night depositories	80 W per location plus 25 per additional ATM	80 W per location plus 25 per additional ATM	80 W per location plus 25 per additional ATM	80 W per location plus 25 per additional ATM
Uncovered entrances and gatehouse inspection stations at guarded facilities	0.144 W/ft ²	0.252 W/ft ²	0.360 W/ft ²	0.504 W/ft²
Uncovered loading areas for law enforcement, fire, ambulance and other emergency service vehicles	0.104 W/ft ²	0.182 W/ft ²	0.260 W/ft ²	0.364 W/ft²
Drive-up windows/doors	53 W per drive through	92 W per drive through	132 W per drive through	185 W per drive through
Parking near 24-hour retail entrances	80 W per main entry	140 W per main entry	200 W per main entry	280 W per main entry))

C405.5.3.1 Additional exterior lighting power. Any increase in the exterior lighting power allowance is limited to the specific lighting applications indicated in Table C405.5.3(3). The additional power shall be used only for the luminaires that are serving these applications and shall not be used for any other purpose.

C405.5.4 Gas lighting. Gas-fired lighting appliances shall not be equipped with continuously burning pilot ignition systems.

C405.5.5 Full cutoff luminaires. For open parking and outdoor areas and roadways, luminaires mounted more than 15 feet above the ground shall have a luminaire light distribution in which zero candela intensity occurs at an angle of 90 degrees above nadir, and all greater angles from nadir.

C405.6 Electrical transformers. Low-voltage dry-type distribution electric transformers shall meet the minimum efficiency requirements of Table C405.6 as tested and rated in accordance with the test procedure listed in DOE 10 C.F.R. 431. The efficiency shall be verified through certification under an approved certification program or, where no certification program exists, the equipment efficiency ratings shall be supported by data furnished by the transformer manufacturer.

EXCEPTION: The following transformers are exempt:

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

**Table C405.6
Minimum Nominal Efficiency Levels For 10 C.F.R. 431 Low Voltage Dry-Type Distribution Transformers**

Single Phase Transformers		Three Phase Transformers	
kVA ^a	Efficiency (%) ^b	kVA ^a	Efficiency (%) ^b
15	97.70	15	97.89
25	98.00	30	98.23
37.5	98.20	45	98.40
50	98.30	75	98.60
75	98.50	112.5	98.74
100	98.60	150	98.83
167	98.70	225	98.94
250	98.80	300	99.02
333	98.90	500	99.14
		750	99.23
		1000	99.28

a kiloVolt-Amp rating.

b Nominal efficiencies shall be established in accordance with the DOE 10 C.F.R. 431 test procedure for low voltage dry-type transformers.

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

EXCEPTION: Dwelling units in other than Group R-2 multi-family and live/work units are not required to provide a separate electrical metering at each dwelling unit where electrical usage is metered separately for each of the following building end uses:

1. Dwelling units.
2. Sleeping units.
3. Commercial kitchens.
4. Central laundries.

C405.7.1 Electric receptacles at dwelling unit gas appliances. Where *dwelling unit* appliances are served by natural gas, an electrical receptacle or junction box and circuit shall be provided at each gas appliance with sufficient capacity to serve a future electric appliance in the same location. The receptacles and circuits shall be included in the electrical service load calculation and shall meet the requirements of items 1 through 3 below. The receptacle or junction box for each gas appliance shall be located within 12 inches of the appliance and without obstructions between the appliance and the outlet. An electric receptacle is not required for a decorative gas fireplace.

GENERAL REQUIREMENTS

1. Each gas range, cooktop, or oven, or combination appliance, location shall be served by a dedicated 240/208-volt, 40-amp receptacle connected to the *dwelling unit* electric panel with a 3-conductor branch circuit complying with 210.19(A)(3) of the NEC as adopted by Washington state and a minimum included load of 9600 VA for 240-volt systems or 8000 VA for 208-volt systems.
2. Each gas clothes dryer location shall be served by a dedicated 240/208-volt, 30-amp receptacle connected to the *dwelling unit* electric panel with a 3-conductor branch circuit and a minimum included load of 5000 VA.
3. The location of each gas domestic water heater installed within a *dwelling unit* shall be served by a dedicated 240/208-volt, 30-amp junction box connected to the *dwelling unit* electrical panel with a 3-conductor branch circuit and a minimum included load of 4500 VA.

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

EXCEPTION: The standards in this section shall not apply to the following exempt electric motors.

1. Air-over electric motors.
2. Component sets of an electric motor.
3. Liquid-cooled electric motors.
4. Submersible electric motors.
5. Inverter-only electric motors.
6. Mechanical ventilation system types with an input power less than 746 watts that comply with the requirements of Section C403.8.4.

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

EXCEPTIONS:

1. Motors that are an integral part of specialized process equipment.
 2. Where the motor is integral to a listed piece of equipment for which no complying motor has been approved.
 3. Motors used as a component of the equipment meeting the minimum efficiency requirements of Section C403.3.2 and Tables C403.3.2(1) through C403.3.2(16), provided that the motor input is included when determining the equipment efficiency.
 4. Motors in the airstream within fan coils and terminal units that operate only when providing heating to the space served.
 5. ~~((Fan motors that are not covered by Tables C405.8(1) through C405.8(4) and are used to power heat recovery ventilators, energy recovery ventilators, or local exhaust fans in Group R subject to the efficacy requirements of Section C403.8.4.))~~ Mechanical ventilation system types with an input power less than 746 watts that comply with the requirements of Section C403.8.4.
 6. Domestic clothes dryer booster fans, range hood exhaust fans, and domestic range booster fans that operate intermittently.
 7. Radon and contaminated soil exhaust fans.
- ~~((8. Group R heat recovery ventilator and energy recovery ventilator fans that are less than 400 cfm.))~~

Table C405.8(1)
Minimum Nominal Full-load Efficiency for NEMA Design A, NEMA Design B and IEC Design N Motors
(Excluding Fire Pump) Electric Motors at 60 Hz^{a,b}

Motor horsepower (Standard kilowatt equivalent)	Nominal full-load efficiency (%) as of June 1, 2016							
	2 pole		4 pole		6 pole		8 pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open	Enclosed	Open
1 (0.75)	77.0	77.0	85.5	85.5	82.5	82.5	75.5	75.5
1.5 (1.1)	84.0	84.0	86.5	86.5	87.5	86.5	78.5	77.5
2 (1.5)	85.5	85.5	86.5	86.5	88.5	87.5	84.0	86.5
3 (2.2)	86.5	85.5	89.5	89.5	89.5	88.5	85.5	87.5

Table C405.8(1)—continued
Minimum Nominal Full-load Efficiency for NEMA Design A, NEMA Design B and IEC Design N Motors
(Excluding Fire Pump) Electric Motors at 60 Hz^{a,b}

Motor horsepower (Standard kilowatt equivalent)	Nominal full-load efficiency (%) as of June 1, 2016							
	2 pole		4 pole		6 pole		8 pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open	Enclosed	Open
5 (3.7)	88.5	86.5	89.5	89.5	89.5	89.5	86.5	88.5
7.5 (5.5)	89.5	88.5	91.7	91.0	91.0	90.2	86.5	89.5
10 (7.5)	90.2	89.5	91.7	91.7	91.0	91.7	89.5	90.2
15 (11)	91.0	90.2	92.4	93.0	91.7	91.7	89.5	90.2
20 (15)	91.0	91.0	93.0	93.0	91.7	92.4	90.2	91.0
25 (18.5)	91.7	91.7	93.6	93.6	93.0	93.0	90.2	91.0
30 (22)	91.7	91.7	93.6	94.1	93.0	93.6	91.7	91.7
40 (30)	92.4	92.4	94.1	94.1	94.1	94.1	91.7	91.7
50 (37)	93.0	93.0	94.5	94.5	94.1	94.1	92.4	92.4
60 (45)	93.6	93.6	95.0	95.0	94.5	94.5	92.4	93.0
75 (55)	93.6	93.6	95.4	95.0	94.5	94.5	93.6	94.1
100 (75)	94.1	93.6	95.4	95.4	95.0	95.0	93.6	94.1
125 (90)	95.0	94.1	95.4	95.4	95.0	95.0	94.1	94.1
150 (110)	95.0	94.1	95.8	95.8	95.8	95.4	94.1	94.1
200 (150)	95.4	95.0	96.2	95.8	95.8	95.4	94.5	94.1
250 (186)	95.8	95.0	96.2	95.8	95.8	95.8	95.0	95.0

- a Nominal efficiencies shall be established in accordance with DOE 10 C.F.R. 431.
- b For purposes of determining the required minimum nominal full-load efficiency of an electric motor that has a horsepower or kilowatt rating between two horsepower or two kilowatt ratings listed in this table, each such motor shall be deemed to have a listed horsepower or kilowatt rating, determined as follows:
 1. A horsepower at or above the midpoint between the two consecutive horsepower shall be rounded up to the higher of the two horsepower.
 2. A horsepower below the midpoint between the two consecutive horsepower shall be rounded down to the lower of the two horsepower.
 3. A kilowatt rating shall be directly converted from kilowatts to horsepower using the formula $1 \text{ kW} = (1/0.746) \text{ horsepower}$. The conversion should be calculated to three significant decimal places, and the resulting horsepower shall be rounded in accordance with 1 or 2, whichever applies.

Table C405.8(2)
Minimum Nominal Full-load Efficiency for NEMA Design C and IEC Design H Motors at 60 Hz^{a,b}

Motor horsepower (Standard kilowatt equivalent)	Nominal full-load efficiency (%) as of June 1, 2016					
	4 pole		6 pole		8 pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open
1 (0.75)	85.5	85.5	82.5	82.5	75.5	75.5
1.5 (1.1)	86.5	86.5	87.5	86.5	78.5	77.5
2 (1.5)	86.5	86.5	88.5	87.5	84.0	86.5
3 (2.2)	89.5	89.5	89.5	88.5	85.5	87.5
5 (3.7)	89.5	89.5	89.5	89.5	86.5	88.5
7.5 (5.5)	91.7	91.0	91.0	90.2	86.5	89.5
10 (7.5)	91.7	91.7	91.0	91.7	89.5	90.2
15 (11)	92.4	93.0	91.7	91.7	89.5	90.2
20 (15)	93.0	93.0	91.7	92.4	90.2	91.0
25 (18.5)	93.6	93.6	93.0	93.0	90.2	91.0
30 (22)	93.6	94.1	93.0	93.6	91.7	91.7
40 (30)	94.1	94.1	94.1	94.1	91.7	91.7
50 (37)	94.5	94.5	94.1	94.1	92.4	92.4
60 (45)	95.0	95.0	94.5	94.5	92.4	93.0
75 (55)	95.4	95.0	94.5	94.5	93.6	94.1
100 (75)	95.4	95.4	95.0	95.0	93.6	94.1
125 (90)	95.4	95.4	95.0	95.0	94.1	94.1
150 (110)	95.8	95.8	95.8	95.4	94.1	94.1
200 (150)	96.2	95.8	95.8	95.4	94.5	94.1

GENERAL REQUIREMENTS

NR - No requirement.

a Nominal efficiencies shall be established in accordance with DOE 10 C.F.R. 431.

b For purposes of determining the required minimum nominal full-load efficiency of an electric motor that has a horsepower or kilowatt rating between two horsepower or two kilowatt ratings listed in this table, each such motor shall be deemed to have a listed horsepower or kilowatt rating, determined as follows:

1. A horsepower at or above the midpoint between the two consecutive horsepowers shall be rounded up to the higher of the two horsepowers.
2. A horsepower below the midpoint between the two consecutive horsepowers shall be rounded down to the lower of the two horsepowers.
3. A kilowatt rating shall be directly converted from kilowatts to horsepower using the formula 1 kW = (1/0.746) horsepower. The conversion should be calculated to three significant decimal places, and the resulting horsepower shall be rounded in accordance with 1 or 2, whichever applies.

**Table C405.8(3)
Minimum Average Full Load Efficiency for Polyphase Small Electric Motors^a**

OPEN MOTORS			
NUMBER OF POLES ==>	2	4	6
SYNCHRONOUS SPEED (RPM) ==>	3600	1800	1200
MOTOR HORSEPOWER ▼			
0.25	65.6	69.5	67.5
0.33	69.5	73.4	71.4
0.50	73.4	78.2	75.3
0.75	76.8	81.1	81.7
1	77.0	83.5	82.5
1.5	84.0	86.5	83.8
2	85.5	86.5	N/A
3	85.5	86.9	N/A

a Average full load efficiencies shall be established in accordance with 10 C.F.R. 431.

**Table C405.8(4)
Minimum Average Full Load Efficiency For Capacitor-start Capacitor-run and Capacitor-start Induction-run Small Electric Motors^a**

OPEN MOTORS			
NUMBER OF POLES ==>	2	4	6
SYNCHRONOUS SPEED (RPM) ==>	3600	1800	1200
MOTOR HORSEPOWER ▼			
0.25	66.6	68.5	62.2
0.33	70.5	72.4	66.6
0.50	72.4	76.2	76.2
0.75	76.2	81.8	80.2
1	80.4	82.6	81.1
1.5	81.5	83.8	N/A
2	82.9	84.5	N/A
3	84.1	N/A	N/A

a Average full load efficiencies shall be established in accordance with 10 C.F.R. 431.

C405.9 Vertical and horizontal transportation systems and equipment. Vertical and horizontal transportation systems and equipment shall comply with this section.

C405.9.1 Elevator cabs. For the luminaires in each elevator cab, not including signals and displays, the sum of the lumens divided by the sum of the watts shall be no less than 35 lumens per watt. Ventilation fans in elevators that do not have their own air conditioning system shall not consume more than 0.33 watts/cfm at the maximum rated speed of the fan. Controls shall be provided that will deenergize ventilation fans and lighting systems when the elevator is stopped, unoccupied and with its doors closed for over 15 minutes.

C405.9.2 Escalators and moving walks. Escalators and moving walks shall comply with ASME A17.1/CSA B44 and shall have automatic controls that reduce speed as permitted speed in accordance with ASME A17.1/CSA B44 and applicable local code when not conveying passengers.

EXCEPTION: A variable voltage drive system that reduces operating voltage in response to light loading conditions is allowed to be provided in lieu of the variable speed function.

C405.9.2.1 Energy recovery. Escalators shall be designed to recover electrical energy when resisting overspeed in the down direction.

C405.10 Automatic receptacle control. The following shall have automatic receptacle control complying with Section C405.10.1:

1. At least 50 percent of all 125V, 15- and 20-amp receptacles installed in enclosed offices, conference rooms, rooms used primarily for copy or print functions, breakrooms, classrooms and individual workstations, including those installed in modular partitions and module office workstation systems.
2. At least 50 percent of branch circuit feeders installed for modular furniture not shown on the construction documents.

C405.10.1 Automatic receptacle control function. Automatic receptacle controls shall comply with the following:

1. Either split controlled receptacles shall be provided with the top receptacle controlled, or a controlled receptacle shall be located within 12 inches (304.8 mm) of each uncontrolled receptacle.
2. One of the following methods shall be used to provide control:
 - 2.1. A scheduled basis using a time-of-day operated control device that turns receptacle power off at specific programmed times and can be programmed separately for each day of the week. The control device shall be configured to provide an independent schedule for each portion of the building of not more than 5,000 square feet (464.5 m²) and not more than one floor. The occupant shall be able to manually override an area for not more than 2 hours. Any individual override switch shall control the receptacles of not more than 5,000 feet (1524 m).
 - 2.2. An occupant sensor control that shall turn off receptacles within 20 minutes of all occupants leaving a space.
 - 2.3. An automated signal from another control or alarm system that shall turn off receptacles within 20 minutes after determining that the local area is unoccupied.
3. All controlled receptacles shall be permanently marked in accordance with NFPA 70 and be uniformly distributed throughout the space.
4. Plug-in devices shall not ~~((empty))~~ be permitted to substitute for controlled receptacles.

EXCEPTION: Automatic receptacle controls are not required for the following:

1. Receptacles specifically designated for equipment requiring continuous operation (24 hours per day, 365 days per year).
2. Spaces where an automatic control would endanger the safety or security of the room or building occupants.
3. Within a single modular office workstation, noncontrolled receptacles are permitted to be located more than 12 inches (304.8 mm), but not more than 72 inches (1828 mm) from the controlled receptacles serving that workstation.

SDCI Informative Note: The requirements of this section also apply to rooms and spaces that have substantially similar functions to those listed even when they are labeled with different names. For example, an area designed for office functions that is labeled “work room,” or a room used as a classroom that is labeled “student learning” would each be required to provide *controlled receptacles*.

C405.11 Voltage drop. The total voltage drop across the combination of customer-owned service conductors, feeder conductors and branch circuit conductors shall not exceed five percent.

C405.12 Alternating current-output uninterruptible power supplies (AC-output UPS). *AC-output UPS* systems serving a *computer room* shall meet or exceed the calculation and testing requirements identified in ENERGY STAR Program Requirements for Uninterruptible Power Supplies (UPSs) - Eligibility Criteria Version 2.0.

EXCEPTION: AC-output UPS that utilizes standardized NEMA-1-15P or NEMA 5-15P input plug, as specified in ANSI/NEMA WD 6.

C405.13 Commissioning. Controlled receptacles and lighting systems shall be commissioned in accordance with Section C408.

C405.14 Commercial food service. The following types of equipment within the scope of the applicable Energy Star program shall comply with the energy-efficiency and water-efficiency criteria required to achieve the Energy Star label:

- a. Commercial fryers: Energy Star Program Requirements for Commercial Fryers.
- b. Commercial hot food holding cabinets: Energy Star Program Requirements for Hot Food Holding Cabinets.
- c. Commercial steam cookers: Energy Star Program Requirements for Commercial Steam Cookers.
- d. Commercial dishwashers: Energy Star Program Requirements for Commercial Dishwashers.

**SECTION C406
ADDITIONAL ENERGY EFFICIENCY AND LOAD MANAGEMENT CREDITS**

C406.1 Additional energy efficiency and load management measures credit requirements. The project as defined in the building permit shall meet the following requirements as applicable:

1. New buildings, changes in *space conditioning category*, change of occupancy group, and building additions in accordance with Chapter 5 shall comply with sufficient measures from Section C406.2 so as to achieve the minimum number of required efficiency credits shown in Table C406.1.
2. New buildings greater than 5000 gross square feet of floor area shall comply with sufficient measures from Section C406.3 so as to achieve the minimum number of required load management credits shown in Table C406.1.
3. Tenant spaces shall comply in accordance with Section C406.1.1.

SDCI Informative Note: In this section “tenant space” means any conditioned area within a new building that is constructed for first occupancy under a separate permit from the shell and core permits.

4. Projects using discrete area credit weighting shall comply in accordance with Section C406.1.2.

EXCEPTIONS:

1. Low energy spaces in accordance with Section C402.1.1.1, equipment buildings in accordance with Section C402.1.2, unconditioned spaces, open parking garages, and enclosed parking garages that comply with sufficient measures from Table C406.2(1) to achieve a minimum of 50 percent of the efficiency credits required for new construction. Such projects shall be exempt from the load management requirements in Table C406.1.
2. Building additions that have less than 1,000 square feet of *conditioned floor area* that comply with sufficient measures from Table C406.2(1) to achieve a minimum of 50 percent of the efficiency credits required for additions.
3. Warehouses are exempt from the load management credit requirements in Table C406.1.

**Table C406.1
Energy Measure Credit Requirements**

Required Credits for Projects	Section	Occupancy Group					
		Group R-1	Group R-2	Group B	Group E	Group M	All Other
New building energy efficiency credit requirement	C406.2	54	41	42	48	74	49
Building additions energy efficiency credit requirement	C406.2	27	20	21	23	36	21
New building load management credit requirement	C406.3	12	15	27	15	13	26

C406.1.1 Tenant spaces. An initial tenant improvement shall comply with sufficient measures from Table C406.2(1) to achieve a minimum of efficiency credits required in Table C406.1 and are not required to achieve any load management credits. In projects with multiple tenant spaces, each tenant space is permitted to apply for different measures provided the weighted average of all areas in the project (~~comply~~) **complies** with the overall efficiency credit requirement in Table C406.1. Whole building or addition energy credits shall be allocated to tenant spaces in accordance with Sections C406.1.1.1 and C406.1.1.2. This provision only applies to the initial buildout of a tenant space.

EXCEPTIONS:

1. An initial tenant improvement where the core and shell building complied via Section C407 in 2018 or later edition of the (~~Washington State~~) Seattle Energy Code.
2. Previously occupied tenant spaces in existing buildings that comply with this code in accordance with Section C501.

C406.1.1.1 Applicable envelope, renewable and elevator energy credits. Where an entire building or building addition complies with Section (~~C406.2.4, C406.2.9, C406.2.10, or C406.2.14~~) C406.2.5, C406.2.12, C406.2.13, or C406.2.18, under an initial tenant improvement permit, tenant spaces within the building qualify for the number of credits assigned to the occupancy group of the tenant space in accordance with Table C406.2(1). Where prior energy credits were achieved under the 2018 Washington State Energy Code, they shall be multiplied by 6 for applicability to this code.

C406.1.1.2 Applicable HVAC and service water heating credits. Where HVAC and service water heating systems and services are installed and comply with Section (~~C406.2.4;~~) C406.2.2, C406.2.8, or C406.2.9, (~~C406.2.10, or C406.2.14~~) under an initial tenant improvement permit, those systems and services shall be considered a part of the tenant space. Tenant spaces qualify for the credits assigned to the occupancy group of the tenant space in accordance

with Table C406.2(1) if the tenant space includes the distribution system and equipment that the central HVAC systems or service water heating systems were designed to support.

C406.1.2 Discrete area-weighted project compliance. Discrete building areas are permitted to select different packages of measures provided that the whole project complies with both the energy and load management credit requirements. Compliance shall be determined as follows:

1. Required project credits shall be prorated on an area-weighted basis for each occupancy group by multiplying the occupancy group floor area by the number of credits required, and then dividing this value by the total area of all the occupancy groups combined. Where one occupancy group is less than 10 percent of the floor area of the project, use the primary occupancy group for those credits.
2. Occupancies are permitted to be subdivided into discrete areas, with required and achieved credits for each area prorated on an area-weighted basis as required for the occupancy group.
3. Where envelope or lighting power credits in Section C406.2.3.1, C406.2.3.2, or C406.2.3.12 are applied, the lighting power or envelope UA percentage reduction shall be calculated for the project as a whole to determine achieved credits.
4. Determine total project credits achieved by area-weighting the achieved credits by occupancy group in the same manner as for required project credits.
5. A project complies when the achieved number of area-weighted energy and load management credits are equal to or greater than the required area-weighted number of credits.

C406.2 Additional energy efficiency credit measures. Each energy efficiency credit measure used to meet credit requirements for the project shall include efficiency that is greater than the energy efficiency required for the building type and configuration requirements in Sections C402 through C405. Measures installed in the project that meet the requirements in Sections C406.2.1 through C406.2.14 shall achieve the credits listed for the measure and occupancy group in Table C406.2(1) or Table C406.2(2) or where calculations required by Sections C406.2.1 through C406.2.14 create or modify the table credits, the credits achieved shall be based upon the section calculations. Projects that (~~choose~~) choose to comply with either fossil fuel pathway in Section C406.1.3 shall use Table C406.2(2) to achieve credits.

For mixed fuel space heating systems, the number of space heating energy efficiency credits available for measures with a prorating flag “Heat” are calculated using the following equation:

$$C_{SH} = CHP_{SH} \times B/C + CFF_{SH} \times (1 - B/C)$$

Where:

C_{SH} = Blended credits for mixed fuel systems.

CHP_{SH} = Credits available in Table C406.2(1).

CFF_{SH} = Credits available in Table C406.2(2).

B = Installed space heating capacity in kBTU/h of space heating appliances that comply with any of the exceptions to Section C403.1.4.

C = Total installed space heating capacity in kBTU/h of all space heating appliances.

For mixed fuel service water heating systems, the number of service water heating energy efficiency credits available for measures with a prorating flag “SWH” are calculated using the following equation:

$$C_{WH} = CHP_{WH} \times B/C + CFF_{WH} \times (1 - B/C)$$

Where:

C_{WH} = Blended credits for mixed fuel systems.

CHP_{WH} = Credits available in Table C406.2(1).

CFF_{WH} = Credits available in Table C406.2(2).

B = Installed service water heating capacity in kBTU/h of service water heating appliances that comply with any of the exceptions to Section C404.2.1.

C = Total installed service water heating capacity in kBTU/h of all service water heating appliances.

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Table C406.2(1)
Efficiency Measure Credits

Measure Title	Applicable Section	Prorating Flag	Occupancy Group					
			Group R-1	Group R-2	Group B	Group E	Group M	All Other
1. Dwelling unit HVAC control	((C406.2.2)) C406.2.1	Heat	NA	7	NA	NA	NA	NA
2. Improved HVAC TSPR ^a	C406.2.2.1	Heat	NA	8	11	17	22	NA
3. Improve cooling and fan efficiency	C406.2.2.2	Heat	((2)) 8	((2)) 5	((3)) 10	((4)) 10	((3)) 8	((2)) 8
4. Improve heating efficiency	C406.2.2.3	Heat	((2)) 1	((3)) 1	((3)) 1	((10)) 1	((16)) 2	((7)) 1
5. Improved low-carbon district energy system (10% better)	C406.2.2.4		3	3	4	11	17	8
6. Improved low-carbon district energy system (20% better) ^b	C406.2.2.5		9	10	12	33	52	24
7. High performance DOAS	C406.2.2.6	Heat	31	31	21	39	40	21/ (Group A: 40) ^c
8. Fault detection & diagnostics (FDD)	C406.2.2.7	Heat	2	2	2	6	9	4
9. 10% reduced lighting power	C406.2.3.1	Heat	7	4	18	16	((20)) 36	((15)) 16
10. 20% reduced lighting power ^d	C406.2.3.2	Heat	13	8	36	32	((52)) 72	((29)) 32
11. Lamp efficacy improvement	C406.2.3.3	Heat	5	6	NA	NA	NA	NA
12. Residential lighting control	C406.2.4.1	Heat	NA	8	NA	NA	NA	NA
13. Enhanced lighting control	C406.2.4.2	Heat	1	1	6	6	11	((6)) 5
14. Renewable energy	C406.2.5		7	12	13	13	10	11
15. Shower drain heat recovery	C406.2.6.1	SWH	9	30	NA	3	NA	NA
16. Service water heat recovery	C406.2.6.2	SWH	35	111	13	14	(Grocery) 41 ^e	NA
((17. Heat pump water heating	C406.2.6.3	SWH	135	163	17	33	(Grocery) 95^e	(A-2) 95^f)
18 High efficiency service water heating, gas-fired	C406.2.6.4	SWH	NA	NA	NA	NA	NA	NA
19. Heat trace system	C406.2.7.1	SWH	6	13	4	1	NA	6
20. Point of use water heater	C406.2.7.2	SWH	NA	NA	19	5	NA	NA
21. Service hot water distribution right sizing	C406.2.8	SWH	NA	((42)) 10	NA	NA	NA	NA
22. High performance service hot water temperature maintenance system	C406.2.9	SWH	6	13	4	1	NA	6
((23. High efficiency service hot water recirculation system	C406.2.10	SWH	3	6	2	1	NA	4)
24. Low flow residential showerheads	C406.2.11	SWH	3	3	NA	NA	NA	NA
25. Enhanced envelope performance ^g	C406.2.12	Heat	24	20	13	5	19	((14)) 16
26. Base reduced air leakage ^g	C406.2.13.2		29	24	6	3	9	((11)) 14
27. Enhanced reduced air leakage ^g	C406.2.13.3	Heat	53	44	11	5	16	((20)) 26
((28. Enhanced commercial kitchen equipment	C406.2.14	Heat	30^h	18^h	18^h	30^h	30^h	31^h)
29. Enhanced residential kitchen equipment	C406.2.15	Heat	12	19	NA	NA	NA	NA
30. Enhanced residential laundry equipment	C406.2.16	Heat	NA	6	NA	NA	NA	NA
31. Heat pump clothes dryers	C406.2.17	Heat	6	6	NA	NA	NA	NA
32. Efficient elevator equipment	C406.2.18	Heat	3	5	5	5	4	4
Measure Title	Applicable Section	Prorating Flag	Occupancy Group					
			Group R-1	Group R-2	Group B	Group E	Group M	All Other
1. Dwelling unit HVAC control	((C406.2.2)) C406.2.1	Heat	NA	7	NA	NA	NA	NA
2. Improved HVAC TSPR ^a	C406.2.2.1	Heat	NA	8	11	17	22	NA
3. Improve cooling and fan efficiency	C406.2.2.2	Heat	((2)) 8	((2)) 5	((3)) 10	((4)) 10	((3)) 8	((2)) 8
4. Improve heating efficiency	C406.2.2.3	Heat	((2)) 1	((3)) 1	((3)) 1	((10)) 1	((16)) 2	((7)) 1

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5. Improved low-carbon district energy system (10% better)	C406.2.2.4		3	3	4	11	17	8
6. Improved low-carbon district energy system (20% better) ^b	C406.2.2.5		9	10	12	33	52	24
7. High performance DOAS	C406.2.2.6	Heat	31	31	21	39	40	21/ (Group A: 40) ^c
8. Fault detection & diagnostics (FDD)	C406.2.2.7	Heat	2	2	2	6	9	4
9. 10% reduced lighting power	C406.2.3.1	Heat	7	4	18	16	((20)) 36	((15)) 16
10. 20% reduced lighting power ^d	C406.2.3.2	Heat	13	8	36	32	((52)) 72	((29)) 32
11. Lamp efficacy improvement	C406.2.3.3	Heat	5	6	NA	NA	NA	NA
12. Residential lighting control	C406.2.4.1	Heat	NA	8	NA	NA	NA	NA
13. Enhanced lighting control	C406.2.4.2	Heat	1	1	6	6	11	((6)) 5
14. Renewable energy	C406.2.5		7	12	13	13	10	11
15. Shower drain heat recovery	C406.2.6.1	SWH	9	30	NA	3	NA	NA
16. Service water heat recovery	C406.2.6.2	SWH	35	111	13	14	(Grocery) 41 ^e	NA
((17. Heat pump water heating	C406.2.6.3	SWH	81	261	17	33	(Grocery) 95^e	(A-2) 95^f)
18. Heat trace system	C406.2.7.1	SWH	6	13	4	1	NA	6
19. Point of use water heater	C406.2.7.2	SWH	NA	NA	19	5	NA	NA
20. Service hot water distribution right sizing	C406.2.8	SWH	13	((42)) 10	NA	NA	NA	NA
21. High performance service hot water temperature maintenance system	C406.2.9	SWH	6	13	4	1	NA	6
22. High efficiency service hot water circulation system	C406.2.10	SWH	3	6	2	1	NA	4
23. Low flow residential showerheads	C406.2.11	SWH	3	3	NA	NA	NA	NA
24. Enhanced envelope performance ^g	C406.2.12	Heat	24	20	13	5	19	((14)) 16
25. Base reduced air leakage ^g	C406.2.13.2		29	24	6	3	9	((11)) 14
26. Enhanced reduced air leakage ^g	C406.2.13.3	Heat	53	44	11	5	16	((20)) 26
((27. Enhanced commercial kitchen equipment	C406.2.14	Heat	30^h	18^h	18^h	30^h	30^h	31^h)
28. Enhanced residential kitchen equipment	C406.2.15	Heat	12	19	NA	NA	NA	NA
29. Enhanced residential laundry equipment	C406.2.16	Heat	NA	6	NA	NA	NA	NA
30. Heat pump clothes dryers	C406.2.17	Heat	6	6	NA	NA	NA	NA
31. Efficient elevator equipment	C406.2.18	Heat	3	5	5	5	4	4

a. Projects using Item 2 shall not use Items ((3 through 5)) 3, 4, or 7.

b. Projects using C406.2.2.5 shall not use C406.2.2.4.

c. For C406.2.2.6, occupancy Group A achieves 40 credits while other occupancy groups within the “all other” category achieve 21 credits.

d. Projects using C406.2.3.2 shall not use C406.2.3.1.

e. Service water heat recovery and heat pump water heating are available in Group M only for grocery stores larger than 10,000 ft². Large mixed retail with full grocery and butcher sections shall achieve half the credits. This credit is not available where refrigeration recovery to heat service hot water is used to meet the requirements of Section C403.9.2.3.

f. Heat pump water heating efficiency credits are available in the “all other” category only for Group A-2.

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g. Buildings or building areas that are exempt from the thermal envelope requirements in accordance with Sections C402.1.1 and C402.1.2, do not qualify for this package.

~~(h. Additional energy efficiency credits, up to the maximum shown in Table C406.2(2), shall be calculated according to Section C406.2.14.)~~

**Table C406.2(2)
Efficiency Measure Credits for use with Fossil Fuel Compliance Path**

Measure Title	Applicable Section	Prorating Flag	Occupancy Group					
			Group R-1	Group R-2	Group B	Group E	Group M	All Other
1. Dwelling unit HVAC control	C406.2.2	Heat	NA	8	NA	NA	NA	NA
2. Improved HVAC TSPR ^a	C406.2.2.1	Heat	NA	9	12	19	24	NA
3. Improve cooling and fan efficiency	C406.2.2.2	Heat	12	8	14	8	10	10
4. Improve heating efficiency	C406.2.2.3	Heat	2	3	3	11	18	8
5. Improved low-carbon district energy system (10% better)	C406.2.2.4		3	3	4	12	19	9
6. Improved low-carbon district energy system (20% better) ^b	C406.2.2.5		10	11	13	36	57	26
7. High performance DOAS	C406.2.2.6	Heat	34	34	23	43	44	23/ (A) 40 ^c
8. Fault detection & diagnostics (FDD)	C406.2.2.7	Heat	2	2	2	6	9	4
9. 10% reduced lighting power	C406.2.3.1	Heat	7	4	18	16	20	15
10. 20% reduced lighting power ^d	C406.2.3.2	Heat	13	8	36	32	40	29
11. Lamp efficacy improvement	C406.2.3.3	Heat	5	6	NA	NA	NA	NA
12. Residential lighting control	C406.2.4.1	Heat	NA	8	NA	NA	NA	NA
13. Enhanced lighting control	C406.2.4.2	Heat	1	1	6	6	11	6
14. Renewable energy	C406.2.5		7	12	13	13	10	11
15. Shower drain heat recovery	C406.2.6.1	SWH	10	33	NA	3	NA	NA
16. Service water heat recovery	C406.2.6.2	SWH	35	111	13	14	(Grocery) 41 ^e	NA
17. Heat pump water heating	C406.2.6.3	SWH	81	261	17	33	(Grocery) 95 ^e	(A-2) 95 ^f
18 High efficiency service water heating, gas-fired	C406.2.6.4	SWH	59	65	6	11	18	32
19. Heat trace system	C406.2.7.1	SWH	6	13	4	1	NA	6
20. Point of use water heater	C406.2.7.2	SWH	NA	NA	19	5	NA	NA
21. Service hot water distribution right sizing	C406.2.8	SWH	NA	((42)) 10	NA	NA	NA	NA
22. High performance service hot water temperature maintenance system	C406.2.9	SWH	6	13	4	1	NA	6
((23. High efficiency service hot water circulation system	C406.2.10	SWH	3	6	2	4	NA	4))
24. Low flow residential showerheads	C406.2.11	SWH	3	3	NA	NA	NA	NA
25. Enhanced envelope performance ^g	C406.2.12	Heat	24	20	13	5	19	14
26. Base reduced air leakage ^g	C406.2.13.2		29	24	6	3	9	11
27. Enhanced reduced air leakage ^g	C406.2.13.3	Heat	53	44	11	5	16	20
((28. Enhanced commercial kitchen equipment	C406.2.14	Heat	30^h	18^h	18^h	30^h	30^h	31^h))
29. Enhanced residential kitchen equipment	C406.2.15	Heat	12	19	NA	NA	NA	NA
30. Enhanced residential laundry equipment	C406.2.16	Heat	NA	6	NA	NA	NA	NA
31. Heat pump clothes dryers	C406.2.17	Heat	6	6	NA	NA	NA	NA
32. Efficient elevator equipment	C406.2.18	Heat	3	5	5	5	4	4
Measure Title	Applicable Section	Prorating Flag	Occupancy Group					
			Group R-1	Group R-2	Group B	Group E	Group M	All Other
1. Dwelling unit HVAC control	C406.2.2	Heat	NA	8	NA	NA	NA	NA
2. Improved HVAC TSPR ^a	C406.2.2.1	Heat	NA	9	12	19	24	NA
3. Improve cooling and fan efficiency	C406.2.2.2	Heat	12	8	14	8	10	10
4. Improve heating efficiency	C406.2.2.3	Heat	2	3	3	11	18	8
5. Improved low-carbon district energy system (10% better)	C406.2.2.4		3	3	4	12	19	9

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6. Improved low-carbon district energy system (20% better) ^b	C406.2.2.5		10	11	13	36	57	26
7. High performance DOAS	C406.2.2.6	Heat	34	34	23	43	44	23/ (A) 40 ^c
8. Fault detection & diagnostics (FDD)	C406.2.2.7	Heat	2	2	2	6	9	4
9. 10% reduced lighting power	C406.2.3.1	Heat	7	4	18	16	20	15
10. 20% reduced lighting power ^d	C406.2.3.2	Heat	13	8	36	32	40	29
11. Lamp efficacy improvement	C406.2.3.3	Heat	5	6	NA	NA	NA	NA
12. Residential lighting control	C406.2.4.1	Heat	NA	8	NA	NA	NA	NA
13. Enhanced lighting control	C406.2.4.2	Heat	1	1	6	6	11	6
14. Renewable energy	C406.2.5		7	12	13	13	10	11
15. Shower drain heat recovery	C406.2.6.1	SWH	10	33	NA	3	NA	NA
16. Service water heat recovery	C406.2.6.2	SWH	35	111	13	14	(Grocery) 41 ^e	NA
17. Heat pump water heating	C406.2.6.3	SWH	81	261	17	33	(Grocery) 95 ^e	(A-2) 95 ^f
18. Heat trace system	C406.2.7.1	SWH	6	13	4	1	NA	6
19. Point of use water heater	C406.2.7.2	SWH	NA	NA	19	5	NA	NA
20. Service hot water distribution right sizing	C406.2.8	SWH	13	((42)) 10	NA	NA	NA	NA
21. High performance service hot water temperature maintenance system	C406.2.9	SWH	6	13	4	1	NA	6
((22. High efficiency service hot water circulation system	C406.2.10	SWH	3	6	2	1	NA	4))
23. Low flow residential showerheads	C406.2.11	SWH	3	3	NA	NA	NA	NA
24. Enhanced envelope performance ^g	C406.2.12	Heat	24	20	13	5	19	14
25. Base reduced air leakage ^g	C406.2.13.2		29	24	6	3	9	11
26. Enhanced reduced air leakage ^g	C406.2.13.3	Heat	53	44	11	5	16	20
((27. Enhanced commercial kitchen equipment	C406.2.14	Heat	30^h	18^h	18^h	30^h	30^h	31^h))
28. Enhanced residential kitchen equipment	C406.2.15	Heat	12	19	NA	NA	NA	NA
29. Enhanced residential laundry equipment	C406.2.16	Heat	NA	6	NA	NA	NA	NA
30. Heat pump clothes dryers	C406.2.17	Heat	6	6	NA	NA	NA	NA
31. Efficient elevator equipment	C406.2.18	Heat	3	5	5	5	4	4

- a. Projects using Item 2 shall not use Items ~~((3 through 5))~~ 3, 4, or 7.
- b. Projects using C406.2.2.5 shall not use C406.2.2.4.
- c. For C406.2.2.6, occupancy Group A achieves 40 credits while other occupancy groups within the “all other” category achieve 21 credits.
- d. Projects using C406.2.3.2 shall not use C406.2.3.1.
- e. Service water heat recovery and heat pump water heating are available in Group M only for grocery stores larger than 10,000 ft². Large mixed retail with full grocery and butcher sections shall achieve half the credits. This credit is not available where refrigeration recovery to heat service hot water is used to meet the requirements of Section C403.9.2.3.
- f. Heat pump water heating efficiency credits are available in the “all other” category only for Group A-2.
- g. Buildings or building areas that are exempt from the thermal envelope requirements in accordance with Sections C402.1.1 and C402.1.2, do not qualify for this package.
- ~~((h. Additional energy efficiency credits, up to the maximum shown in Table C406.2(2), shall be calculated according to Section C406.2.14.))~~

C406.2.1 Dwelling unit and Group R-1 sleeping unit HVAC controls. HVAC systems serving *dwelling units* or Group R-1 sleeping units shall be controlled with a programmable *thermostat* that is configured to automatically activate a setback condition of at least 5°F (3°C) for both heating and cooling. The programmable *thermostat* shall be configured to provide setback during occupied sleep periods. The unoccupied setback mode shall be configured to operate in conjunction with one of the following:

1. A manual main control device by each *dwelling unit* or Group R-1 sleeping unit main entrance that initiates setback for all HVAC units in the *dwelling unit* and is clearly identified as “Heating/Cooling Master Setback.”
2. Occupancy sensors in each room of the *dwelling unit* or Group R-1 sleeping unit combined with a door switch to initiate setback for all HVAC units in the dwelling within 20 minutes of all spaces being vacant immediately following a door switch operation. Where separate room HVAC units are used, an individual occupancy sensor on each unit that is configured to provide setback shall meet this requirement.
3. An advanced learning thermostat that senses occupant presence and automatically creates a schedule for occupancy and provides a dynamic setback schedule based on when the spaces are generally unoccupied.
4. An automated control and sensing system that uses geographic sensing connected to the *dwelling unit* occupants’ cell phones and initiates the setback condition when all occupants are away from the building.

C406.2.2 More efficient HVAC system performance. All heating and cooling systems shall meet the minimum requirements of Section C403 and efficiency improvements shall be referenced to the minimum efficiency requirements listed in the tables in Section C403.3.2. Where multiple efficiency requirements are listed, equipment shall meet the seasonal efficiencies including SEER, EER/IEER, IPLV or AFUE. Equipment that is larger than the maximum capacity range indicated in the tables in Section C403.3.2 shall utilize the values listed for the largest capacity equipment for the associated equipment type shown in the table. Where multiple individual heating or cooling systems serve the project, the improvement shall be the weighted average improvement based on individual system capacity. This credit shall not be utilized for low energy or semi-heated space conditioning categories. No HVAC systems incorporating fossil fuel-fired equipment, or heat from district energy systems that are primarily heated by fossil fuel combustion, are permitted to utilize this credit unless the Section C401.3 fossil fuel compliance path is utilized for energy code compliance.

For occupancies and systems required to comply with Section C403.1.1, credits are permitted to be achieved by meeting the requirements of Section C406.2.2.1. Other systems are permitted to achieve credits by meeting the requirements of either:

1. Section C406.2.2.2, More efficient HVAC equipment cooling and fan performance.
2. Section C406.2.2.3, More efficient HVAC equipment heating performance.
3. Section C406.2.2.4, High performance dedicated outdoor air system (DOAS).
4. Any combination of Sections C406.2.2.2, C406.2.2.3, and C406.2.2.4.

In addition, energy credits are permitted to be achieved for Section C406.2.2.7, Fault detection and diagnostics, where not otherwise required by Section C403.2.3 or C403.6.10(15).

C406.2.2.1 Improved HVAC TSPR. For systems required to comply with Section C403.1.1, the *HVAC TSPR* shall exceed the minimum requirement by five percent. If improvement is greater, the credits in Table C406.2(1) are permitted to be prorated up to a 20 percent improvement.

C406.2.2.2 More efficient HVAC equipment cooling and fan performance. No less than 90 percent of the total HVAC capacity serving the total *conditioned floor area* of the entire building, building addition or tenant space in accordance with Section C406.1.1 shall comply with Sections C406.2.2.2.1 through C406.2.2.2.3. Where individual equipment efficiencies vary, weigh them based on capacity.

C406.2.2.2.1 HVAC system selection. Equipment installed shall be types that are listed in the tables in Section C403.3.2.

C406.2.2.2.2 Cooling equipment efficiency. Equipment shall exceed the minimum cooling efficiency requirements listed in the tables in Section C403.3.2 by at least 5 percent. Where equipment exceeds the minimum annual cooling efficiency and heat rejection efficiency requirements by more than 5 percent, energy efficiency credits for cooling shall be determined using Equation 4-15, rounded to the nearest whole number.

$$EEC_{HEC} = EEC_5 \times \left[1 + \frac{CEI - 0.05}{0.05} \right] \quad \text{(Equation 4-15)}$$

Where:

EEC_{HEC} = Energy efficiency credits for cooling efficiency improvement.

EEC_5 = Section C406.2.2.2 credits from Table C406.2(1).

CEI = The lesser of the improvement above minimum cooling efficiency requirements, minimum heat rejection efficiency requirements, or 20 percent (0.20). Where cooling efficiency varies by system, use the capacity weighted average efficiency improvement for all cooling equipment combined. The CEI expressed as a fraction shall be determined one of the following ways:

For metrics that increase as efficiency increases, CEI shall be calculated as follows:

$$CEI = \frac{CM_{DES}}{CM_{MIN}} - 1$$

For metrics that decrease as efficiency increases, CEI shall be calculated as follows:

$$CEI = \frac{CM_{MIN}}{CM_{DES}} - 1$$

Where:

CM_{DES} = Design cooling efficiency metric, part-load or annualized where available.

CM_{MIN} = Minimum required cooling efficiency metric, part-load or annualized where available from Section C403.3.2.

For data centers using ASHRAE 90.4, CEI shall be calculated as follows:

$$CEI = \frac{AMLC_{MAX}}{AMLC_{DES}} - 1$$

Where:

$AMLC_{DES}$ = As-designed annualized mechanical load component calculated in accordance with ASHRAE 90.4 Section 6.5.

$AMLC_{MAX}$ = Maximum annualized mechanical load component from ASHRAE 90.4 Table 6.5.

C406.2.2.2.3 Minimum fan efficiency. Where fan energy is not included in packaged equipment rating or it is and the fan size has been increased from the as-rated equipment condition, fan power or horsepower shall be less than 95 percent of the allowed fan power in Section C403.8.1.

C406.2.2.3 More efficient HVAC equipment heating performance. No less than 90 percent of the total HVAC capacity serving the total *conditioned floor area* of the entire building, building addition or tenant space in accordance with Section C406.1.1 shall comply with Sections C406.2.2.3.1 through C406.2.2.3.2.

C406.2.2.3.1 HVAC system selection. Equipment installed shall be types that are listed in the tables in Section C403.3.2. Electric resistance heating shall be limited to 20 percent of system capacity, with the exception of heat pump supplemental heating. No HVAC systems incorporating fossil fuel-fired equipment, or heat from district energy systems that are primarily heated by fossil fuel combustion, are permitted to utilize this credit unless the Section C401.3 fossil fuel compliance path is utilized for energy code compliance.

C406.2.2.3.2 Heating equipment efficiency. Equipment shall exceed the minimum heating efficiency requirements of the tables in Section C403.3.2 by at least 5 percent. Where equipment exceeds the minimum annual heating efficiency requirements by more than 5 percent, energy efficiency credits for heating shall be determined using Equation 4-16, rounded to the nearest whole number.

$$EEC_{HEH} = EEC_5 \times \left[1 + \frac{HEI - 0.05}{0.05} \right] \tag{Equation 4-16}$$

Where:

EEC_{HEH} = Energy efficiency credits for heating efficiency improvement.

EEC_5 = Section C406.2.2.2 credits from Table C406.2(1).

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HEI = The lesser of the improvement above minimum heating efficiency requirements or 20 percent (0.20). Where heating efficiency varies by system, use the capacity weighted average percentage for all heating equipment combined. For metrics that increase as efficiency increases, HEI shall be calculated as follows:

$$HEI = \frac{HM_{DES}}{HM_{MIN}} - 1$$

Where:

HM_{DES} = Design heating efficiency metric, part-load or annualized where available.

HM_{MIN} = Minimum required heating efficiency metric, part-load or annualized where available from Section C403.3.2.

EXCEPTION: In low energy spaces complying with Section C402.1.1 and *semi-heated spaces* complying with Section C402.1.1.2, no less than 90 percent of the installed heating capacity is provided by electric infrared or gas-fired radiant heating equipment for localized heating applications. Such spaces shall achieve credits for EEC₅.

C406.2.2.4 Improved low-carbon district energy systems (10 percent better). Not less than 90 percent of the annual service hot water and space heating load, or not less than 90 percent of the annual service hot water, space heating, and space cooling load shall meet the criteria of Section C406.2.2.4.1 or C406.2.2.4.2.

Documentation for the low-carbon district system that is operational prior to the final inspection shall be provided to demonstrate that the definition as modified in Section C406.2.2.4.1 or C406.2.2.4.2 of *low-carbon district energy exchange system* is satisfied.

C406.2.2.4.1 Improved low-carbon district energy exchange systems (10 percent better). Low-carbon district energy exchange systems must demonstrate the following:

1. Forty-five percent of the annual district-system-net-load-met (sum of heating and cooling energy provided to attached buildings) comes from heat recovery between connected buildings, waste heat, or renewable energy resources; and
2. No more than 25 percent of the annual heat input to the system comes from fossil fuel or electric-resistance sources.

C406.2.2.4.2 Improved low-carbon district energy heating and cooling or heating only systems (10 percent better). Distribution losses must be accounted for and may not exceed 5 percent of the annual load delivered to buildings served by the system. *Low-carbon district energy heating and cooling or heating only systems* must demonstrate the following:

1. Forty-five percent of the annual district-system-net-load-met (sum of heating and cooling energy provided to attached buildings) comes from heat recovery between connected buildings, waste heat, or renewable energy resources and no more than 25 percent of the annual heat input to the system comes from fossil fuel or electric-resistance sources; or
2. No more than 10 percent of the system annual heat input to the system comes from fossil fuels or electric-resistance sources. The remaining annual heat input must be provided using heat pump technology with a minimum annual operating COP of 3.0.

C406.2.2.5 Improved low-carbon district energy systems (20 percent better). Not less than 90 percent of the annual service hot water and space heating load, or not less than 90 percent of the annual service hot water, space heating, and space cooling load shall meet the criteria of Section C406.2.2.5.1 or C406.2.2.5.2.

Documentation for the low-carbon district system that is operational prior to the final inspection shall be provided to demonstrate that the definition as modified in Section C406.2.2.4.1 or C406.2.2.4.2 of *low-carbon district energy exchange system* is satisfied.

C406.2.2.5.1 Improved low-carbon district energy exchange systems (20 percent better). Low-carbon district energy exchange systems must demonstrate the following:

1. Fifty percent of the annual district-system-net-load-met (sum of heating and cooling energy provided to attached buildings) comes from heat recovery between connected buildings, waste heat, or renewable energy resources; and
2. No more than 10 percent of the annual heat input to the system comes from fossil fuel or electric-resistance sources.

C406.2.2.5.2 Improved low-carbon district energy heating and cooling or heating only systems (20 percent better). Distribution losses must be accounted for and may not exceed 5 percent of the annual load delivered to buildings served by the system. *Low-carbon district energy heating and cooling or heating only systems* must demonstrate the following:

1. Fifty percent of the annual district-system-net-load-met (sum of heating and cooling energy provided to attached buildings) comes from heat recovery between connected buildings, waste heat, or renewable energy resources and no more than 10 percent of the annual heat input to the system comes from fossil fuel or electric-resistance sources; or
2. No more than 10 percent of the system annual heat input to the system comes from fossil fuels or electric-resistance sources. The remaining annual heat input must be provided using heat pump technology with a minimum annual operating COP of 4.0.

C406.2.2.6 High performance dedicated outdoor air system (DOAS). No less than 90 percent of the total conditioned floor area of the whole project, excluding floor area of unoccupied spaces that do not require ventilation as specified by the *International Mechanical Code*, shall be served by DOAS installed in accordance with Section C403.3.5 with the following adjustments:

1. Minimum heat recovery sensible effectiveness of 80 percent, calculated in accordance with Section C403.3.5.1, or C403.7.6.1 for R-2 occupancies.
2. Where design outdoor airflow is greater than 500 cfm (250 L/s), the DOAS shall be equipped with an economizer bypass, damper control, or wheel speed control that is active between 55°F (13°C) and 75°F (24°C) outdoor air temperature and minimizes energy recovery or maintains an appropriate DOAS leaving air temperature when the building is generally in cooling, based either on outdoor air temperature or a DDC zone-based cooling system reset.
3. DOAS total combined fan power shall comply with the fan power limits in Table C403.8.4 where applicable and shall be less than either:
 - 3.1. 0.769 W/cfm (1.55 W/L/s) when calculated in accordance with Section C403.3.5.2.
 - 3.2. Eighty percent of fan power allowance for a constant volume system when calculated in accordance with Section ~~((C406.8.1))~~ C403.8.1.

This option is not available to areas served by systems utilizing Section C403.2.2.1 exception 5. No HVAC systems incorporating fossil fuel-fired equipment, or heat from district energy systems that are primarily heated by fossil fuel combustion, are permitted to utilize this credit unless the Section C401.3 fossil fuel compliance path is utilized for energy code compliance.

C406.2.2.7 Fault detection and diagnostics system. A project not required to comply with Section C403.2.3 or C403.6.10(16) shall achieve energy credits for installing a fault detection and diagnostics system to monitor the HVAC system's performance and automatically identify faults. The installed system shall comply with items 1 through 6 in Section C403.2.3.

C406.2.3 Reduced lighting power. Interior lighting within the whole project, consisting of a whole building, building area, occupancy type, building addition, or tenant space, shall achieve credits by complying with Section C406.2.3.1 or C406.2.3.2. In Group R-1 and Group R-2 occupancies, dwelling and sleeping units shall comply with Section C406.2.3.3 and all other areas shall comply with section C406.2.3.1 or C406.2.3.2. Credits apply to the whole Group R-1 or Group R-2 area.

C406.2.3.1 Reduced lighting power option 1. The total connected interior lighting power calculated in accordance with Section C405.4.1 shall be 90 percent or less of the lighting power values specified in Table C405.4.2(1) times the floor area for the building types, or 90 percent or less of the total interior lighting power allowance calculated in accordance with Section C405.4.2.

C406.2.3.2 Reduced lighting power option 2. The total connected interior lighting power calculated in accordance with Section C405.4.1 shall be 80 percent or less of the lighting power values specified in Table C405.4.2(1) times the floor area of the building types, or 80 percent or less of the total interior lighting power allowance calculated in accordance with Section C405.4.2.

C406.2.3.3 Lamp efficacy. No less than 95 percent of the permanently installed light fixtures in dwelling units and sleeping units shall be provided by lamps with a minimum efficacy of 90 lumens per watt.

C406.2.4 Lighting controls. For buildings with nontransient dwelling units and sleeping units, energy credits shall be achieved by installation of systems that comply with the requirements of Section C406.2.4.1. All other buildings shall achieve energy credits by complying with Section C406.2.4.2. For buildings with mixed occupancies, credits shall be prorated based on floor area.

C406.2.4.1 Residential building lighting control. In buildings with nontransient *dwelling units* and *sleeping units*, lighting controls shall be configured to meet the following:

1. Each *dwelling unit* or *sleeping unit* shall have a main control by the main entrance that turns off all the lights and switched receptacles in the unit. The main control shall be permitted to have two controls, one for permanently wired lighting and one for switched receptacles. The main controls shall be clearly identified as "lights master off" and "switched outlets master off."

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2. Switched receptacles shall be clearly identified and all switched receptacles shall be located within 12 inches of an unswitched receptacle. Each room shall have a minimum of two switched receptacles except bathrooms, kitchens, and closets.

C406.2.4.2 Enhanced digital lighting controls. Measure credits shall be achieved where no less than 50 percent of the gross floor area within the project has luminaires and lighting controls that include high end trim in compliance with Section C405.2.8.3 and either *luminaire-level lighting controls* in compliance with Section C405.2.8.1 or networked lighting controls in accordance with Section C405.2.8.2. Open office areas subject to the requirements of Section C405.2.8 are not permitted to take credit for this option. Where *general lighting* in more than 50 percent of the gross floor area complies, the base credits from Table C406.2(1) shall be prorated as follows:

$$[\text{Floor area with high end trim, \%}] \times [\text{Base energy credits for C406.2.4.2}] / 50\%$$

C406.2.5 On-site and off-site renewable energy. Projects installing on-site or off-site renewable energy systems with a capacity of at least 0.1 watts per gross square foot (1.08 W/m²) of building area in addition to the renewable energy capacity required elsewhere in this code shall achieve energy credits for this measure. Renewable energy systems achieving energy credits shall not be used to satisfy other requirements of this code. Off-site renewable energy systems shall comply with Sections C411.2.2 and C411.2.3. Credits shall be prorated from the table value in accordance with Equation 4-17.

$$AEC_{RRa} = AEC_b \times \frac{\sum(REF \times RR_t) - RR_r}{RR_b \times PGFA} \quad \text{(Equation 4-17)}$$

Where:

AEC_{RRa}	= Section C406.2.5 achieved energy credits for this project as calculated in accordance with Equation 4-17, limited to 50 percent of the required credits in Section C406.1.
RR_t	Actual total rating of on-site and off-site renewable energy systems (W) for each type of renewable energy source in Table C411.2.1.
RR_r	Rating of renewable energy systems required by Section C411.1, other sections in this code, or used to qualify for exceptions in this code (W).
RR_b	= 0.1 W/square foot (1.08 W/m ²)
PGFA	= Project gross floor area, square feet (m ²).
AEC_b	= Section C406.2.5 base credits from Table C406.2(1).
REF	= Renewable Energy Factor from Table C411.2.1.

Informative Note: On-site renewable energy may include thermal service water heating or pool water heating, in which case ratings in Btu/h can be converted to W where $W = \text{Btu/h} / 3.413$.

C406.2.6 Reduced energy use in service water heating. Buildings with service hot water heating equipment that serves the whole building, building addition or tenant space shall achieve credits through compliance with:

1. Section C406.2.6.1, C406.2.6.2, or C406.2.6.3.
2. Sections C406.2.6.1 and C406.2.6.2.
3. Sections C406.2.6.1 and C406.2.6.3.

No service water heating systems incorporating fossil fuel-fired equipment, or heat from district energy systems that are primarily heated by fossil fuel combustion, are permitted to utilize this credit.

C406.2.6.1 Shower drain heat recovery. Shower drain heat recovery units shall comply with Section C404.10 and preheat cold water supply to the showers. Potable waterside pressure loss shall be less than 10 psi (69 kPa) at maximum design flow. The efficiency of drain water heat recovery units shall be no less than 54 percent in accordance with CSA B55.1. Full credits are applicable to the following building use types: Multi-family, hotel, motel, dormitory, and schools with locker room showers. Where not all showers in the project have drain heat recovery, the credit is adjusted based on the following:

$$[\text{Section C406.2.6.1 table credits}] \times [\text{Showers with drain recovery}] / [\text{Total number of showers}]$$

C406.2.6.2 Service water heating energy recovery. Not less than 30 percent of the annual service hot water heating energy use, or not less than 70 percent of the annual service hot water heating energy use in buildings with condenser water systems subject to the requirements of Section C403.9.2.1 or qualifying for one of its exceptions, shall be provided by one or more of the following:

1. Waste heat recovery from service hot water, heat recovery chillers, building equipment, process equipment, or other *approved* system. Qualifying heat recovery must be above and beyond heat recovery required by other sections of this code.
2. On-site renewable energy water-heating systems where not used to meet other requirements or to obtain other energy credits.

C406.2.6.3 Heat pump water heating. Projects shall achieve credits through compliance with Section C406.2.6.3.1.

C406.2.6.3.1 Heat pump water heater. Credit shall be achieved where the primary heat pump service water heating system is sized to deliver no less than 100 percent of the net calculated demand for service water production during the peak demand period with entering dry bulb or wet bulb outdoor air temperature at 40°F (4°C) for air-source heat pumps, or 44°F (7°C) ground temperature for ground-source heat pumps, as calculated using the equipment manufacturer's selection criteria or another *approved* methodology. For this credit, the net calculated demand shall be the gross building demand less any portion of the demand complying with the exceptions to Section C404.2.1. Supplemental heating is permitted in accordance with Section C404.2.1, but cannot use fossil fuels. The refrigerant used in the heat pump system must have a global warming potential (GWP) no greater than 680. Heat pump water heaters shall comply with one of the following:

1. The COP rating shall be a minimum COP of 3.0 reported at the design leaving heat pump water temperature with an entering air temperature of 60°F (16°C) or lower. For water-source equipment, the COP rating will be reported at the design leaving load water temperature with an entering load water temperature of 74°F (23°C) or lower.
2. The uniform energy factor (UEF) shall be a minimum of 3.40 rated based on U.S. Department of Energy requirements.

C406.2.6.4 High efficiency service water heating, gas-fired. The credit achieved shall be from Table C406.2(2) where hot water is supplied by gas-fired equipment with minimum efficiency of 0.91 UEF.

C406.2.7 Improved service hot water temperature maintenance. For buildings with gross floor area greater than 10,000 square feet, credit shall be achieved when hot water temperature maintenance is installed in accordance with Section C406.2.7.1 or C406.2.7.2.

C406.2.7.1 Self-regulated heat trace system. The credit achieved shall be from Table C406.2(1). This system shall include self-regulating electric heat cables, connection kits and electronic controls. The cable shall be installed directly on the hot water supply pipes underneath the insulation to replace standby losses.

C406.2.7.2. Point of use water heater. The credit achieved shall be from Table C406.2(1) where any fixtures requiring hot water shall be supplied from a localized electric source of hot water with no recirculation or heat trace and limited to 2 kW and 6 gallons of storage. The supply pipe length from the point of use water heater to the termination of the fixture supply pipe shall be no more than 20 feet.

C406.2.8 Service hot water distribution right sizing. To achieve this credit, where Group ~~((R-1 and R-2))~~ occupancies are served by a central service hot water system, the distribution system serving *dwelling units* ~~((= sleeping units and guestrooms))~~ shall be sized using Appendix M of the *Uniform Plumbing Code*.

SDCI Informative Note: Section C404.3.3 requires use of UPC Appendix M for determining demand load, and permits pipes to be one pipe size larger than the minimum determined using that demand load. However, this credit requires use of the minimum pipe sizes permitted by the demand load as determined using UPC Appendix M.

C406.2.9 High performance service hot water temperature maintenance system. Systems with multiple riser service hot water circulation systems shall use only heat pump technology for temperature maintenance. The heat pump technology shall have a minimum COP of 3.0 or UEF of 3.4. For air-source equipment, the COP rating will be reported at the design leaving heat pump water temperature with an entering dry bulb air temperature of 60°F (16°C) or lower and a relative humidity of 50 percent or lower. For water-source equipment, the COP rating will be reported at the design leaving load side water temperature with an entering source side water temperature of 74°F (23°C) or lower. The system shall comply with the requirements of Section C404.7.1.

C406.2.10 High efficiency service hot water circulation system. Multiple riser service hot water circulation systems shall use a variable volume circulation pump controlled to vary the pump speed based on system demand and shall include self-actuated thermostatic balancing valves to control the system flow at each riser.

C406.2.11 Low flow showerheads for Group R-1 and R-2 occupancies. All showerheads installed in Group R-1 and R-2 *dwelling units* or *sleeping units* shall have a maximum listed flowrate of 1.25 gallons per minute or less at 80 psi operating pressure for fixed showerheads and a maximum listed flowrate of 1.50 gallons per minute or less at 80 psi operating pressure for handheld showerheads. When a shower is served by more than one showerhead, including handheld showerheads, the combined flow rate of all showerheads and/or other shower outlets controlled by a single valve shall not exceed

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1.25 gallons per minute or less for fixed or 1.5 gallons per minute or less for handheld, or the shower shall be designed to allow only one shower outlet to be in operation at a time.

C406.2.12 Enhanced envelope performance. The Proposed Total UA of the thermal envelope of the project shall be 15 percent lower than the Allowable Total UA determined in accordance with Section C402.1.5 and Equation 4-2.

C406.2.13 Reduced air leakage. Energy credits shall be achieved where measured air leakage of the total *conditioned floor area* of the whole building, fully isolated building addition or tenant space is determined in accordance with Section C402.5.1.2 and complies with the maximum leakage in either Section C406.2.13.1 or C406.2.13.2.

C406.2.13.1 Base reduced air leakage. Measured air leakage shall not exceed 68 percent of the maximum leakage allowed by Section C402.5.1.2.

C406.2.13.2 Enhanced reduced air leakage. Measured air leakage shall not exceed 33 percent of the maximum leakage allowed by Section C402.5.1.2.

~~((C406.2.14 Enhanced commercial kitchen equipment. For buildings or areas designated as Group A-2, or facilities whose primary business type involves the use of a commercial kitchen with at least one gas or electric fryer, all fryers, dish washers, steam cookers and ovens shall comply with all of the following:-~~

~~1.— Achieve the ENERGY STAR label in accordance with the specifications current as of January 1, 2022.~~

~~2.— Be installed prior to the issuance of the certificate of occupancy.~~

~~3.— Have the ENERGY STAR qualified model number listed on the construction documents submitted for permitting.~~

~~Energy efficiency credits for efficient commercial kitchen equipment shall be determined based on Equation 4-19, rounded to the nearest whole number.))~~

SDCI Informative Note: Energy Star commercial kitchen equipment is required for all commercial kitchen projects by Section C405.14.

C406.2.15 Residential kitchen equipment. For projects with Group R-1 and R-2 occupancies, energy credits shall be achieved where not less than 90 percent of dishwashers, refrigerators, and freezers comply with all of the following:

1. Achieve the ENERGY STAR Most Efficient label in accordance with the 2021 specifications.
2. Be installed prior to the issuance of the certificate of occupancy.

For Group R-1 where only some guestrooms are equipped with both refrigerators and dishwashers, the table credits shall be prorated as follows:

$$[\text{Section C406.2.15 table credits}] \times [\text{Floor area of guestrooms with kitchens}] / [\text{Total guestroom floor area}]$$

C406.2.16 Residential laundry appliances. For projects with Group R-2 occupancies, energy credits shall be achieved where not less than 90 percent of clothes washers and dryers in the project meet the following requirements:

1. Each dwelling unit contains in-unit washing washer and dryer equipment that meets the following requirements:
 - 1.1. Achieve the ENERGY STAR Most Efficient label in accordance with the 2021 specifications.
 - 1.2. Be installed prior to the issuance of the certificate of occupancy.
2. Where only some dwelling units are equipped with both washers and dryers, the table credits shall be prorated as follows:

$$[\text{Section C406.2.16 table credits}] \times [\text{Floor area of dwelling units with laundry}] / [\text{Total dwelling unit floor area}]$$

C406.2.17 Heat pump clothes dryers. Not less than 90 percent of domestic clothes dryers located in Group R-1 and R-2 of the whole project are ENERGY STAR rated heat pump dryers. Credit applies only to buildings where laundry facilities are provided either within each residential dwelling or sleeping units or grouped together in central multi-family use laundry rooms, or a mix of the two.

To claim this credit, the building permit drawings shall specify the appliance type and provide documentation of ENERGY STAR compliance. At the time of inspection, all appliances shall be installed and connected to utilities.

C406.2.18 Efficient elevator equipment. Qualifying elevators in the building shall be Energy Efficient Class A in accordance with ISO 25745-2, Table 7. Only buildings three or more floors above grade shall be permitted to use this credit. Credits shall be prorated based on Equation 4-18, rounded to the nearest whole credit. Projects with a compliance ratio (CR_e in Equation 4-18) below 0.5 do not qualify for this credit.

$$EC_e = EC_t \times CR_e \quad \text{(Equation 4-18)}$$

Where:

- EC_e = Elevator energy credit achieved for building.
- EC_t = Section C406.2.18 table energy credit.

$$CR_e = \frac{F_A}{F_B}$$

- F_A = Sum of floors served by Class A elevators.
- F_B = Sum of floors served by all building elevators and escalators.

C406.3 Load management credits. Load management measures installed in the building that meet the requirements in Sections C406.3.1 through C406.3.7 shall achieve the credits listed for the occupancy group in Table C406.3 or where calculations required by Sections C406.3.1 through C406.3.7 create or modify the table credits the credits achieved will be based upon the section calculations.

Each load management measure shall require automatic controls activated by either utility demand response, utility price response signal, peak price period time control, or local building demand monitoring. Controls shall be capable of and configured to provide the required load management sequences. As used in this section, “peak period” shall be either the coincident peak building load period, the peak price period, the peak utility load period, or the peak building demand period. The following additional requirements apply to these measures:

1. Where credit is taken for C406.3.6, service water heating energy storage, the equipment shall be provided with controls that comply with ANSI/CTA 2045-B.
2. For load management measures in Sections C406.3.1 through C406.3.5:
 - 2.1. Where the serving utility has a real-time demand response or pricing program, an interface compliant with serving utility requirements shall be installed.
 - 2.2. Where the serving utility does not have a real-time demand response or pricing program, a digital input to the system to support future utility programs shall be installed and building demand monitoring shall be installed and integrated into the load management sequence.
 - 2.3. All equipment involved in the required load management sequence shall have controls connected to a central DDC system.

Table C406.3
Load Management Measure Credits

Measure Title	Applicable Section	Occupancy Group					
		Group R-1	Group R-2	Group B	Group E	Group M	All Other
1. Lighting load management	C406.3.1	12	15	27	15	NA	NA
2. HVAC load management	C406.3.2	29	24	42	23	13	26
3. Automated shading	C406.3.3	NA	7	12	16	NA	NA
4. Electric energy storage	C406.3.4	41	50	126	72	37	65
5. Cooling energy storage	C406.3.5	13	10	14	19	NA	14
6. Service hot water energy storage	C406.3.6	31	248	59	8	5	70
7. Building thermal mass	C406.3.7	NA	NA	50	95	96	80

C406.3.1 Lighting load management. Automatic controls shall be capable of gradually reducing general lighting power with continuous dimming in 75 percent of the building area by at least 20 percent during peak demand periods. Where less than 75 percent, but at least 50 percent, of the building area lighting is controlled, the credits from Table C406.3 shall be prorated as follows:

$$\frac{[Area\ of\ building\ with\ lighting\ load\ management,\ \%]}{75\%} \times [Table\ credits\ for\ C406.3.1]$$

EXCEPTION: Warehouse or retail storage building areas shall be permitted to achieve this credit by switching off at least 25 percent of lighting power in 75 percent of the building area without dimming.

C406.3.2 HVAC load management. Automatic controls shall:

1. Where electric cooling is used, be configured to gradually increase, over a minimum of three hours, the cooling setpoint by at least 3°F during the summer peak periods.

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2. Where electric heating is used, be configured to gradually reduce, over a minimum of three hours, the heating setpoint by at least 3°F during winter peak periods.

C406.3.3 Automated shading load management. Where fenestration on south and west exposures exceeds 20 percent of the wall area, automatic controls shall be configured to operate movable exterior shading devices or dynamic glazing to reduce solar gain through sunlit fenestration on southern and western exposures by at least 50 percent during summer peak periods.

Informative Note: This credit can be met by exterior roller, movable blind or movable shutter shading devices; however, fixed overhang, screen or shutter shading will not meet the requirement. Roller shades that reject solar gain but still allow a view are allowed as long as they provide an effective 50 percent reduction in net solar gain (e.g., have a shading coefficient of less than 0.5 for the shading material itself). Interior shading devices will not meet the requirement. Electrochromatic windows that achieve 50 percent of SHGC would qualify.

C406.3.4 Electric energy storage. Automatic controls shall store electricity in electric storage devices during nonpeak periods and use stored energy during peak periods. Electric storage devices shall have a minimum capacity of 5 Wh/ft² (58 Wh/m²) of gross building area. For greater storage capacity up to 15 Wh/ft² (160 Wh/m²), credits shall be prorated as follows:

$$[\text{Installed electric storage capacity, Wh/ft}^2]/5 \times [\text{C406.3.4 credits from Table C406.3}]$$

C406.3.5 Cooling energy storage. Automatic controls shall be capable of activating ice or chilled water storage to reduce peak period electric demand. Credits shown in Table C406.3 are based on storage capacity of 2 ton-hours per design day ton of cooling load (2 kWh per design day kW) with a 1.15 sizing factor. Credits shall be prorated for installed storage systems sized between 0.5 and 3.5 ton-hours per design day ton (kWh per design day kW) of cooling load rounded to the nearest whole credit. The storage tank shall have no more than 1.5 percent of storage capacity standby loss per day.

C406.3.6 Service hot water energy storage. To achieve this credit, where service hot water is heated by electricity, automatic controls shall preheat stored service hot water before the peak period and suspend electric water heating during the peak period. Storage capacity shall be provided by either:

1. Preheating water above 140°F (60°C) delivery temperature with at least 1.34 kWh of energy storage per kW of water heating capacity. Tempering valves shall be provided at the water heater delivery location.
2. Providing additional heated water tank storage capacity above peak service hot water demand with equivalent peak storage capacity to item 1.

C406.3.7 Building thermal mass. To achieve this credit, the building shall have both additional passive interior mass and a night-flush control of the HVAC system.

1. Interior to the *building thermal envelope* insulation, provide 15 pounds of passive thermal mass per square foot of building floor area. Mass construction shall be in the building interior and the indoor facing portion of the exterior wall, and interior floor construction. Mass construction shall have mass surfaces in direct contact with the air in conditioned spaces with directly attached wall board or hard surface flooring allowed. Mass with carpet or furred wallboard shall not be counted toward the building mass required. For integral insulated concrete block walls complying with ASTM C90, only the mass of the interior face shall be counted toward the building mass required.
2. When summer mode is active and indoor average temperature is 5°F (3°C) or more above outdoor temperature and between 10:00 p.m. and 6:00 a.m., *automatic* night flush controls shall operate outdoor air economizers at low fan speed less than 66 percent during the unoccupied period until the average indoor air temperature falls to the occupied heating setpoint. Summer mode shall be activated when outdoor air exceeds 70°F (21°C) and continues until deactivated when outdoor air falls below 45°F (7°C). Another night flush strategy shall be permitted where demonstrated to be effective, avoids added morning heating and is *approved* by the *code official*.

Informative Note: The simplified night flush sequence described will operate in “summer mode” below the 70°F outdoor air trigger temperature down until outdoor air of 45°F is hit when the “summer mode” is deactivated until the outdoor air temperature rises above 70°F again. Other strategies may be implemented that cool the space below the heating setpoint and adjust the morning heating setpoint to avoid morning reheating.

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.

EXCEPTION: Energy used to recharge or refuel vehicles that are used for on-road and off-site transportation purposes.

C407.2 Mandatory requirements. Compliance with Section C407 also requires compliance with those sections shown in Table C407.2.

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~~) start of building construction. 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 in the baseline in accordance with ANSI/ASHRAE/IESNA 90.1 Appendix G and in the proposed model in accordance with the requirements of the (~~Washington State~~) Seattle Energy Code.

**Table C407.2
Mandatory Compliance Measures for Total Building Performance Method**

Section ^a	Title	Comments
Envelope		
C401	Thermal envelope certificate	
C402.2.7	Airspaces	
C402.5	Air leakage	
Mechanical		
C403.1.2	Calculation of heating and cooling loads	
C403.1.3	Data centers	
C403.2	System design	
C403.3.1	Equipment and system sizing	
C403.3.2	HVAC equipment performance requirements	
C403.3.3	Hot gas bypass limitation	
C403.3.4.4	Boiler turndown	
((C403.3.6	Ventilation for Group R occupancy))	
C403.4.1	Thermostatic controls	
C403.4.2	Off-hour controls	
C403.4.7	Combustion heating equipment controls	
C403.4.8	Group R-1 hotel/motel guestrooms	See Section C403.7.4
C403.4.9	Group R-2 and R-3 dwelling units	
C403.4.10	Group R-2 sleeping units	
C403.4.11	Direct digital control systems	
C403.5.5	Economizer fault detection and diagnostics (FDD)	
C403.7	Ventilation and exhaust systems	Except for C403.7.6.2
C403.8	Fan and fan controls	
C403.9.1.1	Variable flow controls	For cooling tower fans ≥ 7.5 hp
((C403.9.1.2))	Limitation on centrifugal fan cooling towers	For open cooling towers
<u>C403.9.1.3</u>		
C403.10	Construction of HVAC elements	
C403.11	Mechanical systems located outside of the building thermal envelope	
C403.14	Commissioning	
Service Water Heating		
C404	Service water heating	Except for C404.2.1
Lighting and Electrical		
C405	Electrical power and lighting systems	
Other Requirements		
C407	Total building performance	
C408	System commissioning	
C409	Energy metering	

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Table C407.2—continued
Mandatory Compliance Measures for Total Building Performance Method

Section ^a	Title	Comments
C410	Refrigeration requirements	
C411 ^b	Renewable energy	
C412	Compressed air systems	

a Reference to a code section includes all the relative subsections except as indicated in the table.

b Compliance with any of these sections includes compliance with any exception to that section.

C407.3 Performance-based compliance. Compliance with this section requires compliance with ASHRAE Standard 90.1 Appendix G, Performance Rating Method, in accordance with Standard 90.1 Section 4.2.1 with the following modifications:

1. The mandatory requirements of the ((Washington State)) Seattle Energy Code are required to be met, instead of those of Section G1.2.1a of ANSI/ASHRAE/IESNA 90.1
2. Compliance with Section C407 requires meeting both a regulated site energy target and a total site energy reduction target in accordance with the following:
 - 2.1. Regulated site energy target. The regulated site energy target is focused on regulated load energy efficiency, thus shall be met only via regulated load savings without consideration of the contribution of on-site or off-site renewable energy or unregulated load savings. Adjustments to the PCI, to account for the contribution of renewable energy found in ANSI/ASHRAE/IESNA 90.1 Section 4.2.1.1 shall not be used. References to energy cost in Section 4.2.1.1 and Appendix G shall be replaced by site energy use. Heating or cooling energy provided by a district energy system may utilize coefficient of performance (COP) ratios acceptable to the *code official* for the respective district energy sources. The building performance factors in Table 4.2.1.1 of ANSI/ASHRAE/IESNA 90.1 shall be replaced with those in Table C407.3(2).
 - 2.2. Total site energy target. The total site energy performance target shall be met including the contributions of on-site or off-site renewable energy as described in Section C411.2 as well as the contributions of improvements in unregulated loads as allowed by Section C407.3.4. The annual on-site and off-site renewable energy production (as adjusted by the factors in Table C411.2.1) shall be subtracted from the proposed building annual site energy use. Compliance with the site energy performance target requires that the proposed building site energy use/baseline building site energy use is less than or equal to the site energy performance target from Table C407.3(3).
3. Documentation requirements in Section G1.3.2.d shall be replaced by a list showing compliance with the mandatory provisions of Table C407.2.
4. Forms demonstrating compliance with Appendix G developed by the U.S. Department of Energy shall be completed and submitted to the *code official*. The forms are available at energycodes.gov/ashrae-standard-901-performance-based-compliance-form.
5. References to yet-to-be-designed future building components in the Proposed Building Performance column of Table G3.1 shall be modified to reference the corresponding sections of the ((Washington State)) Seattle Energy Code in lieu of the requirements of ANSI/ASHRAE/IESNA 90.1 in the following sections of the table:
 - 5.1. No. 1, Design Model, subclause c.
 - 5.2. No. 6, Lighting, subclause c.
 - 5.3. No. 11, Service Water Heating System, subclause c.
 - 5.4. No. 12, Receptacle and Other Loads, subclause b.
6. HVAC systems, subclauses c and d of Table G3.1, shall meet the following requirements:
 - 6.1. For yet-to-be-designed systems in office, retail, library, education, and multifamily buildings and occupancies subject to the TSPR requirements of Section C403.1.1, the system type and efficiency parameters in the proposed model shall meet but not exceed those shown in Table D602.11 Standard Reference Design HVAC Systems.
 - 6.2. For all other buildings and occupancies, the system type shall be the same as the system modeled in the baseline design and shall comply with but not exceed the requirements of Section C403 in lieu of ANSI/ASHRAE/IESNA 90.1.
 - 6.3. For HVAC systems serving future tenant spaces, where the current building permit applies to only a portion of an HVAC system, and future components will receive HVAC services from systems included in the current building permit, those future components shall be modeled as the type required to complete the HVAC system portions under the current permit and shall meet but not exceed the requirements found in Section C403.
7. The requirements for proposed and baseline building lighting system shall be modified in accordance with Addendum af to ANSI/ASHRAE/IESNA 90.1.

8. Energy modeler qualifications. The energy analyst in responsible charge of the Section C407 submittal shall meet at least one of the following:
 - 8.1. ASHRAE Building Energy Modeling Professional (BEMP) certification.
 - 8.2. Association of Energy Engineer’s Building Energy Simulation Analyst (BESA) certification.
 - 8.3. Successful completion of at least five projects modeled following any version of ANSI/ASHRAE/IESNA 90.1 Appendix G within the last three years that were reviewed and approved by a *code official* or rating authority.

SDCI Informative Note: The permit applicant is encouraged to schedule a pre-application meeting to discuss the modeling approach for any yet-to-be designed areas that are not included in the C407 permit submissions. In general, future permit submissions should not contribute energy savings to the C407 submission beyond prescriptive code requirements, assuming use of the base building HVAC systems. Future systems must be modeled for the base building permit as being no better than the current prescriptive code, because plans often change and the City does not have a mechanism for ensuring that future tenant projects meet any beyond-code performance modeled in the original C407 submission.

**Table C407.3(1)
Carbon Emissions Factors**

Type	CO ₂ e (lb/unit)	Unit
Electricity	0.44	kWh
Natural gas	11.7	Therm
Oil	19.2	Gallon
Propane	10.5	Gallon
Other ^a	195.00	mmBtu
On-site renewable energy	0.00	

^a District energy systems may use alternative emissions factors supported by calculations approved by the *code official*.

**Table C407.3(2)
Building Performance Factors (BPF) to be used for Compliance with Section C407.3**

Building Area Type	Building Performance Factor
Multifamily	0.51
Health care/hospital	0.70
Hotel/motel	0.51
Office	0.44
Restaurant	0.33
Retail	0.41
School	0.35
Warehouse	0.18
All others	0.43

**Table C407.3(3)
Site Energy Performance Targets to be used for Compliance with Section C407.3**

Building Area Type	Site Energy Performance Targets
Multifamily	0.59
Health care/hospital	0.72
Hotel/motel	0.62
Office	0.58
Restaurant	0.59
Retail	0.46
School	0.52
Warehouse	0.29
All others	0.55

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C407.3.1 Limits on ((~~nonmandatory measures~~)) substandard building envelopes. The Proposed Total UA of the proposed building shall be no more than ((~~29~~)) 10 percent higher than the Allowed Total UA as defined in Section C402.1.5.

C407.3.2 On-site and off-site renewable energy accounting for use with Appendix G. Qualifying on-site and off-site renewable energy delivered or credited to the building project to comply with Section C407.3 item 2.2 shall meet the requirements of Section C411.2.

C407.3.3 Low-carbon district energy use with Appendix G. Qualifying *low-carbon district heating and cooling or heating only systems* and *low-carbon district energy exchange systems* shall meet the requirements of Section C407.3.3.1 or C407.3.3.2, as applicable.

C407.3.3.1 Utilization of low-carbon district heating and cooling or heating only systems. Applicable if heating and cooling or heating only is provided to the *proposed building* from a *low-carbon district heating and cooling or heating only system* that is fully operational prior to the final inspection. Proposed model shall account for all on-site HVAC and service hot water related equipment, such as circulation pump energy and heat-exchanger efficiency.

1. The following modifications shall be applied to Appendix G of ANSI/ASHRAE/IESNA 90.1 in addition to what is described in Section C407.3:
 - 1.1. For low-carbon district heating and cooling systems, strike the text of Sections G3.1.1.1, G3.1.1.2, G3.1.1.3.1, G3.1.1.3.3, and G3.1.1.3.4. Baseline system shall be selected based on unmodified versions of Tables G3.1.1-3 and G3.1.1-4, comparing energy use to determine compliance.
 - 1.2. For low-carbon district heating only systems, strike the text of Sections G3.1.1.1, G3.1.1.3.1, and G3.1.1.3.4. Baseline system shall be selected based on unmodified versions of Tables G3.1.1-3 and G3.1.1-4, with carbon emission factors from Table C407.3(1).
2. Any heating or cooling energy provided by the *low-carbon district heating and cooling or heating only system* shall utilize a calculated energy use reduction factor acceptable to the code official to account for energy use reduction from those end uses.
3. Energy “credit” for any waste/recoverable heat exported to the *low-carbon district heating and cooling or heating only systems* shall be accounted for in the proposed design by multiplying the quantity of heat exported by the appropriate seasonal utilization factor in Items 3.1 and 3.2 below. This energy “credit” is subtracted from the total proposed design energy use calculated in accordance with ASHRAE 90.1 Section 4.2.1.1.
 - 3.1. Fifty percent of the waste heat exported to the *low-carbon district heating and cooling or heating only systems* during the months of October through December and January through March.
 - 3.2. Twenty-five percent of the waste heat exported to the *low-carbon district heating and cooling or heating only systems* during the months of April through September.

EXCEPTION: Waste heat exported from the building to the *low-carbon district heating and cooling or heating only system* shall not be subtracted from the proposed design energy use if they are already accounted for in the calculation of energy use from the district heating or cooling plant as part of the *district energy efficiency factor*.

Documentation for the low-carbon district system that is operational prior to the final inspection shall be provided to demonstrate the following:

1. Distribution losses must be accounted for and may not exceed 10 percent of the annual load delivered to buildings served by the system.
2. Twenty-five percent of the annual district-system-net-load-met (sum of heating and cooling energy provided to attached buildings) comes from heat recovery between connected buildings, waste heat or renewable energy resources and no more than 25 percent of the annual heat input to the system comes from fossil fuel or electric-resistance sources, or not more than 10 percent of the system annual heat input to the system comes from fossil fuel or electric-resistance sources.

C407.3.3.2 Utilization of low-carbon district energy exchange systems. Applicable if heating or cooling is provided to the *proposed building* from a *low-carbon district energy exchange system* that is fully operational prior to the final inspection. Proposed model shall account for all on-site HVAC and service hot water related equipment, such as circulation pump energy and heat-exchanger efficiency.

1. The following modifications shall be applied to Appendix G of ANSI/ASHRAE/IESNA 90.1 in addition to what is described in Section C407.3:
 - 1.1. Strike the text of Sections G3.1.1.1, G3.1.1.2, G3.1.1.3, G3.1.1.3.1, G3.1.1.3.2, G3.1.1.3.3, and G3.1.1.3.4. Baseline system shall be selected based on unmodified versions of Tables G3.1.1-3 and G3.1.1-4.

2. Any heating or cooling energy provided by a low-carbon district energy exchange system shall utilize a calculated energy use reduction factor acceptable to the *code official* to account for the reduction in the proposed model.
3. Energy use “credit” for any waste/recoverable heating exported to the *low-carbon district energy exchange system* shall be accounted for in the proposed design by multiplying the quantity of heat exported by the appropriate seasonal utilization factor in Items 3.1 and 3.2 below. This energy use “credit” is subtracted from the total proposed design energy use calculated in accordance with ASHRAE 90.1 Section 4.2.1.1.
 - 3.1. Fifty percent of the waste heat exported to the *low-carbon district energy exchange system* during the months of October through December and January through March.
 - 3.2. Twenty-five percent of the waste heat exported to the *low-carbon district energy exchange system* during the months of April through September.

EXCEPTION: Waste heat exported from the building to the *low-carbon district heating and cooling or heating only system* shall not be subtracted from the proposed design energy use if they are already accounted for in the calculation of energy use from the district heating or cooling plant as part of the *district energy efficiency factor*.

Documentation for the low-carbon district system that is operational prior to the final inspection shall be provided to demonstrate that the definition of *low-carbon district energy exchange system* is satisfied.

C407.3.4 Credit for improvements in unregulated loads when using Appendix G. When calculating savings for site energy targets in accordance with Section C407.3 item 2.2, but not when calculating savings for ((emissions)) *site energy* targets in accordance with Section C407.3 item 2.1, differences in the simulation of unregulated loads and equipment modeled in the baseline building design from those in the *proposed design* shall be approved by the *code official* based on documentation that the equipment installed in the *proposed design* represents a significant verifiable departure from documented current conventional practice. All unregulated equipment for which savings is claimed must be installed by the time of final inspection. The burden of this documentation is to demonstrate that accepted conventional practice would result in baseline building equipment different from that installed in the *proposed design*. Occupancy and occupancy schedules shall not be changed.

C407.3.4.1 Approved unregulated load types. Unregulated load types for which reductions of energy use are claimed shall be one of those listed in Table C407.3.4.1 or shall be approved and publicly listed by SDCI. Requests for approval of such load types shall include the identification with predicted energy use of the baseline case in addition to the identification with predicted energy use of the proposed alternate. Listings for specific load types may be withdrawn and made unavailable for subsequent permit applications in cases by SDCI where it is considered that the unregulated load type listed has become accepted conventional practice. Unregulated load savings shall follow the methodology outlined in this section, and not use the language from Appendix G Table G3.1 - No. 12 Receptacle and Other Load Baseline Building Performance Exception.

Table C407.3.4.1
Approved Unregulated Load Types

<u>In compliance with the requirements of section</u>	<u>Predicted energy reductions (%)</u>	
	<u>Group R-1</u>	<u>Group R-2</u>
<u>C406.2.15, Enhanced residential kitchen equipment</u>	<u>1.2</u>	<u>1.9</u>
<u>C406.2.16, Enhanced residential laundry equipment</u>	<u>N/A</u>	<u>0.6</u>
<u>C406.2.17, Heat pump clothes dryers</u>	<u>0.6</u>	<u>0.6</u>

SECTION C408
SYSTEM COMMISSIONING

C408.1 General. A building commissioning process led by a *certified commissioning professional* and functional testing requirements shall be completed for mechanical systems in Section C403; service water heating systems in Section C404; controlled receptacle and lighting control systems in Section C405; equipment, appliances and systems installed to comply with Sections C406 or C407; energy metering in Section C409; and refrigeration systems in Section C410.

EXCEPTION: Buildings, or portions thereof, which are exempt from Sections C408.2 through C408.7 may be excluded from the commissioning process.

1. Mechanical systems that are not required to comply with Section C403.3.5 are exempt from the commissioning process where the installed total mechanical equipment capacity is less than 180,000 Btu/h (15 tons) cooling capacity and less than 240,000 Btu/h (20 tons) heating capacity and energy recovery ventilation (ERV) equipment is less than 300 cfm capacity.

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2. Service water heating systems are exempt from the commissioning process in buildings where the largest service water heating system capacity is less than 200,000 Btu/h and where there are ~~((any))~~ none of the following:
 - 2.1. ~~((No))~~ pools or permanent spas.
 - 2.2. ~~((No))~~ solar thermal water heating.
 - 2.3. ~~((No))~~ recirculation pumps.
 - 2.4. ~~((No))~~ heat pump water heaters, except fully-packaged for individual residential dwelling unit use.
3. Lighting control systems are exempt from the commissioning process in buildings where both the total installed lighting load is less than 10 kW and the lighting load controlled by occupancy sensors or automatic daylighting controls is less than 5 kW.
4. Refrigeration systems are exempt from the commissioning process in buildings if they are limited to self-contained units.

C408.1.1 Commissioning in construction documents. Construction documents shall clearly indicate provisions for commissioning process. Electrical permit documents shall indicate required commissioning work for lighting and metering systems, and mechanical permit documents shall indicate required commissioning work for mechanical and water heating systems. The construction documents shall minimally include the following:

1. A narrative description of the activities that will be accomplished during the commissioning process. At a minimum, the commissioning process is required to include:
 - 1.1. Development and execution of the commissioning plan, including all subsections of Section C408.1.2;
 - 1.2. The *certified commissioning professional's* review of the building documentation and close out submittals in accordance with Section C103.6; and
 - 1.3. The commissioning report in accordance with Section C408.1.3.
2. Roles, responsibilities, and required qualifications of the *certified commissioning professional*.
3. A listing of the specific equipment, appliances, or systems to be tested.

C408.1.2 Commissioning plan. A commissioning plan shall be developed by the project's *certified commissioning professional*, shall be submitted to SDCI prior to the first mechanical inspection, and shall outline the organization, schedule, allocation of resources, and documentation requirements of the commissioning process.

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, systems testing and balancing, functional performance testing, and verification of the building documentation requirements in Section C103.6.
2. Roles and responsibilities of the commissioning team, including the name and statement of qualifications of the *certified commissioning professional*.
3. A listing of the specific equipment, appliances or systems to be tested and a description of the tests to be performed.

C408.1.2.1 In-house commissioning disclosure and conflict management plan. Where the *certified commissioning professional's* contract or employment is other than directly with the building owner, an in-house commissioning disclosure and conflict management plan shall be a part of the commissioning process. A copy shall be included in the commissioning plan. This plan shall disclose the *certified commissioning professional's* contractual relationship with other team members and provide a conflict management plan demonstrating that the *certified commissioning professional* is free to identify any issues discovered and report directly to the owner.

C408.1.2.2 Functional performance testing. Functional performance testing shall be conducted for mechanical systems in Sections C403; service water heating systems in Section C404; controlled receptacles and lighting control systems in Section C405; equipment, appliances, systems installed to comply with Section C406 or C407; energy metering in Section C409; and refrigeration systems in Section C410. Written procedures which clearly describe the individual systematic test procedures, the expected system response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion shall be followed. This testing shall include control systems which will be tested to document that control devices, components, equipment, and systems are calibrated and adjusted to operate in accordance with approved construction documents. Testing shall affirm the conditions required within Sections C408.2 through C408.7 under system testing.

C408.1.2.3 Functional performance testing - Sampling. For projects with 7 or fewer similar systems, each system shall be tested. For projects with more than 7 systems, testing shall be done for each unique combination of control types. Where multiples of each unique combination of control types exist, no fewer than 20 percent of each combination shall be tested unless the code official or design professional requires a higher percentage to be tested. Where 30 percent or more of the tested system fail, all remaining identical combinations shall be tested.

C408.1.2.4 Deficiencies. Deficiencies found during testing shall be resolved including corrections and retesting.

C408.1.3 Commissioning report. A commissioning report shall be completed and certified by the *certified commissioning professional* and delivered to the building owner or owner's authorized agent. The report shall be organized with mechanical, service water heating, controlled receptacle and lighting control systems, energy metering, and refrigeration findings in separate sections to allow independent review. The report shall record the activities and results of the commissioning process and be developed from the final commissioning plan with all of its attached appendices. The report shall be submitted to SDCI prior to the final inspection 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. Commissioning plan.
5. Testing, adjusting and balancing report.

EXCEPTION: Deferred tests which cannot be performed at the time of report preparation due to climatic conditions.

C408.1.4 Commissioning process completion requirements. Prior to the final mechanical, plumbing and electrical inspections or obtaining a certificate of occupancy, the *certified commissioning professional* shall provide evidence of *building commissioning* in accordance with the provisions of this section.

C408.1.4.1 Commissioning compliance. ~~((Buildings, or portions thereof, shall not be considered acceptable for a final inspection pursuant to Section C104.2.6 until the code official has received a letter of transmittal from the building owner acknowledging that the building owner or owner's authorized agent has received the Commissioning Report. Completion of Commissioning Compliance Checklist (Figure C408.1.4.1) is deemed to satisfy this requirement. Phased acceptance of Commissioning Compliance Checklist for portions of the work specific to the trade that is being inspected is permissible where accepted by the code official and where the certified commissioning professional remains responsible for completion of the commissioning process. If there are unresolved deficiencies when the final inspection is scheduled, the Commissioning Report shall be submitted and shall describe the unresolved deficiencies.~~

C408.1.4.2 Copy of report. The code official shall be permitted to require that a copy of the Commissioning Report be made available for review by the code official.))

The mechanical and water heating portions of the commissioning report, in compliance with Sections C408.2, C408.3, and C408.7, shall be submitted to SDCI prior to completion and approval of mechanical permit final inspection.

The controlled receptacle, lighting, and metering portions of the commissioning report, in compliance with Sections C408.4 and C408.6, shall be submitted to SDCI prior to completion and approval of electrical permit final inspection.

The following items shall be submitted to SDCI prior to completion and approval of final inspection as per Seattle Building Code Section 108.9.10 to demonstrate commissioning compliance:

1. Full commissioning report, in compliance with Section C408.1.3.
 - a. The commissioning report shall include a list of all unresolved deficiencies and any incomplete commissioning work required by Section C408, with description and anticipated date of completion for each, or a statement signed by the certified commissioning professional attesting to successful commissioning of the entire project with no unresolved deficiencies or incomplete tests.
 - b. Where tenant spaces will be built out under separate permits, the commissioning report shall describe the certified commissioning professional's scope of work required to complete commissioning of the central building HVAC systems and lighting control systems as the tenant spaces are completed.
2. Commissioning checklist, from Figure C408.1.4.1, signed by the certified commissioning professional.
3. Statement that the owner has received a copy of the commissioning report, signed by the owner or owner's authorized agent.

SDCI Informative Note: An electronic version of the Commissioning Compliance Checklist is available on the SDCI Seattle Energy Code web page.

C408.2 Mechanical systems commissioning. Mechanical equipment and controls subject to Section C403 shall be included in the commissioning process required by Section C408.1. The commissioning process shall minimally include all energy code requirements for which the code states that equipment or controls shall "be capable of" or "configured to" perform specific functions.

Exception: Mechanical systems are exempt from the commissioning process where the installed total mechanical equipment capacity is less than ((240,000)) 180,000 Btu/h cooling capacity and less than ((300,000)) 240,000 Btu/h heating capacity, and energy recovery ventilation (ERV) equipment is less than 300 cfm capacity.

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C408.2.1 Reserved.

FIGURE C408.1.4.1
COMMISSIONING COMPLIANCE CHECKLIST

Project Information	Project Name:	_____
	Project Address:	_____
	Certified Commissioning Professional:	_____
	Type of ISO Certification and Number:	_____
Supporting Documents	<input type="checkbox"/> Manuals, record documents and training have been completed or are scheduled (Section C103.6) <ul style="list-style-type: none"> • Building operations and maintenance information (C103.6.2) have been submitted to the owner or scheduled date: _____ • Manuals (C103.6.2.1) have been submitted to the owner or scheduled date: _____ • Compliance documentation (C103.6.3) has been provided to the owner or scheduled date: _____ • System operation training (C103.6.4) has been provided to the owner or scheduled date: _____ 	
Commissioning Plan	<input type="checkbox"/> Commissioning Plan was used during construction (Section C408.1.2)	
Commissioning Report	<input type="checkbox"/> Commissioning Report has been submitted (Section C408.1.3)	
Commissioned Systems	<input type="checkbox"/> Mechanical Systems were included in the commissioning process (Section C408.2) <ul style="list-style-type: none"> <input type="checkbox"/> Testing, adjusting and balancing is complete (Section C408.2.2) <input type="checkbox"/> There are unresolved deficiencies with the mechanical systems. These are described in the attached Commissioning Report submitted to the Owner. 	
	<input type="checkbox"/> Service Water Heating Systems were included in the commissioning process (Section C408.3) <ul style="list-style-type: none"> <input type="checkbox"/> There are unresolved deficiencies with the service water heating systems. These are described in the attached Commissioning Report submitted to the Owner. 	
	<input type="checkbox"/> Controlled receptacles and lighting control systems were included in the commissioning process (Section C408.4) <ul style="list-style-type: none"> <input type="checkbox"/> There are unresolved deficiencies with the electrical power and/or <i>automatic</i> lighting controls. These are described in the attached Commissioning Report submitted to the Owner. 	
	<input type="checkbox"/> Additional systems were included in the commissioning process (Section C408.5) <ul style="list-style-type: none"> <input type="checkbox"/> There are unresolved deficiencies with systems required by C406 or C407. These are described in the attached Commissioning Report submitted to the Owner. 	
	<input type="checkbox"/> Metering systems were included in the commissioning process (Section C408.6) <ul style="list-style-type: none"> <input type="checkbox"/> There are unresolved deficiencies with the metering system. These are described in the attached Commissioning Report submitted to the Owner. 	
	<input type="checkbox"/> Refrigeration systems were included in the commissioning process (Section C408.7) <ul style="list-style-type: none"> <input type="checkbox"/> There are unresolved deficiencies with systems required by Section C410. These are described in the attached Commissioning Report submitted to the Owner. 	
Certification	<input type="checkbox"/> I hereby certify that requirements for Section C408 System Commissioning have been completed in accordance with the Washington State Energy Code, including all items above. <div style="display: flex; justify-content: space-between; margin-top: 10px;"> _____ _____ </div> <div style="display: flex; justify-content: space-between; margin-top: 5px;"> <i>Certified Commissioning Professional</i> Date </div>	
	<input type="checkbox"/> I hereby certify that requirements for Section C408 System Commissioning have been completed in accordance with the Washington State Energy Code, including all items above. <div style="display: flex; justify-content: space-between; margin-top: 10px;"> _____ _____ </div> <div style="display: flex; justify-content: space-between; margin-top: 5px;"> Building Owner or Owner's Representative Date </div>	

C408.2.2 Systems adjusting and balancing. HVAC systems shall be balanced in accordance with generally accepted engineering standards. Air and water flow rates shall be measured and adjusted to deliver final flow rates within the tolerances provided in the project specifications. Test and balance activities shall include air system and hydronic system balancing.

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

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

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

EXCEPTION: The following equipment is not required to be equipped with means for balancing or measuring flow:

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

C408.2.3 System testing. Functional performance testing shall demonstrate the components, systems, and system-to-system interfacing relationships are installed and operate in accordance with *approved* construction documents. Testing shall include the *sequence of operation*, and be conducted under full-load, part-load and the following conditions:

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

C408.3 Service water heating systems commissioning. Service water heating equipment and controls subject to Section C404 shall be included in the commissioning process required by Section C408.1. The commissioning process shall minimally include equipment and components installed to meet all energy code requirements for devices to “start,” “automatically turn off,” “automatically adjust,” “limit operation,” and “limit the temperature” and “be configured to.”

C408.3.1 System testing. Functional performance testing shall demonstrate that heaters, piping, distribution systems, and system-to-system interfacing relationships are installed and operate in accordance with *approved* construction documents. Testing shall include the *sequence of operation*, and be conducted under at least 50 percent water heating load, part-load and the following conditions:

1. Normal operation;
2. Redundant or *automatic* back-up mode;
3. Performance of alarms; and
4. Mode of operation upon a loss of power and restoration of power.

C408.4 Controlled receptacle and lighting control system commissioning. *Controlled receptacles* and lighting control systems subject to Section C405 shall be included in the commissioning process required by Section C408.1. The configuration and function of *controlled receptacles* and lighting control systems required by this code shall be tested and shall comply with Section C408.4.1.

EXCEPTION: Lighting control systems *and controlled receptacles* are exempt from the commissioning process in buildings where:

1. The total installed lighting load is less than 20 kW, and
2. The lighting load controlled by occupancy sensors or *automatic* daylighting controls is less than 10 kW.

C408.4.1 System testing. Functional performance testing shall demonstrate that occupant sensors, time switches, manual overrides, (~~(night sweep-off)~~) *time switch scheduled lighting shutoff*, *daylight responsive control*, and *controlled receptacles* are installed and operate in accordance with *approved* construction documents. Testing shall include the *sequence of operation* and be conducted under the following conditions:

1. Normal operation;
2. Redundant or *automatic* back-up mode;

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3. Performance of alarms; and
4. Mode of operation upon a loss of power and restoration of power.

C408.5 Systems installed to meet Section C406 or C407. Equipment, components, controls or configuration settings for systems which are included in the project to comply with Section C406 or C407 shall be included in the commissioning process required by Section C408.1.

C408.5.1 System testing. Functional performance testing for these appliances, equipment, components, controls and/or configuration settings shall demonstrate operation, function and maintenance serviceability for each of the commissioned systems in accordance with the *approved* construction documents.

C408.6 Metering system commissioning. Energy metering systems required by Section C409 shall comply with Section C408.6 and be included in the commissioning process required by Section C408.1. The commissioning process shall include all energy metering equipment and controls required by Section C409.

C408.6.1 System testing. Functional performance testing shall demonstrate that energy source meters, end-use meters, *data acquisition systems*, and energy displays are installed and operate in accordance with *approved* construction documents. 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 in a location with *access* 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).

C408.7 Refrigeration system commissioning. All installed refrigeration systems subject to Section C410 shall be included in the commissioning process required by Section C408.1.

EXCEPTIONS:

1. Self-contained refrigeration systems are exempt from the commissioning process.
2. Total installed capacity for refrigeration is equal to or less than 240 kBtu/h.

C408.7.1 System Testing. Functional performance testing shall demonstrate that compressors, heat exchangers, piping, distribution systems, and system-to-system interfacing relationships are installed and operate in accordance with *approved* construction documents. Testing shall include the *sequence of operation* and be conducted under full-load at, part-load and the following conditions:

1. Normal mode;
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.

SECTION C409 ENERGY METERING AND ENERGY CONSUMPTION MANAGEMENT

C409.1 General. All new buildings and additions shall have the capability of metering all source energy usage in accordance with Section C409.2 in addition to the source energy for on-site renewable energy production in accordance with Section C409.2.4 and the end-use energy usage for electric vehicle charging in accordance with Section C409.3.4. New buildings and additions with a gross conditioned floor area over (~~(25,000)~~) 20,000 square feet shall comply with Sections C409.2, C409.3, and C409.4. New buildings and additions 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. Existing buildings shall comply with the energy metering provisions of Section C506.1. For Group R-2 buildings, the floor area of dwelling units and sleeping units shall be excluded from the total conditioned floor area for the purposes of determining the 20,000 square foot threshold. Alterations and additions to existing buildings shall conform to Section C506.

EXCEPTIONS:

1. Tenant spaces smaller than (~~(25,000)~~) 20,000 ft² square feet within buildings if the tenant space has its own utility service and utility meters shall comply with Section C409.2 and are exempt from the end-use metering, measurement devices, data acquisition system and energy display requirements of Sections C409.3 and C409.4.
2. Buildings in which there is no gross conditioned floor area over (~~(25,000)~~) 10,000 square feet, including building common area, that is served by its own utility services and meters shall comply with Section C409.2 and are exempt from the end-use metering, measurement devices, data acquisition system and energy display requirements of Sections C409.3 and C409.4.

SDCI Informative Note: Seattle’s “Building Tune-ups” ordinance will continue to be in effect, requiring buildings with over 50,000 square feet of *conditioned floor area* to periodically assess and optimize the functioning of energy-consuming systems. The cost and complexity of these tune-ups can potentially be minimized by careful configuration of the metering system.

C409.1.1 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 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.

C409.1.3 Dwelling units. See Sections C404.9 and C405.7 for additional metering requirements for Group R-2 dwelling units.

C409.2 Energy source metering. Buildings shall have a meter at each energy source. For each energy supply source listed in Section C409.2.1 through C409.2.4, meters shall collect data for the whole building or for each separately metered portion of the building where not exempted by the exceptions to Section C409.1.

Exceptions:

1. Energy source metering is not required where end use metering for an energy source accounts for all usage of that energy type within a building, and the *data acquisition system* accurately totals the energy delivered to the building or separately metered portion of the building.
2. Solid fuels such as coal, firewood or wood pellets that are delivered via mobile transportation do not require metering.

C409.2.1 Electrical energy. This category shall include all electrical energy supplied to the building and its associated site, including site lighting, parking, recreational facilities, and other areas that serve the building and its occupants.

EXCEPTION: Where site lighting and other exterior non-building electrical loads are served by an electrical service and meter that are separate from the building service and meter, the metering data from those loads is permitted to be either combined with the building’s electrical service load data or delivered to a separate *data acquisition system*.

C409.2.2 Gas and liquid fuel supply energy. This category shall include all natural gas, fuel oil, propane and other gas or liquid fuel energy supplied to the building and site.

C409.2.3 District energy. This category shall include all net energy extracted from district steam systems, district chilled water loops, district hot water systems, or other energy sources serving multiple buildings.

C409.2.4 Site-generated renewable energy. This category shall include all net energy generated from on-site solar, wind, geothermal, tidal or other natural sources, and waste heat reclaimed from sewers or other off-site sources. For buildings exempt from data collection systems, the data from these meters is permitted to either be stored locally using a manual totalizing meter or other means at the meter or fed into a central data collection system.

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 C409.3.7. These meters shall collect data for the whole building or for each separately metered portion of the building where not exempted by the exception to Section C409.1. Not more than 10 percent of the total connected load of any of the end-use metering categories in Sections C409.3.1 through C409.3.6 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 C409.3.6 is permitted to consist of loads not part of that category. Multiple meters may be used for any end-use category, provided that the *data acquisition system* totals all of the energy used by that category. Full-floor tenant space submetering data shall be provided to the tenant in accordance with Section C409.7, and the data shall not be required to be included in other end-use categories.

EXCEPTIONS:

1. HVAC and service water heating equipment serving only an individual *dwelling unit* or sleeping unit does not require end-use metering.
2. Separate metering is not required for fire pumps, stairwell pressurization fans or other life safety systems that operate only during testing or emergency.
3. End use metering is not required for individual tenant spaces not exceeding 2,500 square feet in floor area when a dedicated source meter meeting the requirements of Section C409.4.1 is provided for the tenant space.
4. Healthcare facilities with loads in excess of 150 kVA are permitted to have submetering that measures electrical energy usage in accordance with the normal and essential electrical systems as identified in Section 517 of the Seattle Electrical Code except that submetering is required for the following load categories:

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- 4.1. HVAC system energy use in accordance with the requirements of Section C409.3.1.
- 4.2. Service water heating energy use in accordance with the requirements of Section C409.3.2.
- 4.3. Process load system energy in accordance with the requirements of Section ((~~C409.3.5~~) C409.3.6) 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 the facility exceeds 100 kVA.
5. End-use metering is not required for electrical circuits serving only (~~land~~) hotel rooms and guest suites within Group R-1 occupancies. This exception does not apply to common areas or to equipment serving multiple sleeping rooms.

C409.3.1 HVAC system energy use. This category shall include all energy including electrical, gas, liquid fuel, district steam and district chilled water that is used by boilers, chillers, pumps, fans and other equipment used to provide space heating, space cooling, dehumidification and ventilation to the building, but not including energy that serves process loads, service 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. 120 volt equipment.
2. An HVAC branch circuit where the total MCA of equipment served equates to less than 10 kVA.
3. Individual fans or pumps that are not on a variable frequency drive.

C409.3.2 Service 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: Service water heating energy use less than 50 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 Electric vehicle charging energy use. This category shall include all energy used for electrical vehicle charging. For buildings exempt from data collection systems, the data from these meters is permitted to either be stored locally using a manual totalizing meter or other means at the meter or fed into a central data collection system.

C409.3.5 Plug load system energy use. This category shall include all energy used by appliances, computers, plug-in task lighting, and other 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.

EXCEPTIONS:

1. Where the total connected load of all plug load circuits is less than 50 kVA, end-use metering is not required.
2. Electric receptacles located in fire-rated or smoke-rated corridors, enclosed stairwells, or egress passageways are not required to be metered.

C409.3.6 Process load system energy use. This category shall include all energy used by any non-building process load, including but not limited to nonresidential refrigeration and cooking equipment, laundry equipment, industrial equipment and stage lighting.

EXCEPTION: Where the process load energy use is less than 50 kVA, end-use metering is not required.

C409.3.7 Full-floor tenant space electrical submetering. In a multi-tenant building where more than 90 percent of the leasable area of a floor is occupied by a single tenant, an electrical energy use display shall be provided to the tenant in accordance with the requirements of Section C409.4.3. Electrical loads from areas outside of the tenant space or from equipment that serves areas outside of the tenant space shall not be included in the tenant space 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 be configured to automatically communicate energy data to a data acquisition system and energy display. Source meters may be any digital-type meters. Current sensors or flow meters are allowed for end use metering, provided that they have an accuracy of +/- 5%. All required metering systems and equipment shall provide data that is fully integrated into the data acquisition and display system per the requirements of Section C409. Electrical meters shall be configured to communicate data to the data acquisition system and energy display for both consumption (e.g., kWh) and consumption rate (e.g., kW). Other meters and measurement devices shall be configured to communicate data to the data acquisition system for consumption.

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.

C409.4.2 Data acquisition system. The data acquisition system shall store the data from the required meters and other sensing devices in a single database for a minimum of 36 months. For each energy supply and end use category required by C409.2 and C409.3, it shall provide energy consumption logged in one-hour or less intervals and energy consumption rate logged in 10-minute or less intervals. Data from the data acquisition system shall be viewable via the energy display in accordance with the requirements of Section C409.4.3.

C409.4.3 Energy display. For each building subject to Section C409.2 and C409.3, either a single visible display in a location with *ready access*, or a single web page or other electronic document available for access to building operation and management personnel or to a third-party energy data analysis service shall be provided in the building; for metering data acquisition systems and energy displays monitored by a third-party energy data analysis service, building operation and management personnel shall retain access to the metering data acquisition system and energy display. The display shall numerically provide the current energy consumption rate and energy consumption total for each whole building energy source and each end use category. The energy display shall also graphically and numerically display logged data from the data acquisition system for energy consumption for each whole building energy source and energy consumption rate for whole building electrical use and each end use category for any selected day, week, month, or year.

C409.4.4 Commissioning. Energy metering and energy consumption management systems shall be commissioned in accordance with Section C408.6.

**SECTION C410
REFRIGERATION SYSTEM REQUIREMENTS**

C410.1 General. Walk-in coolers, walk-in freezers, refrigerated warehouse coolers, refrigerated warehouse freezers, and refrigerated display cases shall comply with this Section. Where they comprise any portion of the thermal envelope of the building, they shall also comply with the requirements of Section C402, using the R-values or U-values listed in this Section C410. Section C402.1.5 component performance alternative is permitted to be used for the thermal envelope of the refrigerated space where approved by the code official.

**Table C410.2
Minimum Efficiency Requirements: Commercial Refrigerators and Freezers and Refrigeration**

Equipment Category	Condensing Unit Configuration	Equipment Family	Rating Temp. °F	Operating Temp. °F	Equipment Classification ^c	Maximum Daily Energy Consumption kWh/day ^{d,e}	Test Standard
Remote condensing commercial refrigerators and commercial freezers	Remote (RC)	Vertical open (VOP)	38 (M)	≥32	VOP.RC.M	0.64 × TDA + 4.07	AHRI 1200
			0 (L)	<32	VOP.RC.L	2.20 × TDA + 6.85	
		Semivertical open (SVO)	38 (M)	≥32	SVO.RC.M	0.66 × TDA + 3.18	
			0 (L)	<32	SVO.RC.L	2.20 × TDA + 6.85	
		Horizontal open (HZO)	38 (M)	≥32	HZO.RC.M	0.35 × TDA + 2.88	
			0 (L)	<32	HZO.RC.L	0.55 × TDA + 6.88	
		Vertical closed transparent (VCT)	38 (M)	≥32	VCT.RC.M	0.15 × TDA + 1.95	
			0 (L)	<32	VCT.RC.L	0.49 × TDA + 2.61	
		Horizontal closed transparent (HCT)	38 (M)	≥32	HCT.RC.M	0.16 × TDA + 0.13	
			0 (L)	<32	HCT.RC.L	0.34 × TDA + 0.26	
		Vertical closed solid (VCS)	38 (M)	≥32	VCS.RC.M	0.10 × V + 0.26	
			0 (L)	<32	VCS.RC.L	0.21 × V + 0.54	
		Horizontal closed solid (HCS)	38 (M)	≥32	HCS.RC.M	0.10 × V + 0.26	
			0 (L)	<32	HCS.RC.L	0.21 × V + 0.54	
		Service over counter (SOC)	38 (M)	≥32	SOC.RC.M	0.44 × TDA + 0.11	
			0 (L)	<32	SOC.RC.L	0.93 × TDA + 0.22	

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Table C410.2—continued
Minimum Efficiency Requirements: Commercial Refrigerators and Freezers and Refrigeration

Equipment Category	Condensing Unit Configuration	Equipment Family	Rating Temp. °F	Operating Temp. °F	Equipment Classification ^c	Maximum Daily Energy Consumption kWh/day ^{d,e}	Test Standard			
Self-contained commercial refrigerators and commercial freezers with and without doors	Self-contained (SC)	Vertical open (VOP)	38 (M)	≥32	VOP.RC.M	$1.69 \times TDA + 4.71$	AHRI 1200			
			0 (L)	<32	VOP.RC.L	$4.25 \times TDA + 11.82$				
		Semivertical open (SVO)	38 (M)	≥32	SVO.RC.M	$1.70 \times TDA + 4.59$				
			0 (L)	<32	SVO.RC.L	$4.26 \times TDA + 11.51$				
		Horizontal open (HZO)	38 (M)	≥32	HZO.RC.M	$0.72 \times TDA + 5.55$				
			0 (L)	<32	HZO.RC.L	$1.90 \times TDA + 7.08$				
		Vertical closed transparent (VCT)	38 (M)	≥32	VCT.RC.M	$0.10 \times V + 0.86$				
			0 (L)	<32	VCT.RC.L	$0.29 \times V + 2.95$				
		Vertical closed solid (VCS)	38 (M)	≥32	VCS.RC.M	$0.05 \times V + 1.36$				
			0 (L)	<32	VCS.RC.L	$0.22 \times V + 1.38$				
		Self-contained commercial refrigerators and commercial freezers with and without doors	Self-contained (SC)	Horizontal closed transparent (HCT)	38 (M)	≥32		HCT.RC.M	$0.06 \times V + 0.37$	AHRI 1200
					0 (L)	<32		HCT.RC.L	$0.08 \times V + 1.23$	
Horizontal closed solid (HCS)	38 (M)			≥32	HCS.RC.M	$0.05 \times V + 0.91$				
	0 (L)			<32	HCS.RC.L	$0.06 \times V + 1.12$				
Service over counter (SOC)	38 (M)			≥32	SOC.RC.M	$0.52 \times TDA + 1.00$				
	0 (L)			<32	SOC.RC.L	$1.10 \times TDA + 2.10$				
Self-contained commercial refrigerators with transparent doors for pull-down temperature applications	Self-contained (SC)	Pull-down	38(M)	≥32	PD.SC.M	$0.11 \times V + 0.81$	AHRI 1200			

Table C410.2—continued
Minimum Efficiency Requirements: Commercial Refrigerators and Freezers and Refrigeration

Equipment Category	Condensing Unit Configuration	Equipment Family	Rating Temp. °F	Operating Temp. °F	Equipment Classification ^c	Maximum Daily Energy Consumption kWh/day ^{d,e}	Test Standard
Commercial ice cream freezers	Remote (RC)	Vertical open (VOP)	-15 (I)	≤-5 ^b	VOP.RC.I	2.79 × TDA + 8.70	AHRI 1200
		Semivertical open (SVO)			SVO.RC.I	2.79 × TDA + 8.70	
		Horizontal open (HZO)			HZO.RC.I	0.70 × TDA + 8.74	
		Vertical closed transparent (VCT)			VCT.RC.I	0.58 × TDA + 3.05	
		Horizontal closed transparent (HCT)			HCT.RC.I	0.40 × TDA + 0.31	
		Vertical closed solid (VCS)			VCS.RC.I	0.25 × V + 0.63	
		Horizontal closed solid (HCS)			HCS.RC.I	0.25 × V + 0.63	
		Service over counter (SOC)			SOC.RC.I	1.09 × TDA + 0.26	
	Self-contained (SC)	Vertical open (VOP)	-15 (I)	≤-5 ^b	VOP.SC.I	× TDA +	AHRI 1200
		Semivertical open (SVO)			SVO.SC.I	× TDA +	
		Horizontal open (HZO)			HZO.SC.I	× TDA +	
		Vertical closed transparent (VCT)			VCT.SC.I	× TDA +	
		Horizontal closed transparent (HCT)			HCT.SC.I	× TDA +	
		Vertical closed solid (VCS)			VCS.SC.I	× V +	
		Horizontal closed solid (HCS)			HCS.SC.I	× V +	
		Service over counter (SOC)			SOC.SC.I	× TDA +	

For SI: 1 square foot = 0.0929 m², 1 cubic foot = 0.02832 m³, °C = (°F - 32)/1.8.

a The meaning of the letters in this column is indicated in the columns to the left.

b Ice cream freezer is defined in DOE 10 C.F.R. Part 431.62 as a commercial freezer that is designed to operate at or below -5°F and that the manufacturer designs, markets or intends for the storing, displaying, or dispensing of ice cream.

c Equipment class designations consist of a combination [(in sequential order separated by periods (AAA).(BB).(C))]:

(AAA) An equipment family code where:

- VOP = Vertical open
- SVO = Semi-vertical open
- HZO = Horizontal open
- VCT = Vertical transparent doors
- VCS = Vertical solid doors
- HCT = Horizontal transparent doors
- HCS = Horizontal solid doors
- SOC = Service over counter

(BB) An operating mode code:

- RC = Remote condensing
- SC = Self-contained

(C) A rating temperature code:

- M = Medium temperature (38°F)
- L = Low temperature (0°F)
- I = Ice cream temperature (15°F)

For example, “VOP.RC.M” refers to the “vertical-open, remote-condensing, medium-temperature” equipment class.

d V is the volume of the case (ft³) as measured in AHRI 1200, Appendix C.

e TDA is the total display area of the case (ft²) as measured in AHRI 1200, Appendix D.

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C410.2 Commercial refrigerators, freezers and refrigerator-freezers. Refrigeration equipment, defined in DOE 10 C.F.R. Part 431.62, shall have an energy use in kWh/day not greater than the values of Table C410.2 when tested and rated in accordance with AHRI Standard 1200. The energy use shall be verified through certification under an approved certification program or, where a certification program does not exist, the energy use shall be supported by data furnished by the equipment manufacturer.

C410.2.1 Refrigerated display cases. Refrigerated display cases shall comply with the following:

1. Lighting in refrigerated display cases shall be controlled by one of the following:
 - 1.1. Time switch controls to turn off lights during nonbusiness hours. Timed overrides for display cases shall turn the lights on for up to 1 hour and shall automatically time out to turn the lights off.
 - 1.2. Motion sensor controls on each display case section that reduce lighting power by at least 50 percent within 3 minutes after the area within the sensor range is vacated.
2. Low-temperature display cases shall incorporate temperature-based defrost termination control with a time-limit default. The defrost cycle shall terminate first on an upper temperature limit breach and second upon a time limit breach.
3. Antisweat heater controls shall reduce the energy use of the antisweat heater as a function of the relative humidity in the air outside the door or to the condensation on the inner glass pane.

C410.3 Walk-in coolers, walk-in freezers, refrigerated warehouse coolers and refrigerated warehouse freezers. Site-assembled and site-constructed *walk-in coolers* and *walk-in freezers* and *refrigerated warehouse coolers* and *refrigerated warehouse freezers* shall comply with the following:

1. Automatic door-closers shall be provided that fully close walk-in doors that have been closed to within 1 inch (25 mm) of full closure.

EXCEPTION: Automatic closers are not required for doors more than 45 inches (1143 mm) in width or more than 7 feet (2134 mm) in height.
2. Doorways shall be provided with strip doors, curtains, spring-hinged doors or other method of minimizing infiltration when doors are open.
3. *Walk-in coolers* and *refrigerated warehouse coolers* shall be provided with wall, ceiling, and door insulation of not less than R-25 or have wall, ceiling and door assembly *U*-factors no greater than *U*-0.039. *Walk-in freezers* and *refrigerated warehouse freezers* shall be provided with wall, ceiling and door insulation of not less than R-32 or have wall, ceiling and door assembly *U*-factors no greater than *U*-0.030.

EXCEPTION: Insulation is not required for glazed portions of doors or at structural members associated with the walls, ceiling or door frame.
2. The floor of *walk-in coolers* shall be provided with floor insulation of not less than R-25 or have a floor assembly *U*-factor no greater than *U*-0.40. The floor of *walk-in freezers* shall be provided with floor insulation of not less than R-28 or have a floor assembly *U*-factor no greater than *U*-0.035.

EXCEPTION: Insulation is not required in the floor of a *walk-in cooler* that is mounted directly on a slab on grade.
5. Transparent fixed window and reach-in doors for *walk-in freezers* and windows in *walk-in freezer* doors shall be provided with triple-pane glass, with the interstitial spaces filled with inert gas or be provided with heat-reflective treated glass.
6. Transparent fixed window and reach-in doors for *walk-in coolers* and windows for *walk-in coolers* doors shall be provided with double-pane or triple-pane glass, with interstitial space filled with inert gas, or be provided with heat-reflective treated glass.
7. Evaporator fan motors that are less than 1 hp (0.746 kW) and less than 460 volts shall be provided with electronically commutated motors, brushless direct-current motors, or 3-phase motors.
8. Condenser fan motors that are less than 1 hp (0.746 kW) shall use electronically commutated motors, permanent split capacitor-type motors or 3-phase motors.
9. Antisweat heaters that are not provided with antisweat heater controls shall have a total door rail, glass and frame heater power draw of not greater than 7.1 W/ft² (76 W/m²) of door opening for *walk-in freezers* and not greater than 3.0 W/ft² (32 W/m²) of door opening for *walk-in coolers*.
10. Where antisweat heater controls are provided, they shall be capable of reducing the energy use of the antisweat heater as a function of the relative humidity in the air outside the door or to the condensation on the inner glass pane.
11. Lights in *walk-in coolers*, *walk-in freezers*, *refrigerated warehouse coolers* and *refrigerated warehouse freezers* shall either be provided with light sources with an efficacy of not less than 40 lumens per watt, including ballast losses, or shall be provided with a device that automatically turns off the lights within 15 minutes of when the *walk-in cooler* or *walk-in freezer space* is not occupied.

12. Evaporator fans in refrigerated warehouses shall be variable speed, and the speed shall be controlled in response to space conditions.

EXCEPTION: Evaporators served by a single compressor without unloading capability.

13. Where they comprise any portion of the thermal envelope of the building, the floor, wall, and ceiling components shall also comply with the requirements of Section C402, using the R-values or U-values listed in this Section C410.2. Section C402.1.5 component performance alternative is permitted to be used where approved by the code official.

C410.3.1 Performance standards. Site-assembled and site-constructed *walk-in coolers* and *walk-in freezers* shall meet the requirements of Tables C410.3.1(1), C410.3.1(2), and C410.2.1(3).

Table C410.3.1(1)
Walk-in Cooler and Freezer Display Doors Efficiency Requirements

Class Description	Class	Maximum Energy Consumption (kWh/day) ^a
Display door, medium temperature	DD, M	$0.04 \times A_{dd} + 0.41$
Display door, low temperature	DD, L	$0.15 \times A_{dd} + 0.29$

a A_{dd} is the surface area of the display door.

Table C410.3.1(2)
Walk-in Cooler and Freezer Nondisplay Doors Efficiency Requirements

Class Description	Class	Maximum Energy Consumption (kWh/day) ^a
Passage door, medium temperature	PD, M	$0.05 \times A_{nd} + 1.7$
Passage door, low temperature	PD, L	$0.14 \times A_{nd} + 4.8$
Freight door, medium temperature	FD, M	$0.04 \times A_{nd} + 1.9$
Freight door, low temperature	FD, L	$0.12 \times A_{nd} + 5.6$

a A_{nd} is the surface area of the display door.

Table C410.3.1(3)
Walk-in Cooler and Freezer Refrigeration Systems Efficiency Requirements

Class Description	Class	Minimum Annual Walk-in Energy Factor AWEF (Btu/hW-h)	Test Procedure
Dedicated condensing, medium temperature, indoor system	DC.M.I	5.61	AHRI 1250
Dedicated condensing, medium temperature, outdoor system	DC.M.O	7.60	
Dedicated condensing, low temperature, indoor system, net capacity (q_{net}) < 6,500 Btu/h	DC.L.I, < 6,500	$9.091 \times 10^{-5} \times q_{net} + 1.81$	
Dedicated condensing, low temperature, indoor system, net capacity (q_{net}) ≥ 6,500 Btu/h	DC.L.I, ≥ 6,500	2.40	
Dedicated condensing, low temperature, outdoor system, net capacity (q_{net}) < 6,500 Btu/h	DC.L.O, < 6,500	$9.091 \times 10^{-5} \times q_{net} + 2.73$	
Dedicated condensing, low temperature, outdoor system, net capacity (q_{net}) ≥ 6,500 Btu/h	DC.L.O, ≥ 6,500	3.15	
Unit cooler, medium	UC.M	9.00	
Unit cooler, low temperature, net capacity (q_{net}) < 15,500 Btu/h	UC.L, < 15,500	$9.091 \times 10^{-5} \times q_{net} + 2.73$	
Unit cooler, low temperature, net capacity (q_{net}) ≥ 15,500 Btu/h	UC.L, ≥ 15,500	4.15	

C410.4 Refrigerated case and walk-in display doors. Lighting in glass doors in all *walk-in coolers* and *walk-in freezers* and all *refrigerated warehouse coolers* and *refrigerated warehouse freezers* shall comply with the following:

1. Time switch controls to turn off lights during nonbusiness hours. Timed overrides for display cases shall turn the lights on for up to 1 hour and shall automatically time out to turn the lights off.

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2. Motion sensor controls on each display case section that reduce lighting power by at least 50 percent within 3 minutes after the area within the sensor range is vacated.

C410.5 Refrigeration systems. Refrigerated display cases, *walk-in coolers* or *walk-in freezers* that are served by remote compressors and remote condensers not located in a *condensing unit*, shall comply with Sections C410.5.1, C410.5.2, and C403.9.2.3.

EXCEPTION: Systems where the working fluid in the refrigeration cycle goes through both subcritical and supercritical states (transcritical) or that use ammonia refrigerant are exempt.

C410.5.1 Condensers serving refrigeration systems. Fan-powered condensers shall comply with the following:

1. The design *saturated condensing temperatures* for air-cooled condensers shall not exceed the design dry-bulb temperature plus 10°F (5.6°C) for *low-temperature refrigeration systems*, and the design dry-bulb temperature plus 15°F (8°C) for *medium temperature refrigeration systems* where the *saturated condensing temperature* for blend refrigerants shall be determined using the average of liquid and vapor temperatures as converted from the condenser drain pressure.
2. Condenser fan motors that are less than 1 hp (0.75 kW) shall use electronically commutated motors, permanent split-capacitor-type motors or 3-phase motors.
3. Condenser fans for air-cooled condensers, evaporatively cooled condensers, air- or water-cooled fluid coolers or cooling towers shall reduce fan motor demand to not more than 30 percent of design wattage at 50 percent of design air volume, and incorporate one of the following continuous variable speed fan control approaches:
 - 3.1. Refrigeration system condenser control for air-cooled condensers shall use variable setpoint control logic to reset the condensing temperature setpoint in response to ambient dry-bulb temperature.
 - 3.2. Refrigeration system condenser control for evaporatively cooled condensers shall use variable setpoint control logic to reset the condensing temperature setpoint in response to ambient wet-bulb temperature.
4. Multiple fan condensers shall be controlled in unison.
5. The minimum condensing temperature setpoint shall be not greater than 70°F (21°C).

C410.5.2 Compressor systems. Refrigeration compressor systems shall comply with the following:

1. Compressors and multiple-compressor system suction groups shall include control systems that use floating suction pressure control logic to reset the target suction pressure temperature based on the temperature requirements of the attached refrigeration display cases or walk-ins.

EXCEPTION: Controls are not required for the following:

1. Single-compressor systems that do not have variable capacity capability.
2. Suction groups that have a design saturated suction temperature of 30°F (-1.1°C) or higher, suction groups that comprise the high stage of a two-stage or cascade system, or suction groups that primarily serve chillers for secondary cooling fluids.
2. Liquid subcooling shall be provided for all low-temperature compressor systems with a design cooling capacity equal to or greater than 100,000 Btu/hr (29.3 kW) with a design-saturated suction temperature of -10°F (-23°C) or lower. The subcooled liquid temperature shall be controlled at a maximum temperature setpoint of 50°F (10°C) at the exit of the subcooler using either compressor economizer (interstage) ports or a separate compressor suction group operating at a saturated suction temperature of 18°F (-7.8°C) or higher.
 - 2.1. Insulation for liquid lines with a fluid operating temperature less than 60°F (15.6°C) shall comply with Table C403.2.10.
3. Compressors that incorporate internal or external crankcase heaters shall provide a means to cycle the heaters off during compressor operation.
4. Compressor systems utilized in refrigerated warehouses shall conform to the following:
 - 4.1. Compressors shall be designed to operate at a minimum condensing temperature of 70°F or less.
 - 4.2. The compressor speed of a screw compressor greater than 50 hp shall be controllable in response to the refrigeration load or the input power to the compressor shall be controlled to use no more than 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.

C410.6 Commissioning. Refrigeration systems shall be commissioned in accordance with Section C408.

EXCEPTION: Self-contained units.

SECTION C411 RENEWABLE ENERGY

C411.1 On-site renewable energy. Each new building (or) addition, larger than ~~((10,000))~~ 5,000 square feet of *gross conditioned floor area*, shall include a renewable energy generation system consisting of not less than 0.5 W/ft² or 1.7 Btu/ft² multiplied by the sum of the *gross conditioned floor area*.

EXCEPTIONS:

- ~~1. Any building where more than 50 percent of the roof area is shaded from direct beam sunlight by natural objects or by structures that are not part of the building for more than 2500 annual hours between 8:00 a.m. and 4:00 p.m.~~
- ~~2. Any building where more than 80 percent of the roof area is covered by any combination of equipment other than for on-site renewable energy systems, planters, vegetated space, skylights or occupied roof deck.~~
- ~~3. Buildings which can document they do not have adequate roof area to install the required on-site solar and that comply with Section C411.1.1 may install a lesser amount of on-site renewables but not zero.)~~
1. Where a building's net roof area is not large enough to accommodate the entire on-site renewable energy generation system required by this section, the portion of that system that cannot be accommodated within the net roof area is permitted to be provided by one of the following options:
 - a. Additional efficiency credits in accordance with Section C411.1.1.
 - b. Off-site renewable energy in accordance with Section C411.2.1, including the requirements of Sections C411.2 and C411.2.2.

For the purposes of this exception, the net roof area excludes the following:

- a. Areas shaded by existing natural or built objects in accordance with Exception 1 of Section C411.3.
 - b. Areas occupied by mechanical equipment, including adjacent equipment service areas required by manufacturer or by applicable code.
 - c. Areas required by applicable codes to remain clear for egress, fire department access, or equipment access.
 - d. Areas with slopes greater than 2:12.
 - e. Planted or vegetated areas.
 - f. Skylights.
 - g. Occupied roof decks.
2. Reduced Building Performance Factor. For projects utilizing the Section C407 Total Building Performance compliance path the on-site renewable energy generation system is not required where the building performance factor (BPF) is not less than 3 percent lower than the maximum BPF permitted cumulatively by all other sections of this code.

Example: To use this exception, a building with a required BPF of 50 would be required to provide a BPF of $(50 \times 0.97 =) 48.5$ instead.

- 2.1. Where the BPF is not less than 1 percent lower than the BPF required cumulatively by other sections of this code, the size of the on-site renewable energy generation system is permitted to be reduced by 1/3.
- 2.2. Where the BPF is not less than 2 percent lower than the BPF required cumulatively by other sections of this code, the size of the on-site renewable energy generation system is permitted to be reduced by 2/3.
3. Transfer to an affordable housing project. Where approved by SDCI, all or part of the required on-site renewable energy generation system is permitted to be replaced by construction of a system that is 50 percent of the required system size when located on an existing affordable housing project within the City of Seattle, or 75 percent of the required system size when located on a new construction affordable housing project within the City of Seattle. Documentation demonstrating that the renewable energy generation system has been installed on the affordable housing project site, the system is fully operational, and ownership has been transferred to the owner of the affordable housing project, must be submitted prior to issuance of the certificate of occupancy.

SDCI Informative Note: Option 3 will only be available if an *affordable housing* project is available to accept the renewable energy system. There is no assurance that such a project location will be available. It is the owner's responsibility to locate and coordinate with the *affordable housing* project, and to ensure that the installation is completed in a timely manner.

4. Transfer to a Washington State agency program. Where approved by SDCI, all or part of the required renewable energy generation system is permitted to be replaced by a contribution of \$2.50 for each required watt of installed capacity, to a solar energy fund managed by a Washington State agency that will provide solar energy installations

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for affordable housing projects. Documentation demonstrating that the contribution has been received by the state agency must be submitted prior to issuance of the certificate of occupancy.

SDCI Informative Note: Option 4 is available via the solar energy fund for *affordable housing* of the Washington State Housing Finance Commission. Contact: energy@wshfc.org.

5. *Affordable housing.* The on-site renewable energy generation system is not required for *affordable housing* projects.

SDCI Informative Note: Fire Department requirements for solar arrays are located in Section 1204 of the Seattle Fire Code.

C411.1.1 Additional efficiency credits. Buildings which qualify for (~~(one of the exceptions)~~) Exception 1 in Section C411.1 to omit installation of on-site renewable energy (~~(must)~~) are permitted to achieve an additional **18** efficiency package credits from Table C406.2(1) instead of installing the on-site renewable energy. The additional **18** credits can be reduced based on a prorated fraction of renewable capacity that is installed on-site.

On-site renewable energy installations of lower than required capacity can be counted proportionally toward achievement of required or additional efficiency credits in Section C411.1.1 based on the capacity of renewable energy installed compared to the requirements of Section C411.1.

C411.2 On-site and off-site renewable energy accounting. Qualifying on-site and off-site renewable energy delivered or credited to the building project to comply with this code shall meet the requirements of this section. Renewable energy certificates for an on-site or off-site renewable energy system shall be retired on behalf of the building owner for a period of not less than 15 years and tracked in accordance with Section C411.2.3 and submitted to the code official (~~(as part of the permit application)~~) before the final inspection. Renewable energy certificates (RECs) themselves are not a qualifying type of off-site renewable energy system.

C411.2.1 Qualifying types of off-site renewable energy systems. The following are considered qualifying off-site renewable energy systems:

1. Self-generation (an off-site renewable energy system owned by the building project owner) systems complying with Section C411.2.2.
2. Community renewable energy facility systems complying with Section C411.2.2.
3. (~~(Purchase)~~) Renewable power purchase agreement (PPA) contracts complying with Section C411.2.2 and, where applicable, Section C411.2.3.
4. Each source of renewable energy delivered to or credited to the building project shall be connected to the Western Interconnection and energy or capacity multiplied by the factors in Table C411.2.1.

**Table C411.2.1
Multipliers for Renewable Energy Procurement Methods**

Location	Renewable Energy Source	Renewable Energy Factor		
		In the state of Washington	Western Interconnected	In the states of Oregon or Idaho
On-site	On-site renewable energy system	1	NA	NA
Off-site	Directly owned off-site renewable energy system that begins operation after submission of the initial permit application	0.95	0.75	0.85
Off-site	Community renewable energy facility that begins operation after submission of the initial permit application	0.95	0.75	0.85
Off-site	Directly owned off-site renewable energy system that begins operation before submission of the initial permit application	0.75	0.55	0.65
Off-site	Community renewable energy facility that begins operation before submission of the initial permit application	0.75	0.55	0.65
Off-site	Renewable Power Purchase Agreement (PPA)	0.75	0.55	0.65
<u>Off-site</u>	<u>Renewable Energy Investment Fund (REIF)</u>	<u>0.95</u>	<u>0.75</u>	<u>0.85</u>

C411.2.2 Documentation requirements for off-site renewable energy systems. Off-site renewable energy delivered or credited to the building project to comply with Section C407.3 item 2.2, or other requirements of this code, shall be subject to a legally binding contract to procure qualifying off-site renewable energy. Qualifying off-site renewable energy shall meet the following requirements:

1. Documentation of off-site renewable energy procurement shall be submitted to the *code official* before the final inspection.

2. The purchase contract shall have a duration of not less than 15 years. The contract shall be structured to survive a partial or full transfer of ownership of the building property.
3. Records on renewable power purchased by the building owner from the off-site renewable energy generator that specifically assign the RECs to the building owner shall be retained or retired by the building owner on behalf of the entity demonstrating financial or operational control over the building seeking compliance to this standard and made available for inspection by the *code official* upon request.
4. Where multiple buildings in a building project are allocated energy procured by a contract subject to this section, the owner shall allocate for not less than 15 years the energy procured by the contract to the buildings in the building project. A plan on operation shall be developed which shall indicate how renewable energy produced from on-site or off-site systems that is not allocated before issuance of the certificate of occupancy will be allocated to new or existing buildings included in the building project.

C411.2.3 Renewable energy certificate (REC) tracking. For multitenant buildings where RECs are transferred to tenants, the plan for operation shall include procedures for tracking the quantity and vintage of RECs that are required to be retained and retired. The plan shall include provisions to transfer the RECs to building tenants, or to retire RECs on their behalf, in proportion to the gross conditioned and semi-heated floor area leased or rented. The plan shall include provisions to use a REC tracking system that meets the requirements of Section V.B of the Green-e Framework for Renewable Energy Certification. The plan shall describe how the building owner will procure alternative qualifying renewable energy in the case that the renewable energy producer ceases. The plan shall be submitted to the code official prior to the final inspection.

C411.3 Solar readiness. A solar zone shall be provided on buildings that are 20 stories or less in height above grade plan. The solar zone shall be located on the roof of the building or on another structure elsewhere on the site. The solar zone shall be in accordance with this section and the *International Fire Code*.

EXCEPTION: A solar zone is not required under the following conditions:

1. Where the solar exposure of the building's roof area is less than 75 percent of that of an unshaded area, as defined in Section ((~~C411.5~~) C411.3.4), in the same location, as measured by one of the following:
 - 1.1. Incident solar radiation expressed in kWh/ft²-yr using typical meteorological year (TMY) data.
 - 1.2. Annual sunlight exposure expressed in cumulative hours per year using TMY data.
 - 1.3. Shadow studies indicating that the roof area is more than 25 percent in shadow, on September 21st at 10 a.m., 11 a.m., 12 p.m., 1 p.m., and 2 p.m. solar time.
2. Buildings, building additions, changes in space conditioning or occupancy where the total floor area is equal to or less than 500 square feet.

SDCI Informative Note: Requirements for solar arrays are located in Section 1204 of the Seattle Fire Code.

C411.3.1 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, mechanical equipment, mechanical equipment service clearances required by equipment manufacturer or by code, and planted areas.
2. 20 percent of electrical service size. The electrical service size is the rated capacity of the total of all electrical services to the building, and the required solar zone size shall be based upon 10 peak watts of photovoltaic per square foot.

EXCEPTION: Subject to the approval of the code official, buildings with extensive rooftop equipment that would make full compliance with this section impractical shall be permitted to reduce the size of the solar zone required by Section C411.3 to the maximum practicable area.

Example: A building with a 10,000 SF total roof area, 1,000 SF skylight area, and a 400 Amp, 240 volt single phase electrical service is required to provide a solar zone area of the smaller of the following:

1. $[40\% \times (10,000 \text{ SF roof area} - 1,000 \text{ SF skylights})] = 3,600 \text{ SF}$; or
 2. $[400 \text{ Amp} \times 240 \text{ Volts} \times 20\% / 10 \text{ watts per SF}] = 1,920 \text{ SF}$
- Therefore, a *solar zone* of 1,920 square feet is required.

C411.3.2 Contiguous area. The solar zone is permitted to be comprised of separated subzones. Each subzone shall be at least 5 feet wide in the narrowest dimension.

C411.3.3 Obstructions. The solar zone shall be free of pipes, vents, ducts, HVAC equipment, skylights and other obstructions, except those serving photovoltaic systems 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

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elevated solar zone does not shade other portions of the solar zone, and its height is permitted by the *International Building Code* and the *Seattle Land Use Code*. Photovoltaic or solar water heating systems are permitted to be installed within the solar zone.

C411.3.4 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.

C411.3.5 Access. Areas contiguous to the solar zone shall provide access pathways and provisions for emergency smoke ventilation as required by the *International Fire Code*.

C411.3.6 Structural integrity. The as-designed dead load and live load for the solar zone shall be clearly marked on the record drawings and shall accommodate future photovoltaic system arrays at an assumed dead load of 4 pounds per square foot in addition to other required live and dead loads. A location for future inverters shall be designated either within or adjacent to the solar zone, with a minimum area of 2 square feet for each 1000 square feet of solar zone area, and shall accommodate an assumed dead load of 175 pounds per square foot. Where photovoltaic systems are installed in the solar zone, structural analysis shall be based upon calculated loads, not upon these assumed loads.

C411.3.7 Photovoltaic interconnection. A minimum 2-inch diameter roof penetration conduit shall be provided, with threaded caps above and below the roof deck and minimum R-10 insulation wrapping the lower portion, within each 2,500 square foot section of the required solar zone area. Interconnection of the future photovoltaic system shall be provided for at the main service panel, either ahead of the service disconnecting means or at the end of the bus opposite the service disconnecting means, in one of the following forms:

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 all of the following:

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

SECTION C412 COMPRESSED AIR SYSTEMS

C412.1 General. All new *compressed air systems*, and all additions or alterations of *compressed air systems* where the total combined horsepower (hp) of the compressor(s) is 25 hp or more, shall meet the requirements of this section. These requirements apply to the compressors, related piping systems, and related controls that provide compressed air and do not apply to any equipment or controls that use or process the compressed air.

EXCEPTION: Medical gas compressed air systems in health care facilities.

C412.2 Trim compressor and storage. The compressed air system shall be equipped with an appropriately sized trim compressor and primary storage to provide acceptable performance across the range of the system and to avoid control gaps. The compressed air system shall comply with 1 or 2 below:

1. The *compressed air system* shall include one or more variable speed drive (VSD) compressors. For systems with more than one compressor, the total combined capacity of the VSD compressor(s) acting as trim compressors must be at least 1.25 times the *largest net capacity increment* between combinations of compressors. The *compressed air system* shall include *primary storage* of at least one gallon per actual cubic feet per minute (acfm) of the largest trim compressor; or
2. The *compressed air system* shall include a compressor or set of compressors with total effective trim capacity at least the size of the *largest net capacity increment* between combinations of compressors, or the size of the smallest compressor, whichever is larger. The total effective trim capacity of single compressor systems shall cover at least the range from 70 percent to 100 percent of rated capacity. The effective trim capacity of a compressor is the size of the continuous operational range where the specific power of the compressor (kW/100 acfm) is within 15 percent of the specific power at its most efficient operating point. The total effective trim capacity of the system is the sum of the effective trim capacity of the trim compressors. The system shall include *primary storage* of at least 2 gallons per acfm of the largest trim compressor.

EXCEPTIONS:

1. Alterations where the total combined added or replaced compressor horsepower is less than the average per-compressor horsepower of all compressors in the system.
2. Alterations where all added or replaced compressors are variable speed drive (VSD) compressors and *compressed air systems* includes *primary storage* of at least one gallon per acfm of the largest trim compressor.
3. *Compressed air systems* that have been *preapproved* as having demonstrated that the system serves loads for which typical air demand fluctuates less than 10 percent.
4. Alterations of existing *compressed air systems* that include one or more centrifugal compressors.

C412.3 Controls. *Compressed air systems* with three or more compressors and a combined horsepower rating of more than 100 hp, shall operate with controls that are able to choose the most energy efficient combination and loading of compressors within the system based on the current compressed air demand.

C412.4 Monitoring. *Compressed air systems* having a combined horsepower rating equal to or greater than 100 hp shall have an energy and air demand monitoring system with the following minimum requirements:

1. Measurement of system pressure.
2. Measurement of amps or power of each compressor.
3. Measurement or determination of total airflow from compressors in cfm.
4. Data logging of pressure, power in kW, airflow in cfm, and *compressed air system* specific efficiency in kW/100 cfm at intervals of five minutes or less.
5. Maintained data storage of at least the most recent 24 months.
6. Visual trending display of each recorded point, load and specific efficiency.

C412.5 Leak testing of compressed air piping. *Compressed air system* piping greater than 50 adjoining feet in length shall be pressure tested after being isolated from the compressed air supply and end-uses. The piping shall be pressurized to the design pressure and test pressures shall be held for a length of time at the discretion of the local jurisdiction, but in no case for less than 30 minutes, with no perceptible drop in pressure.

If dial gauges are used for conducting this test, for pressure tests less than or equal to 100 psi (689 kPa) gauges shall be incremented in units of 1 psi (7 kPa) less, for pressure tests greater than 100 psi (689 kPa) gauges shall be incremented in units less than 2 percent of the test pressure. Test gauges shall have a pressure range not exceeding twice the test pressure.

Piping less than or equal to 50 adjoining feet in length shall be pressurized and inspected. Connections shall be tested with a noncorrosive leak-detecting fluid or other leak-detecting methods as *preapproved* by the local jurisdiction.

C412.6 Pipe sizing. Compressed air piping greater than 50 adjoining feet in length shall be designed and installed to minimize frictional losses in the distribution network. These piping installations shall meet the requirements of Section C412.6.1 and either Section C412.6.2 or C412.6.3.

C412.6.1 Service line piping. Service line piping shall have inner diameters greater than or equal to 3/4 inch. Service line piping are pipes that deliver compressed air from distribution piping to end uses.

C412.6.2 Piping section average velocity. Compressor room interconnection and main header piping shall be sized so that at coincident peak flow conditions, the average velocity in the segment of pipe is no greater than 20 ft/sec. Compressor room interconnection and main header piping are the pipes that deliver compressed air from the compressor outlets to the inlet to the distribution piping. Each segment of distribution and service piping shall be sized so that at coincident peak flow conditions, the average velocity in the segment of pipe is no greater than 30 ft/sec. Distribution piping are pipes that deliver compressed air from the compressor room interconnection piping or main header piping to the service line piping.

C412.6.3 Piping total pressure drop. Piping shall be designed such that piping frictional pressure loss at coincident peak loads are less than 5 percent of operating pressure between the compressor and end use or end use regulator.

C412.6 Compressed air system acceptance. Before an occupancy permit is granted for a *compressed air system*, a certificate of acceptance shall be submitted to the enforcement agency that certifies that the equipment and systems meet the requirements of this code.

