

Chapter 51-11C WAC
STATE BUILDING CODE ADOPTION AND AMENDMENT OF
THE 2015 EDITION OF THE
INTERNATIONAL ENERGY CONSERVATION CODE,
COMMERCIAL PROVISIONS

**WASHINGTON STATE ENERGY CODE,
COMMERCIAL PROVISIONS**

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Margin Markings

- Indicates where a section has been deleted from the requirements of the 2012 IECC
- Indicates 2015 IECC language deleted by Washington state amendment
- █ Indicates a change from the requirements of the 2012 IECC in the model code
- || Indicates a Washington state amendment to the 2015 IECC (but remains unchanged from the 2012 WSEC language)
- ⋮ Indicates a change from the 2012 Washington state amendment
- * Indicates that text or table has been relocated within the code
- * * Indicates the text or table immediately following has been relocated there from elsewhere in the code.

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CHAPTER 1 [CE]

SCOPE AND ADMINISTRATION

SECTION C101 SCOPE AND GENERAL REQUIREMENTS

C101.1 Title. This code shall be known as the *Washington State Energy Code*, and shall be cited as such. It is referred to herein as "this code."

C101.2 Scope. This code applies to *commercial buildings* and the buildings sites and associated systems and equipment. References in this code to Group R shall include Group I-1, Condition 2 assisted living facilities licensed by Washington state under chapter 388-78A WAC and Group I-1, Condition 2 residential treatment facilities licensed by Washington state under chapter 246-337 WAC.

Exception: The provisions of this code do not apply to *temporary growing structures* used solely for the commercial production of horticultural plants including ornamental plants, flowers, vegetables, and fruits. A temporary growing structure is not considered a building for the purposes of this code. However, the installation of other than listed, portable mechanical equipment or listed, portable lighting fixtures is not allowed.

C101.3 Intent. This code shall regulate the design and construction of buildings for the use and conservation of energy over the life of each building. This code is intended to provide flexibility to permit the use of innovative approaches and techniques to achieve this objective. This code is not intended to abridge safety, health or environmental requirements contained in other applicable codes or ordinances.

C101.4 Applicability. Where, in any specific case, different sections of this code specify different materials, methods of construction or other requirements, the most restrictive shall govern. Where there is a conflict between a general requirement and a specific requirement, the specific requirement shall govern.

C101.4.1 Mixed occupancy. Where a building includes both *residential* and *commercial* occupancies, each occupancy shall be separately considered and meet the applicable provisions of WSEC--Commercial Provisions or WSEC--Residential Provisions.

C101.5 Compliance. *Residential buildings* shall meet the provisions of WSEC--Residential Provisions. *Commercial buildings* shall meet the provisions of WSEC--Commercial Provisions.

C101.5.1 Compliance materials. The *code official* shall be permitted to approve specific computer software, worksheets, compliance manuals and other similar materials that meet the intent of this code.

SECTION C102 ALTERNATE MATERIALS-METHOD OF CONSTRUCTION, DESIGN OR INSULATING SYSTEMS

C102.1 General. This code is not intended to prevent the use of any material, method of construction, design or insulating system not specifically prescribed herein, provided that such construction, design or insulating system has been *approved* by the *code official* as meeting the intent of this code.

SECTION C103 CONSTRUCTION DOCUMENTS

C103.1 General. Construction documents and other supporting data shall be submitted in one or more sets with each application for a permit. The construction documents shall be prepared by a registered design professional where required by the statutes of the jurisdiction in which the project is to be constructed. Where special conditions exist, the *code official* is authorized to require necessary construction documents to be prepared by a registered design professional.

Exception: The *code official* is authorized to waive the requirements for construction documents or other supporting data if the *code official* determines they are not necessary to confirm compliance with this code.

C103.2 Information on construction documents. Construction documents shall be drawn to scale upon suitable material. Electronic media documents are permitted to be submitted when *approved* by the *code official*. Construction documents shall be of sufficient clarity to indicate the location, nature and extent of the work proposed, and show in sufficient detail pertinent data and features of the building, systems and equipment as herein governed. Details shall include, but are not limited to, as applicable:

1. Insulation materials and their *R*-values.
2. Fenestration *U*-factors and SHGCs.
3. Area-weighted *U*-factor and SHGC calculations.
4. Mechanical system design criteria.
5. Mechanical and service water heating system and equipment types, sizes and efficiencies.
6. Economizer description.
7. Equipment and systems controls.
8. Fan motor horsepower (hp) and controls.
9. Duct sealing, duct and pipe insulation and location.
10. Lighting fixture schedule with wattage and control narrative.
11. Location of daylight zones on floor plan.

12. Air barrier details including all air barrier boundaries and associated square foot calculations on all six sides of the air barrier as applicable.

C103.2.1 Building thermal envelope depiction. The building's thermal envelope shall be represented on the construction documents.

C103.3 Examination of documents. The *code official* shall examine or cause to be examined the accompanying construction documents and shall ascertain whether the construction indicated and described is in accordance with the requirements of this code and other pertinent laws or ordinances.

C103.3.1 Approval of construction documents.

When the *code official* issues a permit where construction documents are required, the construction documents shall be endorsed in writing and stamped "Reviewed for Code Compliance." Such *approved* construction documents shall not be changed, modified or altered without authorization from the *code official*. Work shall be done in accordance with the *approved* construction documents.

One set of construction documents so reviewed shall be retained by the *code official*. The other set shall be returned to the applicant, kept at the site of work and shall be open to inspection by the *code official* or a duly authorized representative.

C103.3.2 Previous approvals. This code shall not require changes in the construction documents, construction or designated occupancy of a structure for which a lawful permit has been heretofore issued or otherwise lawfully authorized, and the construction of which has been pursued in good faith within 180 days after the effective date of this code and has not been abandoned.

C103.3.3 Phased approval. The *code official* shall have the authority to issue a permit for the construction of part of an energy conservation system before the construction documents for the entire system have been submitted or *approved*, provided adequate information and detailed statements have been filed complying with all pertinent requirements of this code. The holders of such permit shall proceed at their own risk without assurance that the permit for the entire energy conservation system will be granted.

C103.4 Amended construction documents. Changes made during construction that are not in compliance with the *approved* construction documents shall be resubmitted for approval as an amended set of construction documents.

C103.5 Retention of construction documents. One set of *approved* construction documents shall be retained by the *code official* for a period of not less than 180 days from date of completion of the permitted work, or as required by state or local laws.

C103.6 Building documentation and close out

submittal requirements. The construction documents shall specify that the documents described in this section be provided to the building owner or owner's authorized agent with 180 days of the date of receipt of the certificate of occupancy.

C103.6.1 Record documents. Construction documents shall be updated to convey a record of the completed work. Such updates shall include mechanical, electrical and control drawings red-lined, or redrawn if specified, that show all changes to size, type and locations of components, equipment and assemblies.

C103.6.2 Manuals. An operating and maintenance manual shall be provided for each component, device, piece of equipment, and system governed by this code. The manual shall include all of the following:

1. Submittal data indicating all selected options for each piece of equipment.
2. Manufacturer's operation manuals and maintenance manuals for each device, piece of equipment, and system requiring maintenance, except equipment not furnished as part of the project. Required routine maintenance actions, cleaning and recommended relamping shall be clearly identified.
3. Name and address of at least one service agency.
4. Controls system inspection schedule, maintenance and calibration information, wiring diagrams, schematics, and control sequence descriptions. Desired or field-determined setpoints shall be permanently recorded on control drawings at control devices or, for digital control systems, on the graphic where settings may be changed.
5. A narrative of how each system is intended to operate, including recommended setpoints.

C103.6.3 Compliance documentation. All energy code compliance forms and calculations shall be delivered in one document to the building owner as part of the project record documents, manuals, or as a standalone document. This document shall include the specific energy code year utilized for compliance determination for each system, NFRC certificates for the installed windows, list of total area for each NFRC certificate, the interior lighting power compliance path (building area, space-by-space) used to calculate the lighting power allowance.

For projects complying with Section C401.2 item 1, the documentation shall include:

1. The envelope insulation compliance path (prescriptive or component performance).

2. All completed code compliance forms, and all compliance calculations including, but not limited to, those required by sections C402.1.5, C403.2.12.1, C405.4, and C405.5.

For projects complying with C401.2 item 2, the documentation shall include:

1. A list of all proposed envelope component types, areas and *U*-values.
2. A list of all lighting area types with areas, lighting power allowance, and installed lighting power density.
3. A list of each HVAC system modeled with the assigned and proposed system type.
4. Electronic copies of the baseline and proposed model input and output file. The input files shall be in a format suitable for rerunning the model and shall not consist solely of formatted reports of the inputs

C103.6.4 Systems operation training. Training of the maintenance staff for equipment included in the manuals required by Section C103.6.2 shall include at a minimum:

1. Review of manuals and permanent certificate.
2. Hands-on demonstration of all normal maintenance procedures, normal operating modes, and all emergency shutdown and start-up procedures.
3. Training completion report.

SECTION C104 INSPECTIONS

C104.1 General. Construction or work for which a permit is required shall be subject to inspection by the *code official* or his or her designated agent, and such construction or work shall remain accessible and exposed for inspection purposes until *approved*. It shall be the duty of the permit applicant to cause the work to remain accessible and exposed for inspection purposes. Neither the code official nor the jurisdiction shall be liable for expense entailed in the removal or replacement of any material, product, system or building component required to allow inspection to validate compliance with this code.

C104.2 Required inspections. The *code official* or his or her designated agent, upon notification, shall make the inspections set forth in Sections C104.2.1 through C104.2.6.

C104.2.1 Footing and foundation inspection.

Inspections associated with footings and foundations shall verify compliance with the code as to *R*-value, location, thickness, depth of burial and protection of insulation as required by the code and *approved* plans and specifications.

C104.2.2 Insulation and fenestration inspection.

Inspections shall be made before application of interior finish and shall verify compliance with the code as to types of insulation and corresponding *R*-values and their correct location and proper installation; fenestration properties (*U*-factor, SHGC and VT) and proper installation; and air leakage controls as required by the code and approved plans and specifications.

C104.2.3 Plumbing inspection. Inspections verify compliance as required by the code and *approved* plans and specifications as to types of insulation and corresponding *R*-values and protection, required controls and required heat traps.

C104.2.4 Mechanical inspection. Inspections shall verify compliance as required by the code and *approved* plans and specifications as to installed HVAC equipment type and size, required controls, duct and piping system insulation and corresponding *R*-value, duct system and damper air leakage and required energy recovery and/or economizers.

C104.2.5 Electrical and lighting inspection.

Inspections shall verify compliance as required by the code and *approved* plans and specifications as to installed lighting systems, components and controls; motors and installation of an electric meter for each dwelling unit.

C104.2.6 Final inspection. The building shall have a final inspection and not be occupied until *approved*.

C104.3 Reinspection. A building shall be reinspected when determined necessary by the *code official*.

C104.4 Approved inspection agencies. The *code official* is authorized to accept reports of *approved* inspection agencies, provided such agencies satisfy the requirements as to qualifications and reliability relevant to the building components and systems they are inspecting.

C104.5 Inspection requests. It shall be the duty of the holder of the permit or their duly authorized agent to notify the *code official* when work is ready for inspection. It shall be the duty of the permit holder to provide access to and means for inspections of such work that are required by this code.

C104.6 Reinspection and testing. Where any work or installation does not pass an initial test or inspection, the necessary corrections shall be made so as to achieve compliance with this code. The work or installation shall then be resubmitted to the *code official* for inspection and testing.

C104.7 Approval. After the prescribed tests and inspections indicate that the work complies in all respects with this code, a notice of approval shall be issued by the *code official*.

C104.7.1 Revocation. The *code official* is authorized to, in writing, suspend or revoke a notice of approval issued under the provisions of this code wherever the certificate is issued in error, or on the basis of incorrect information supplied, or where it is determined that the building or structure, premise, or portion thereof is in violation of any ordinance or regulation or any of the provisions of this code.

SECTION C105 VALIDITY

C105.1 General. If a portion of this code is held to be illegal or void, such a decision shall not affect the validity of the remainder of this code.

SECTION C106 REFERENCED STANDARDS

C106.1 Referenced codes and standards. The codes and standards referenced in this code shall be those listed in Chapter 5, and such codes and standards shall be considered as part of the requirements of this code to the prescribed extent of each such reference and as further regulated in Sections C106.1.1 and C106.1.2.

C106.1.1 Conflicts. Where differences occur between provisions of this code and referenced codes and standards, the provisions of this code shall apply.

C106.1.2 Provisions in referenced codes and standards. Where the extent of the reference to a referenced code or standard includes subject matter that is within the scope of this code, the provisions of this code, as applicable, shall take precedence over the provisions in the referenced code or standard.

C106.2 Application of references. References to chapter or section numbers, or to provisions not specifically identified by number, shall be construed to refer to such chapter, section or provision of this code.

C106.3 Other laws. The provisions of this code shall not be deemed to nullify any provisions of local, state or federal law. In addition to the requirements of this code, all occupancies shall conform to the provisions included in the State Building Code (chapter 19.27 RCW). In case of conflicts among the codes enumerated in RCW 19.27.031 (1) through (4) and this code, an earlier named code shall govern over those following. In the case of conflict between the duct sealing and insulation requirements of this code and the duct insulation requirements of Sections 603 and 604 of the *International Mechanical Code*, the duct insulation requirements of this code, or where applicable, a local jurisdiction's energy code shall govern.

SECTION C107 FEES

C107.1 Fees. A permit shall not be issued until the fees prescribed in Section C107.2 have been paid, nor shall an amendment to a permit be released until the additional fee, if any, has been paid.

C107.2 Schedule of permit fees. A fee for each permit shall be paid as required, in accordance with the schedule as established by the applicable governing authority.

C107.3 Work commencing before permit issuance. Any person who commences any work before obtaining the necessary permits shall be subject to an additional fee established by the *code official*, which shall be in addition to the required permit fees.

C107.4 Related fees. The payment of the fee for the construction, *alteration*, removal or demolition of work done in connection to or concurrently with the work or activity authorized by a permit shall not relieve the applicant or holder of the permit from the payment of other fees that are prescribed by law.

C107.5 Refunds. The *code official* is authorized to establish a refund policy.

SECTION C108 STOP WORK ORDER

C108.1 Authority. Whenever the *code official* finds any work regulated by this code being performed in a manner either contrary to the provisions of this code or dangerous or unsafe, the *code official* is authorized to issue a stop work order.

C108.2 Issuance. The stop work order shall be in writing and shall be given to the owner of the property involved, the owner's authorized agent, or to the person doing the work. Upon issuance of a stop work order, the cited work shall immediately cease. The stop work order shall state the reason for the order, and the conditions under which the cited work will be permitted to resume.

C108.3 Emergencies. Where an emergency exists, the *code official* shall not be required to give a written notice prior to stopping the work.

C108.4 Failure to comply. Any person who shall continue any work after having been served with a stop work order, except such work as that person is directed to perform to remove a violation or unsafe condition, shall be liable to a fine as set by the applicable governing authority.

SECTION C109 BOARD OF APPEALS

C109.1 General. In order to hear and decide appeals of orders, decisions or determinations made by the *code official* relative to the application and interpretation of this code, there shall be and is hereby created a board of appeals. The *code official* shall be an ex officio member of said board but shall have no vote on any matter before the board. The board of appeals shall be appointed by the governing body and shall hold office at its pleasure. The board shall adopt rules of procedure for conducting its business, and shall render all decisions and findings in writing to the appellant with a duplicate copy to the *code official*.

C109.2 Limitations on authority. An application for appeal shall be based on a claim that the true intent of this code or the rules legally adopted thereunder have been incorrectly interpreted, the provisions of this code do not fully apply or an equally good or better form of construction is proposed. The board shall have no authority to waive requirements of this code.

C109.3 Qualifications. The board of appeals shall consist of members who are qualified by experience and training and are not employees of the jurisdiction.

SECTION C110 VIOLATIONS

It shall be unlawful for any person, firm, or corporation to erect or construct any building, or remodel or rehabilitate any existing building or structure in the state, or allow the same to be done, contrary to or in violation of any of the provisions of this code.

SECTION C111 LIABILITY

Nothing contained in this code is intended to be nor shall be construed to create or form the basis for any liability on the part of any city or county or its officers, employees or agents for any injury or damage resulting from the failure of a building to conform to the provisions of this code.

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CHAPTER 2 [CE]

DEFINITIONS

SECTION C201 GENERAL

C201.1 Scope. Unless stated otherwise, the following words and terms in this code shall have the meanings indicated in this chapter.

C201.2 Interchangeability. Words used in the present tense include the future; words in the masculine gender include the feminine and neuter; the singular number includes the plural and the plural includes the singular.

C201.3 Terms defined in other codes. Terms that are not defined in this code but are defined in the *International Building Code, International Fire Code, International Fuel Gas Code, International Mechanical Code, Uniform Plumbing Code* or the *International Residential Code* shall have the meanings ascribed to them in those codes.

C201.4 Terms not defined. Terms not defined by this chapter shall have ordinarily accepted meanings such as the context implies.

SECTION C202 GENERAL DEFINITIONS

ABOVE-GRADE WALL. A wall enclosing *conditioned space* that is not a below-grade wall. This includes between-floor spandrels, peripheral edges of floors, roof and basement knee walls, dormer walls, gable end walls, walls enclosing a mansard roof and skylight shafts.

ACCESSIBLE. Admitting close approach as a result of not being guarded by locked doors, elevation or other effective means (see "*Readily accessible*").

ADDITION. An extension or increase in the *conditioned space* floor area or height of a building or structure.

AIR BARRIER. Material(s) assembled and joined together to provide a barrier to air leakage through the building envelope. An air barrier may be a single material or a combination of materials.

AIR CURTAIN. A device, installed at the building entrance, that generates and discharges a laminar air stream intended to prevent the infiltration of external, unconditioned air into the conditioned spaces, or the loss of interior, conditioned air to the outside.

ALTERATION. Any construction, retrofit or renovation to an existing structure other than repair or addition that requires a permit. Also, a change in a building, electrical, gas, mechanical or plumbing system that involves an

extension, addition or change to the arrangement, type or purpose of the original installation that requires a permit.

APPROVED. Approval by the *code official* as a result of investigation and tests conducted by him or her, or by reason of accepted principles or tests by nationally recognized organizations.

APPROVED AGENCY. An established and recognized agency regularly engaged in conducting tests or furnishing inspection services, when such agency has been *approved* by the *code official*.

ATTIC AND OTHER ROOFS. All other roofs, including roofs with insulation entirely below (inside of) the roof structure (i.e., attics, cathedral ceilings, and single-rafter ceilings), roofs with insulation both above and below the roof structure, and roofs without insulation but excluding roofs with insulation entirely above deck and metal building roofs.

AUTOMATIC. Self-acting, operating by its own mechanism when actuated by some impersonal influence, as, for example, a change in current strength, pressure, temperature or mechanical configuration (see "*Manual*").

BELOW-GRADE WALL. That portion of a wall in the building envelope that is entirely below the finish grade and in contact with the ground.

BOILER, MODULATING. A boiler that is capable of more than a single firing rate in response to a varying temperature or heating load.

BOILER SYSTEM. One or more boilers, their piping and controls that work together to supply steam or hot water to heat output devices remote from the boiler.

BUBBLE POINT. The refrigerant liquid saturation temperature at a specified pressure.

BUILDING. Any structure used or intended for supporting or sheltering any use or occupancy, including any mechanical systems, service water heating systems and electric power and lighting systems located on the building site and supporting the building.

BUILDING COMMISSIONING. A process that verifies and documents that the selected building systems have been designed, installed, and function according to the owner's project requirements and construction documents, and to minimum code requirements.

BUILDING ENTRANCE. Any door, set of doors, doorway, or other form of portal that is used to gain access to the building from the outside by the public.

BUILDING SITE. A contiguous area of land that is under the ownership or control of one entity.

BUILDING THERMAL ENVELOPE. The below-grade walls, above-grade walls, floor, roof, and any other building elements that enclose *conditioned space* or provides a boundary between *conditioned space*, *semiheated space* and exempt or unconditioned space.

C-FACTOR (THERMAL CONDUCTANCE). The coefficient of heat transmission (surface to surface) through a building component or assembly, equal to the time rate of heat flow per unit area and the unit temperature difference between the warm side and cold side surfaces (Btu/h ft² x °F) [W/(m² x K)].

CERTIFIED COMMISSIONING PROFESSIONAL. An individual who is certified by an ANSI/ISO/IEC 17024:2012 accredited organization to lead, plan, coordinate and manage commissioning teams and implement commissioning processes, or a licensed professional engineer in Washington state.

CIRCULATING HOT WATER SYSTEM. A specifically designed water distribution system where one or more pumps are operated in the service hot water piping to circulate heated water from the water-heating equipment to the fixture supply and back to the water-heating equipment.

CLERESTORY FENESTRATION. See “Fenestration.”

CLIMATE ZONE. A geographical region based on climatic criteria as specified in this code.

CODE OFFICIAL. The officer or other designated authority charged with the administration and enforcement of this code, or a duly authorized representative.

COEFFICIENT OF PERFORMANCE (COP) - COOLING. The ratio of the rate of heat removal to the rate of energy input, in consistent units, for a complete refrigerating system or some specific portion of that system under designated operating conditions.

COEFFICIENT OF PERFORMANCE (COP) - HEATING. The ratio of the rate of heat removal to the rate of heat delivered to the rate of energy input, in consistent units, for a complete heat pump system, including the compressor and, if applicable, auxiliary heat, under designated operating conditions.

COMMERCIAL BUILDING. For this code, all buildings not included in the definition of “Residential buildings.”

COMPUTER ROOM. A room whose primary function is to house equipment for the processing and storage of electronic data and that has a design electronic data equipment power density exceeding 20 watts per square foot of conditioned area.

CONDENSING UNIT. A factory-made assembly of refrigeration components designed to compress and liquefy a specific refrigerant. The unit consists of one or more refrigerant compressors, refrigerant condensers (air-cooled, evaporatively cooled, or water-cooled), condenser fans and motors (where used) and factory-supplied accessories.

CONDITIONED FLOOR AREA. The horizontal projection of the floors associated with the *conditioned space*.

CONDITIONED SPACE. An area, room or space that is enclosed within the building thermal envelope and that is directly heated or cooled or that is indirectly heated or cooled. Spaces are indirectly heated or cooled where they communicate through openings with conditioned spaces, where they are separated from conditioned spaces by uninsulated walls, floors or ceilings, or where they contain uninsulated ducts, piping or other sources of heating or cooling.

CONTINUOUS AIR BARRIER. A combination of materials and assemblies that restrict or prevent the passage of air through the building thermal envelope.

CONTINUOUS INSULATION (CI). Insulating material that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior or is integral to any opaque surface of the building envelope.

CONTROLLED PLANT GROWTH ENVIRONMENT. Group F and U buildings or spaces that are specifically controlled to facilitate and enhance plant growth and production by manipulating various indoor environmental conditions. Technologies include indoor agriculture, cannabis growing, hydroponics, aquaculture and aquaponics. Controlled indoor environment variables include, but are not limited to, temperature, air quality, humidity and carbon dioxide.

CURTAIN WALL. Fenestration products used to create an external nonload-bearing wall that is designed to separate the exterior and interior environments.

DATA ACQUISITION SYSTEM. An electronic system managed by the building owner to collect, tabulate and display metering information.

DAYLIGHT RESPONSIVE CONTROL. A device or system that provides automatic control of electric light levels based on the amount of daylight in a space.

DAYLIGHT ZONE. The portion of the building interior floor area that is illuminated by natural daylight through sidelight and toplight fenestration.

DEMAND CONTROL VENTILATION (DCV). A ventilation system capability that provides for the automatic reduction of outdoor air intake below design rates when the actual occupancy of spaces served by the system is less than design occupancy.

DEMAND RECIRCULATION WATER SYSTEM. A water distribution system where pumps prime the service hot water piping with heated water upon demand for hot water.

DOOR, NONSWINGING. Roll-up, tilt-up, metal coiling and sliding doors, access hatches, and all other doors that are not swinging doors.

DOORS, SWINGING. Doors that are hinged on one side and revolving doors.

DUCT. A tube or conduit utilized for conveying air. The air passages of self-contained systems are not to be construed as air ducts.

DUCT SYSTEM. A continuous passageway for the transmission of air that, in addition to ducts, includes duct fittings, dampers, plenums, fans and accessory air-handling equipment and appliances.

DWELLING UNIT. A single unit providing complete independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking and sanitation.

DYNAMIC GLAZING. Any fenestration product that has the fully reversible ability to change its performance properties, including *U*-factor, SHGC, or VT.

ECONOMIZER, AIR. A duct and damper arrangement and automatic control system that allows a cooling system to supply outside air to reduce or eliminate the need for mechanical cooling during mild or cold weather.

ECONOMIZER, WATER. A system where the supply air of a cooling system is cooled indirectly with water that is itself cooled by heat or mass transfer to the environment without the use of mechanical cooling.

ENCLOSED SPACE. A volume surrounded by solid surfaces such as walls, floors, roofs, and operable devices such as doors and operable windows.

END USE CATEGORY. A load or group of loads that consume energy in a common or similar manner.

ENERGY ANALYSIS. A method for estimating the annual energy use of the *proposed design* and *standard reference design* based on estimates of energy use.

ENERGY COST. The total estimated annual cost for purchased energy for the building functions regulated by this code, including applicable demand charges.

ENERGY RECOVERY VENTILATION SYSTEM. Systems that employ air-to-air heat exchangers to recover energy from exhaust air for the purpose of preheating, precooling, humidifying or dehumidifying outdoor ventilation air prior to supplying the air to a space, either directly or as part of an HVAC system.

ENERGY SIMULATION TOOL. An *approved* software program or calculation-based methodology that projects the annual energy use of a building.

ENERGY SOURCE METER. A meter placed at the source of the incoming energy that measures the energy delivered to the whole building or metered space.

ENTRANCE DOOR. Fenestration products used for ingress, egress and access in nonresidential buildings including, but not limited to, exterior entrances that utilize latching hardware and automatic closers and contain over 50 percent glass specifically designed to withstand heavy use and possibly abuse.

EQUIPMENT ROOM. A space that contains either electrical equipment, mechanical equipment, machinery, water pumps or hydraulic pumps that are a function of the building's services.

EXTERIOR WALL. Walls including both above-grade walls and below-grade walls.

FAN BRAKE HORSEPOWER (BHP). The horsepower delivered to the fan's shaft. Brake horsepower does not include the mechanical drive losses (belts, gears, etc.).

FAN EFFICIENCY GRADE (FEG). A numerical rating identifying the fan's aerodynamic ability to convert shaft power, or impeller power in the case of a direct-driven fan, to air power.

FAN SYSTEM BHP. The sum of the fan brake horsepower of all fans that are required to operate at fan system design conditions to supply air from the heating or cooling source to the *conditioned space(s)* and return it to the source or exhaust it to the outdoors.

FAN SYSTEM DESIGN CONDITIONS. Operating conditions that can be expected to occur during normal system operation that result in the highest supply fan airflow rate to conditioned spaces served by the system.

FAN SYSTEM MOTOR NAMEPLATE HP. The sum of the motor nameplate horsepower of all fans that are required to operate at design conditions to supply air from the heating or cooling source to the *conditioned space(s)* and return it to the source or exhaust it to the outdoors.

FENESTRATION. Products classified as either vertical fenestration or skylights.

SKYLIGHT. Glass or other transparent or translucent glazing material installed at a slope of less than 60 degrees (91.05 rad) from horizontal.

VERTICAL FENESTRATION. Windows (fixed or moveable), glazed doors, glazed block and combination opaque/glazed doors composed of glass or other transparent or translucent glazing materials and installed at a slope of at least 60 degrees (91.05 rad) from horizontal. Opaque areas such as spandrel panels are not considered vertical fenestration.

CLERESTORY FENESTRATION. An upper region of vertical fenestration provided for the purpose of admitting daylight beyond the perimeter of a space. The entire clerestory fenestration assembly is installed at a height greater than 8 feet above the finished floor.

FENESTRATION AREA. Total area of the fenestration measured using the rough opening, and including the glazing, sash and frame.

FENESTRATION PRODUCT, FIELD-FABRICATED. A fenestration product whose frame is made at the construction site of standard dimensional lumber or other materials that were not previously cut, or otherwise formed with the specific intention of being used to fabricate a fenestration product or exterior door. Field fabricated does not include site-built fenestration.

FENESTRATION PRODUCT, SITE-BUILT. A fenestration designed to be made up of field-glazed or field-assembled units using specific factory cut or otherwise factory-formed framing and glazing units. Examples of site-built fenestration include storefront systems, curtain walls, and atrium roof systems.

F-FACTOR. The perimeter heat loss factor for slab-on-grade floors (Btu/h x ft x °F) [W/(m x K)].

FLOOR AREA, NET. The actual occupied area not including unoccupied accessory areas such as corridors, stairways, toilet rooms, mechanical rooms and closets.

FURNACE ELECTRICITY RATIO. The ratio of furnace electricity use to total furnace energy computed as ratio $:= (3.412 \times E_{AE}) / (1000 \times E_F + 3.412 \times E_{AE})$ where E_{AE} (average annual auxiliary electrical consumption) and E_F (average annual fuel energy consumption) are defined in Appendix N to Subpart B of Part 430 of Title 10 of the Code of Federal Regulations and E_F is expressed in millions of Btus per year.

GENERAL LIGHTING. Lighting that provides a substantially uniform level of illumination throughout an area. General lighting shall not include lighting that provides a dissimilar level of illumination to serve a specific application or decorative feature within such area.

GENERAL PURPOSE ELECTRIC MOTOR (SUBTYPE I). A motor that is designed in standard ratings with either of the following:

1. Standard operating characteristics and standard mechanical construction for use under usual service conditions, such as those specified in NEMA MG1, paragraph 14.02, "Usual Service Conditions," and without restriction to a particular application or type of application.
2. Standard operating characteristics or standard mechanical construction for use under unusual service conditions, such as those specified in NEMA MG1, paragraph 14.03, "Unusual Service

Conditions," or for a particular type of application, and that can be used in most general purpose applications.

General purpose electric motors (Subtype I) are constructed in NEMA T-frame sizes or IEC metric equivalent, starting at 143T.

GENERAL PURPOSE ELECTRIC MOTOR (SUBTYPE II). A motor incorporating the design elements of a general purpose electric motor (Subtype I) that is configured as one of the following:

1. A U-frame motor.
2. A Design C motor.
3. A close-coupled pump motor.
4. A footless motor.
5. A vertical, solid-shaft, normal-thrust motor (as tested in a horizontal configuration).
6. An 8-pole motor (900 rpm).
7. A polyphase motor with voltage of not more than 600 volts (other than 230 or 460 volts).

GREENHOUSE. A structure or a thermally isolated area of a building that maintains a specialized sunlit environment that is used exclusively for, and essential to, the cultivation, protection or maintenance of plants. Greenhouses are those that are erected for a period of 180 days or more.

HEAT TRAP. An arrangement of piping and fittings, such as elbows, or a commercially available heat trap that prevents thermosyphoning of hot water during standby periods.

HEATED SLAB-ON-GRADE FLOOR. Slab-on-grade floor construction in which the heating elements, hydronic tubing, or hot air distribution system is in contact with, or placed within or under, the slab.

HIGH SPEED DOOR. A nonswinging door used primarily to facilitate vehicular access or material transportation, with a minimum opening rate of 32 inches (813 mm) per second, a minimum closing rate of 24 inches (610 mm) per second and that includes an automatic-closing device.

HISTORIC BUILDINGS. Buildings that are listed in or eligible for listing in the National Register of Historic Places, or designated as historic under an appropriate state or local law.

HUMIDISTAT. A regulatory device, actuated by changes in humidity, used for automatic control of relative humidity.

INFILTRATION. The uncontrolled inward air leakage into a building caused by the pressure effects of wind or the effect of differences in the indoor and outdoor air density or both.

INSULATION ENTIRELY ABOVE DECK. A roof with all insulation:

1. Installed above (outside of) the roof structure; and
2. Continuous (i.e., uninterrupted by framing members).

INTEGRATED ENERGY EFFICIENCY RATIO (IEER). A single-number figure of merit expressing cooling part-load EER efficiency for unitary air-conditioning and heat pump equipment on the basis of weighted operation at various load capacities for the equipment.

INTEGRATED PART LOAD VALUE (IPLV). A single number figure of merit based on part-load EER, COP, or kW/ton expressing part-load efficiency for air conditioning and heat pump equipment on the basis of weighted operation at various load capacities for equipment.

LABELED. Equipment, materials or products to which have been affixed a label, seal, symbol or other identifying mark of a nationally recognized testing laboratory, inspection agency or other organization concerned with product evaluation that maintains periodic inspection of the production of the above-labeled items and whose labeling indicates either that the equipment, material or product meets identified standards or has been tested and found suitable for a specified purpose.

LINER SYSTEM (LS). A system that includes the following:

1. A continuous vapor barrier liner membrane that is installed below the purlins and that is uninterrupted by framing members.
2. An uncompressed, unfaced insulation resting on top of the liner membrane and located between the purlins.

For multilayer installations, the last rated *R-value* of insulation is for unfaced insulation draped over purlins and then compressed when the metal roof panels are attached.

LISTED. Equipment, materials, products or services included in a list published by an organization acceptable to the *code official* and concerned with evaluation of products or services that maintains periodic inspection of production of *listed* equipment or materials or periodic evaluation of services and whose listing states either that the equipment, material, product or service meets identified standards or has been tested and found suitable for a specified purpose.

LOW SLOPED ROOF. A roof having a slope less than 2 units vertical in 12 units horizontal.

LOW-VOLTAGE DRY-TYPE DISTRIBUTION

TRANSFORMER. A transformer that is air-cooled, does not use oil as a coolant, has an input voltage less than or equal to 600 volts and is rated for operation at a frequency of 60 hertz.

LOW-VOLTAGE LIGHTING. A lighting system consisting of an isolating power supply, the low voltage luminaires, and associated equipment that are all identified for the use. The output circuits of the power supply operate at 30 volts (42.4 volts peak) or less under all load conditions.

LUMINAIRE. A complete lighting unit consisting of a lamp or lamps together with the housing designed to distribute the light, position and protect the lamps, and connect the lamps to the power supply.

LUMINAIRE-LEVEL LIGHTING CONTROL. A lighting system consisting of one or more luminaire(s) each with embedded lighting control logic, occupancy and ambient light sensors, local or central wireless networking capabilities, and local override switching capability.

MANUAL. Capable of being operated by personal intervention (see "Automatic").

MASS TRANSFER DECK SLAB EDGE. That portion of the above-grade wall made up of the concrete slab where it extends past the footprint of the floor above. The area of the slab edge shall be defined as the thickness of the slab multiplied by the perimeter of the edge condition. Examples of this condition include, but are not limited to, the transition from an above-grade structure to a below-grade structure or the transition from a tower to a podium.

METAL BUILDING ROOF. A roof that:

1. Is constructed with a metal, structural, weathering surface;
2. Has no ventilated cavity; and
3. Has the insulation entirely below deck (i.e., does not include composite concrete and metal deck construction nor a roof framing system that is separated from the superstructure by a wood substrate) and whose structure consists of one or more of the following configurations:
 - a. Metal roofing in direct contact with the steel framing members;
 - b. Metal roofing separated from the steel framing members by insulation;
 - c. Insulated metal roofing panels installed as described in a or b.

METAL BUILDING WALL. A *wall* whose structure consists of metal spanning members supported by steel structural members (i.e., does not include spandrel glass or metal panels in curtain *wall systems*).

METER. A device that measures the flow of energy.

MICROCELL. A wireless communication facility consisting of an antenna that is either: (a) Four (4) feet in height and with an area of not more than 580 square inches; or (b) if a tubular antenna, no more than four (4) inches in diameter and no more than six (6) feet in length; and the associated equipment cabinet that is six (6) feet or less in height and no more than 48 square feet in floor area.

NAMEPLATE HORSEPOWER. The nominal motor horsepower rating stamped on the motor nameplate.

NONSTANDARD PART LOAD VALUE (NPLV). A single-number part-load efficiency figure of merit calculated and referenced to conditions other than IPLV conditions, for units that are not designed to operate at ARI standard rating conditions.

OCCUPANT SENSOR CONTROL. An automatic control device or system that detects the presence or absence of people within an area and causes lighting, equipment or appliances to be regulated accordingly.

ON-SITE RENEWABLE ENERGY. Energy derived from solar radiation, wind, waves, tides, landfill gas, biomass, or the internal heat of the earth. The energy system providing on-site renewable energy shall be located on the project site.

OPAQUE DOOR. A door that is not less than 50 percent opaque in surface area.

PERSONAL WIRELESS SERVICE FACILITY. A wireless communication facility (WCF), including a microcell, which is a facility for the transmission and/or reception of radio frequency signals and which may include antennas, equipment shelter or cabinet, transmission cables, a support structure to achieve the necessary elevation, and reception and/or transmission devices or antennas.

POWERED ROOF/WALL VENTILATORS. A fan consisting of a centrifugal or axial impeller with an integral driver in a weather-resistant housing and with a base designed to fit, usually by means of a curb, over a wall or roof opening.

PROPOSED DESIGN. A description of the proposed building used to estimate annual energy use for determining compliance based on total building performance.

RADIANT HEATING SYSTEM. A heating system that transfers heat to objects and surfaces within a conditioned space, primarily by infrared radiation.

READILY ACCESSIBLE. Capable of being reached quickly for operation, renewal or inspection without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders or access equipment (see "Accessible").

REFRIGERANT DEW POINT. The refrigerant vapor saturation temperature at a specified pressure.

REFRIGERATED WAREHOUSE COOLER. An enclosed storage space that has a total chilled storage area of 3,000 square feet or greater and is designed to maintain a temperature of greater than 32°F but less than 55°F.

REFRIGERATED WAREHOUSE FREEZER. An enclosed storage space that has a total chilled storage area of 3,000 ft² and is designed to maintain temperatures at or below 32°F.

REFRIGERATION SYSTEM, LOW TEMPERATURE. Systems for maintaining food product in a frozen state in refrigeration applications.

REFRIGERATION SYSTEM, MEDIUM TEMPERATURE. Systems for maintaining food product above freezing in refrigeration applications.

REGISTERED DESIGN PROFESSIONAL. An individual who is registered or licensed to practice their respective design profession as defined by the statutory requirements of the professional registration laws of the state or jurisdiction in which the project is to be constructed.

REPAIR. The reconstruction or renewal of any part of an existing building.

REROOFING. The process of recovering or replacing an existing roof covering. See "Roof Recover" and "Roof Replacement."

RESIDENTIAL BUILDING. For this code, includes detached one- and two-family dwellings and multiple single-family dwellings (townhouses) as well as Group R-2, R-3 and R-4 buildings three stories or less in height above grade plane.

ROOF ASSEMBLY. A system designed to provide weather protection and resistance to design loads. The system consists of a roof covering and roof deck or a single component serving as both the roof covering and the roof deck. A roof assembly includes the roof covering, underlayment, roof deck, insulation, vapor retarder and interior finish.

ROOF RECOVER. The process of installing an additional *roof covering* over a prepared existing roof covering without removing the existing roof covering.

ROOF REPAIR. Reconstruction or renewal of any part of an existing roof for the purposes of its maintenance.

ROOF REPLACEMENT. The process of removing the existing roof covering, repairing any damaged substrate and installing a new *roof covering*.

ROOFTOP MONITOR. A raised section of a roof containing vertical fenestration along one or more sides.

R-VALUE (THERMAL RESISTANCE). The inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other surface for a unit temperature difference between the two surfaces, under steady state conditions, per unit area ($h \times \text{ft}^2 \times ^\circ\text{F}/\text{Btu}$) [$(\text{m}^2 \times \text{K})/\text{W}$].

SATURATED CONDENSING TEMPERATURE. The saturation temperature corresponding to the measured refrigerant pressure at the condenser inlet for single component and azeotropic refrigerants, and the arithmetic average of the dew point and *bubble point* temperatures corresponding to the refrigerant pressure at the condenser entrance for zeotropic refrigerants.

SCREW LAMP HOLDERS. A lamp base that requires a screw-in-type lamp, such as a compact-fluorescent, incandescent, or tungsten-halogen bulb.

SEMI-HEATED SPACE. An enclosed space within a building, including adjacent connected spaces separated by an uninsulated component (e.g., basements, utility rooms, garages, corridors), which:

1. Is heated but not cooled, and has a maximum installed heating system output capacity of 3.4 Btu/(h-ft²) but not greater than 8 Btu/(h-ft²);
2. Is not a walk-in or warehouse cooler or freezer space.

SERVICE WATER HEATING. Heating water for domestic or commercial purposes other than space heating and process requirements.

SKYLIGHT. See “Fenestration.”

SLAB BELOW GRADE. Any portion of a slab floor in contact with the ground which is more than 24 inches below the final elevation of the nearest exterior grade.

SLAB-ON-GRADE FLOOR. That portion of a slab floor of the building envelope that is in contact with the ground and that is either above grade or is less than or equal to 24 inches below the final elevation of the nearest exterior grade.

SLEEPING UNIT. A room or space in which people sleep, which can also include permanent provisions for living, eating, and either sanitation or kitchen facilities but not both. Such rooms and spaces that are also part of a dwelling unit are not *sleeping units*.

SMALL BUSINESS. Any business entity (including a sole proprietorship, corporation, partnership or other legal entity) which is owned and operated independently from all other businesses, which has the purpose of making a profit, and which has fifty or fewer employees.

SMALL ELECTRIC MOTOR. A general purpose, alternating current, single speed induction motor.

SOLAR HEAT GAIN COEFFICIENT (SHGC). The ratio of the solar heat gain entering the space through the fenestration assembly to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation which is then reradiated, conducted or convected into the space.

STANDARD REFERENCE DESIGN. A version of the *proposed design* that meets the minimum requirements of this code and is used to determine the maximum annual energy use requirement for compliance based on total building performance.

STEEL-FRAMED WALL. A *wall* with a cavity (insulated or otherwise) whose exterior surfaces are separated by steel framing members (i.e., typical steel stud *walls* and curtain *wall systems*).

STOREFRONT. A nonresidential system of doors and windows mullied as a composite fenestration structure that has been designed to resist heavy use. *Storefront* systems include, but are not limited to, exterior fenestration systems that span from the floor level or above to the ceiling of the same story on commercial buildings, with or without mullied windows and doors.

SUBSYSTEM METER. A meter placed downstream of the energy supply meter that measures the energy delivered to a load or a group of loads.

TEMPORARY GROWING STRUCTURE. A temporary growing structure has sides and roof covered with polyethylene, polyvinyl or similar flexible synthetic material and is used to provide plants with either frost protection or increased heat retention. Temporary structures are those that are erected for a period of less than 180 days.

THERMOSTAT. An automatic control device used to maintain temperature at a fixed or adjustable set point.

TIME SWITCH CONTROL. An automatic control device or system that controls lighting or other loads, including switching off, based on time schedules.

U-FACTOR (THERMAL TRANSMITTANCE). The coefficient of heat transmission (air to air) through a building component or assembly, equal to the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films (Btu/h × ft² × °F) [W/(m² × K)].

UNHEATED SLAB-ON-GRADE FLOOR. A slab-on-grade floor that is not a heated slab-on-grade floor.

UNIFORM ILLUMINATION. A quality of illumination delivered by a lighting system typically comprised of similar fixtures mounted at a regular spacing interval. This lighting system provides a uniform contrast ratio of no greater than 5:1 maximum-to-minimum ratio throughout the entire area served, including task areas.

VARIABLE REFRIGERANT FLOW SYSTEM. An engineered direct-expansion (DX) refrigerant system that incorporates a common condensing unit, at least one variable capacity compressor, a distributed refrigerant

piping network to multiple indoor fan heating and cooling units each capable of individual zone temperature control, through integral zone temperature control devices and a common communications network. Variable refrigerant flow utilizes three or more steps of control on common interconnecting piping.

VENTILATION. The natural or mechanical process of supplying conditioned or unconditioned air to, or removing such air from, any space.

VENTILATION AIR. That portion of supply air that comes from outside (outdoors) plus any recirculated air that has been treated to maintain the desired quality of air within a designated space.

VERTICAL FENESTRATION. See “Fenestration.”

VISIBLE TRANSMITTANCE [VT]. The ratio of visible light entering the space through the fenestration product assembly to the incident visible light, visible transmittance, includes the effects of glazing material and frame and is expressed as a number between 0 and 1.

WALK-IN COOLER. An enclosed storage space capable of being refrigerated to temperatures above 32°F but less than 55°F that can be walked into, has a ceiling height of not less than 7 feet (2134 mm) and has a total chilled storage area of less than 3,000 ft².

WALK-IN FREEZER. An enclosed storage space capable of being refrigerated to temperatures at or below 32°F that can be walked into, has a ceiling height of not less than 7 feet and has a total chilled storage area of less than 3,000 ft².

WALL. That portion of the *building envelope*, including opaque area and *fenestration*, that is vertical or tilted at an angle of 60 degrees from horizontal or greater. This includes *above-grade walls* and *below-grade walls*, between floor spandrels, peripheral edges of floors, and foundation *walls*.

WATER HEATER. Any heating appliance or equipment that heats potable water and supplies such water to the potable hot water distribution system.

WOOD-FRAMED AND OTHER WALLS. All other *wall* types, including wood stud *walls*.

ZONE. A space or group of spaces within a building with heating or cooling requirements that are sufficiently similar so that desired conditions can be maintained throughout using a single controlling device.

CHAPTER 3 [CE]

GENERAL REQUIREMENTS

SECTION C301 CLIMATE ZONES

C301.1 General. Climate zones from Table C301.1 shall be used in determining the applicable requirements from Chapter 4.

**TABLE C301.1
CLIMATE ZONES, MOISTURE REGIMES,
AND WARM-HUMID DESIGNATIONS
BY STATE AND COUNTY**

Key: A - Moist, B - Dry, C - Marine.
Absence of moisture designation indicates
moisture regime is irrelevant.

WASHINGTON

5B Adams	4C Lewis
5B Asotin	5B Lincoln
5B Benton	4C Mason
5B Chelan	5B Okanogan
4C Clallam	4C Pacific
4C Clark	5B Pend Oreille
5B Columbia	4C Pierce
4C Cowlitz	4C San Juan
5B Douglas	4C Skagit
5B Ferry	5B Skamania
5B Franklin	4C Snohomish
5B Garfield	5B Spokane
5B Grant	5B Stevens
4C Grays Harbor	4C Thurston
4C Island	4C Wahkiakum
4C Jefferson	5B Walla Walla
4C King	4C Whatcom
4C Kitsap	5B Whitman
5B Kittitas	5B Yakima
5B Klickitat	

SECTION C302 DESIGN CONDITIONS

C302.1 Interior design conditions. The interior design temperatures used for heating and cooling load calculations shall be a maximum of 72°F (22°C) for heating and minimum of 75°F (24°C) for cooling.

C302.2 Exterior design conditions. The heating or cooling outdoor design temperatures shall be selected from Appendix C.

SECTION C303 MATERIALS, SYSTEMS AND EQUIPMENT

C303.1 Identification. Materials, systems and equipment shall be identified in a manner that will allow a determination of compliance with the applicable provisions of this code.

C303.1.1 Building thermal envelope insulation. An *R*-value identification mark shall be applied by the manufacturer to each piece of *building thermal envelope* insulation 12 inches (305 mm) or greater in width. Alternately, the insulation installers shall provide a certification listing the type, manufacturer and *R*-value of insulation installed in each element of the *building thermal envelope*. For blown or sprayed insulation (fiberglass and cellulose), the initial installed thickness, settled thickness, settled *R*-value, installed density, coverage area and number of bags installed shall be *listed* on the certification. For sprayed polyurethane foam (SPF) insulation, the installed thickness of the areas covered and *R*-value of installed thickness shall be *listed* on the certification. For insulated siding, the *R*-value shall be labeled on the product's package and shall be listed on the certification. The insulation installer shall sign, date and post the certification in a conspicuous location on the job site.

C303.1.1.1 Blown or sprayed roof/ceiling insulation. The thickness of blown-in or sprayed roof/ceiling insulation (fiberglass or cellulose) shall be written in inches (mm) on markers that are installed at least one for every 300 square feet (28 m²) throughout the attic space. The markers shall be affixed to the trusses or joists and marked with the minimum initial installed thickness with numbers of

not less than 1 inch (25 mm) in height. Each marker shall face the attic access opening. Spray polyurethane foam thickness and installed *R*-value shall be *listed* on certification provided by the insulation installer.

C303.1.2 Insulation mark installation. Insulating materials shall be installed such that the manufacturer's *R*-value mark is readily observable upon inspection.

C303.1.3 Fenestration product rating. *U*-factors of fenestration products (windows, doors and skylights) shall be determined in accordance with NFRC 100.

Exception: Where required, garage door *U*-factors shall be determined in accordance with either NFRC 100 or ANSI/SASMA 105.

U-factors shall be determined by an accredited, independent laboratory, and labeled and certified by the manufacturer.

Products lacking such a labeled *U*-factor shall be assigned a default *U*-factor from Table C303.1.3(1), C303.1.3(2) or C303.1.3(4). The solar heat gain coefficient (SHGC) and visible transmittance (VT) of glazed fenestration products (windows, glazed doors and skylights) shall be determined in accordance with NFRC 200 by an accredited, independent laboratory, and labeled and certified by the manufacturer. Products lacking such a labeled SHGC or VT shall be assigned a default SHGC or VT from Table C303.1.3(3).

Exception: Units without NFRC ratings produced by a *small business* may be assigned default *U*-factors from Table C303.1.3(5) for vertical fenestration.

**TABLE C303.1.3(1)
DEFAULT GLAZED FENESTRATION
U-FACTORS**

FRAME TYPE	SINGLE PANE	DOUBLE PANE	SKYLIGHT
Metal	1.20	0.80	See Table C303.1.3(4)
Metal with Thermal Break ¹	1.10	0.65	
Nonmetal or Metal Clad	0.95	0.55	
Glazed Block	0.60		

¹ Metal Thermal Break = A metal thermal break framed window shall incorporate the following minimum design characteristics:

- The thermal conductivity of the thermal break material shall be not more than 3.6 Btu-in/h/ft²/°F;
- The thermal break material must produce a gap in the frame material of not less than 0.210 inches; and
- All metal framing members of the products exposed to interior and exterior air shall incorporate a thermal break meeting the criteria in a) and b) above.

C303.1.4 Insulation product rating. The thermal resistance (*R*-value) of insulation shall be determined in accordance with the U.S. Federal Trade Commission *R*-value rule (C.F.R. Title 16, Part 460) in units of h × ft² × °F/Btu at a mean temperature of 75°F (24°C).

C303.1.4.1 Insulated siding. The thermal resistance (*R*-value) shall be determined in accordance with ASTM C1363. Installation for testing shall be in accordance with the manufacturer's installation instructions.

C303.2 Installation. Materials, systems and equipment shall be installed in accordance with the manufacturer's instructions and the *International Building Code* or *International Residential Code*, as applicable.

C303.2.1 Protection of exposed foundation insulation. Insulation applied to the exterior of basement walls, crawlspace walls and the perimeter of slab-on-grade floors shall have a rigid, opaque and weather-resistant protective covering to prevent the degradation of the insulation's thermal performance. The protective covering shall cover the exposed exterior insulation and extend not less than 6 inches (153 mm) below grade.

C303.3 Maintenance information. Maintenance instructions shall be furnished for equipment and systems that require preventive maintenance. Required regular maintenance actions shall be clearly stated and incorporated on a *readily accessible* label. The label shall include the title or publication number for the operation and maintenance manual for that particular model and type of product.

**TABLE C303.1.3(2)
DEFAULT DOOR *U*-FACTORS**

See Appendix A, Section A107

**TABLE C303.1.3(3)
DEFAULT GLAZED FENESTRATION
SHGC AND VT**

	SINGLE GLAZED		DOUBLE GLAZED		GLAZED BLOCK
	Clear	Tinted	Clear	Tinted	
SHGC	0.40	0.40	0.40	0.40	0.40
VT	0.6	0.3	0.6	0.3	0.6

TABLE C303.1.3(4)
DEFAULT U-FACTORS FOR SKYLIGHTS

Fenestration Type	Frame Type			
	Aluminum Without Thermal Break	Aluminum With Thermal Break	Reinforced Vinyl/ Aluminum-Clad Wood or Vinyl	Wood or Vinyl-Clad Wood/ Vinyl without Reinforcing
Single Glazing glass acrylic/polycarb	U-1.58 U-1.52	U-1.51 U-1.45	U-1.40 U-1.34	U-1.18 U-1.11
Double Glazing air argon	U-1.05 U-1.02	U-0.89 U-0.86	U-0.84 U-0.80	U-0.67 U-0.64
Double Glazing, $e=0.20$ air argon	U-0.96 U-0.91	U-0.80 U-0.75	U-0.75 U-0.70	U-0.59 U-0.54
Double Glazing, $e=0.10$ air argon	U-0.94 U-0.89	U-0.79 U-0.73	U-0.74 U-0.68	U-0.58 U-0.52
Double Glazing, $e=0.05$ air argon	U-0.93 U-0.87	U-0.78 U-0.71	U-0.73 U-0.66	U-0.56 U-0.50
Triple Glazing air argon	U-0.90 U-0.87	U-0.70 U-0.69	U-0.67 U-0.64	U-0.51 U-0.48
Triple Glazing, $e=0.20$ air argon	U-0.86 U-0.82	U-0.68 U-0.63	U-0.63 U-0.59	U-0.47 U-0.43
Triple Glazing, $e=0.20$ on 2 surfaces air argon	U-0.82 U-0.79	U-0.64 U-0.60	U-0.60 U-0.56	U-0.44 U-0.40
Triple Glazing, $e=0.10$ on 2 surfaces air argon	U-0.81 U-0.77	U-0.62 U-0.58	U-0.58 U-0.54	U-0.42 U-0.38
Quadruple Glazing, $e=0.10$ on 2 surfaces air argon krypton	U-0.78 U-0.74 U-0.70	U-0.59 U-0.56 U-0.52	U-0.55 U-0.52 U-0.48	U-0.39 U-0.36 U-0.32

Notes for Table C303.1.3(4)

1. U-factors are applicable to both glass and plastic, flat and domed units, all spacers and gaps.
2. Emissivities shall be less than or equal to the value specified.
3. Gap fill shall be assumed to be air unless there is a minimum of 90% argon or krypton.
4. Aluminum frame with thermal break is as defined in footnote 1 to Table C303.1.3(1).

TABLE C303.1.3(5)
SMALL BUSINESS COMPLIANCE TABLE
DEFAULT *U*-FACTORS FOR VERTICAL FENESTRATION

Vertical Fenestration Description				Frame Type		
				Any Frame	Aluminum Thermal Break ²	Wood/Vinyl/Fiberglass
Panes	Low-e ¹	Spacer	Fill			
Double ³	A	Any	Argon	0.48	0.41	0.32
	B	Any	Argon	0.46	0.39	0.30
	C	Any	Argon	0.44	0.37	0.28
	C	High Performance	Argon	0.42	0.35	Deemed to comply ⁵
Triple ⁴	A	Any	Air	0.50	0.44	0.26
	B	Any	Air	0.45	0.39	0.22
	C	Any	Air	0.41	0.34	0.20
	Any double low-e	Any	Air	0.35	0.32	0.18

¹ Low-eA (emissivity) shall be 0.24 to 0.16.

Low-eB (emissivity) shall be 0.15 to 0.08.

Low-eC (emissivity) shall be 0.07 or less.

² Aluminum Thermal Break = An aluminum thermal break framed window shall incorporate the following minimum design characteristics:

a) The thermal conductivity of the thermal break material shall be not more than 3.6 Btu-in/h/ft²/°F;

b) The thermal break material must produce a gap in the frame material of not less than 0.210 inches; and

c) All metal framing members of the products exposed to interior and exterior air shall incorporate a thermal break meeting the criteria in a) and b) above.

³ A minimum air space of 0.375 inches between panes of glass is required for double glazing.

⁴ A minimum air space of 0.25 inches between panes of glass is required for triple glazing.

⁵ Deemed to comply glazing shall not be used for performance compliance.

CHAPTER 4 [CE]

COMMERCIAL ENERGY EFFICIENCY

SECTION C401 GENERAL

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

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

1. The requirements of Sections C402, C403, C404, C405, C406, C408, C409 and C410.
2. The requirements of Section C407, C408, C409, C410, C402.5, C403.2, C404, C405.2, C405.3, C405.4, C405.6 and C405.7. The building energy consumption shall be equal to or less than 87, 90 or 93 percent of the *standard reference design* building, depending on the option selected per Section C407.3.

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

SECTION C402 BUILDING ENVELOPE REQUIREMENTS

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

C402.1.1 Low energy buildings. The following buildings, or 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 provisions 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. Greenhouses where cooling does not include a condensing unit and that are isolated from any other conditioned space.
4. Unstaffed equipment shelters or cabinets used solely for personal wireless service facilities.

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

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 electronic equipment with installed equipment power totaling at least 7 watts per square foot (75 W/m²) and not intended for human occupancy.
3. Have a heating system capacity not greater than 17,000 Btu/hr (5 kW) and a heating thermostat set point that is restricted to not more than 50°F (10°C).
4. Have an average wall and roof U-factor less than 0.200.

C402.1.3 Insulation component R-value method.

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

C402.1.4 Assembly *U*-factor, *C*-factor or *F*-factor based method. *Building thermal envelope* assemblies intended to comply on an assembly *U*-, *C*-, or *F*-factor basis shall have a *U*-, *C*-, or *F*-factor not greater than that specified in Table C402.1.4. Commercial buildings or portions of commercial buildings enclosing Group R 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 *C*-factor for the below-grade exterior walls of the building envelope, as required in accordance with Table C402.1.4, shall extend to the level of the lowest conditioned floor. Opaque swinging doors shall comply with Table C402.1.4 and opaque nonswinging doors shall comply with Table C402.1.3

or C402.1.4. The *U*-factors for typical construction assemblies are included in Appendix A. These values shall be used for all calculations. Where proposed construction assemblies are not represented in Appendix A, values shall be calculated in accordance with the ASHRAE *Handbook of Fundamentals* using the framing factors listed in Appendix A where applicable and shall include the thermal bridging effects of framing materials.

C402.1.4.1 Thermal resistance of cold-formed steel stud walls. *U*-factors of walls with cold-formed steel studs shall be permitted to be determined in accordance with Equation 4-1:

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

where:

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

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

TABLE C402.1.3
OPAQUE THERMAL ENVELOPE INSULATION COMPONENT
MINIMUM REQUIREMENTS, R-VALUE METHOD^{a, g}

CLIMATE ZONE	5 AND MARINE 4	
	All Other	Group R
Roofs		
Insulation entirely above deck	R-38ci	R-38ci
Metal buildings ^b	R-25 + R-11 LS	R-25 + R-11 LS
Attic and other	R-49	R-49
Walls, Above Grade		
Mass	R-9.5 ^c ci	R-13.3ci
Metal building	R-19ci	R-19ci
Steel framed	R-13 + R-10ci	R-19 + R-8.5ci
Wood framed and other	R-21 int	R-21 int
Walls, Below Grade		
Below-grade wall ^d	Same as above grade	Same as above grade
Floors		
Mass ^f	R-30ci	R-30ci
Joist/framing	R-30 ^e	R-30 ^e
Slab-on-Grade Floors		
Unheated slabs	R-10 for 24" below	R-10 for 24" below
Heated slabs ^d	R-10 perimeter & under entire slab	R-10 perimeter & under entire slab
Opaque Doors		
Nonswinging	R-4.75	R-4.75

For SI: 1 inch = 25.4 mm. ci = Continuous insulation. NR = No requirement. LS = Liner system

- 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 ½-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. Exception: Integral insulated concrete block walls complying with ASTM C90 with all cores filled and meeting both of the following:
 1. At least 50 percent of cores must be filled with vermiculite or equivalent fill insulation; and
 2. The building thermal envelope encloses one or more of the following uses: Warehouse (storage and retail), gymnasium, auditorium, church chapel, arena, kennel, manufacturing plant, indoor swimming pool, pump station, water and waste water treatment facility, storage facility, storage area, motor vehicle service facility. Where additional uses not listed (such as office, retail, etc.) are contained within the building, the exterior walls that enclose these areas may not utilize this exception and must comply with the appropriate mass wall *R*-value from Table C402.1.3/*U*-factor from Table C402.1.4.

- d. Where heated slabs are below grade, they shall comply with the insulation requirements for heated slabs.
- e. Steel floor joist systems shall be insulated to R-38 + R-10ci.
- f. “Mass floors” shall include floors weighing not less than:
1.35 pounds per square foot of floor surface area; or
2.25 pounds per square foot of floor surface area where the material weight is not more than 120 pounds per cubic foot.
- g. For roof, wall or floor assemblies where the proposed assembly would not be continuous insulation, an alternate nominal *R*-value compliance option for assemblies with isolated metal penetrations of otherwise continuous insulation is:

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-19.0ci	R-21ci
R-30ci	R-38ci	R-42ci
R-38ci	R-48ci	R-53ci
R-13 + R-7.5ci	R-13 + R-9.4ci	R-13 + R-10.3ci
R-13 + R-10ci	R-13 + R-12.5ci	R-13 + R-13.8ci
R-13 + R-12.5ci	R-13 + R-15.6ci	R-13 + R-17.2ci
R-13 + R-13ci	R-13 + R-16.3ci	R-13 + R-17.9ci
R-19 + R-8.5ci	R-19 + R-10.6ci	R-19 + R-11.7ci
R-19 + R-14ci	R-19 + R-17.5ci	R-19 + R-19.2ci
R-19 + R-16ci	R-19 + R-20ci	R-19 + R-22ci
R-20 + R-3.8ci	R-20 + R-4.8ci	R-20 + R-5.3ci
R-21 + R-5ci	R-21 + R-6.3ci	R-21 + R-6.9ci

This alternate nominal *R*-value compliance option is allowed for projects complying with all of the following:

1. The ratio of the cross-sectional area, as measured in the plane of the surface, of metal penetrations of otherwise continuous insulation to the opaque surface area of the assembly is greater than 0.0004 (0.04%), but less than 0.0012 (0.12%).
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.

TABLE C402.1.4
OPAQUE THERMAL ENVELOPE ASSEMBLY MAXIMUM REQUIREMENTS, *U*-FACTOR METHOD^{a, f}

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

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. 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. Exception: Integral insulated concrete block walls complying with ASTM C90 with all cores filled and meeting both of the following:

1. At least 50 percent of cores must be filled with vermiculite or equivalent fill insulation; and
2. The building thermal envelope encloses one or more of the following uses: Warehouse (storage and retail), gymnasium, auditorium, church chapel, arena, kennel, manufacturing plant, indoor swimming pool, pump station, water and waste water treatment facility, storage facility, storage area, motor vehicle service facility. Where additional uses not listed (such as office, retail, etc.) are contained within the building, the exterior walls that enclose these areas may not utilize this exception and must comply with the appropriate mass wall R-value from Table C402.1.3/*U*-factor from Table C402.1.4.

- e. "Mass floors" shall include floors weighing not less than:
1.35 pounds per square foot of floor surface area; or
2.25 pounds per square foot of floor surface area where the material weight is not more than 120 pounds per cubic foot.
- f. Opaque assembly U-factors based on designs tested in accordance with ASTM C1363 shall be permitted. The R-value of continuous insulation shall be permitted to be added or subtracted from the original test design.

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

NOMINAL STUD DEPTH (inches)	SPACING OF FRAMING (inches)	CAVITY R-VALUE (insulation)	CORRECTION FACTOR (F_c)	EFFECTIVE R-VALUE (ER) (Cavity $R\text{-Value} \times F_c$)
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

$$A + B + C + D + E \leq \text{Zero} \quad (\text{Equation 4-2})$$

Where:

A = Sum of the (UA Dif) values for each distinct assembly type of the building thermal envelope, other than slabs on grade:

$$\begin{aligned} \text{UA Dif} &= \text{UA Proposed} - \text{UA Table} \\ \text{UA Proposed} &= \text{Proposed U-value} \times \text{Proposed Area} \\ \text{UA Table} &= (\text{U-factor from Table C402.1.4 or C402.4}) \times \text{Area} \end{aligned}$$

B = Sum of the (FL Dif) values for each distinct slab on grade perimeter condition of the building thermal envelope:

$$\begin{aligned} \text{FL Dif} &= \text{FL Proposed} - \text{FL Table} \\ \text{FL Proposed} &= \text{Proposed F-value} \times \text{Proposed Perimeter length} \\ \text{FL Table} &= (\text{F-factor specified in Table C402.1.4}) \times \text{Proposed Perimeter length} \end{aligned}$$

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

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

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

$$C = (CA \times UV) - (CA \times U_{\text{Wall}}), \text{ but not less than zero}$$

$$CA = (\text{Proposed Vertical Fenestration Area}) - (\text{Vertical Fenestration Area allowed})$$

$$U_{\text{Wall}} = \text{Sum of the (UA table) values for each above-grade wall assembly}$$

$$U_{\text{AV}} = U_{\text{AW}} / (\text{sum of Proposed wall area} + CA)$$

$$U_{\text{AV}} = \text{Sum of the (UA table) values for each vertical fenestration assembly}$$

$$UV = U_{\text{AV}} / \text{total vertical fenestration area allowed}$$

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

$$D = (DA \times US) - (DA \times U_{\text{Roof}}), \text{ but not less than zero}$$

$$DA = (\text{Proposed Skylight Area}) - (\text{Allowable Skylight Area from Section C402.4.1})$$

$$U_{\text{AR}} = \text{Sum of the (UA table) values for each roof assembly}$$

$$U_{\text{Roof}} = U_{\text{AR}} / \text{sum of Proposed roof area}$$

$$U_{\text{AS}} = \text{Sum of the (UA table) values for each skylight assembly}$$

$$US = U_{\text{AS}} / \text{total skylight area}$$

Where required by other sections of the code, Proposal Total Envelope UA and Allowed Total Envelope UA shall be calculated as:

<u>Proposed Total Envelope UA</u>	\equiv	<u>Sum of UA Proposed and FL Proposed for each distinct envelope assembly</u>
<u>Allowed Total Envelope UA</u>	\equiv	<u>Sum UA Table – C – D</u>
<u>Where:</u>		
<u>Sum UA Table</u>	\equiv	<u>Sum of UA Table and FL Table for each distinct envelope assembly</u>

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

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

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

C402.1.5.2 SHGC rate calculations. 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 values result in SHGCA_p less than SHGCA_t as determined by Equations 4-3 and 4-4.

EQUATION 4-3 TARGET SHGCA_t

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

Where:

- SHGCA_t := The target combined specific heat gain of the target fenestration area.
- SHGC_{ogt} := The solar heat gain coefficient for skylight fenestration found in Table C402.4.
- A_{ogt} := The proposed skylight area.
- SHGC_{vgt} := The solar heat gain coefficient for fenestration found in Table C402.4 which corresponds to the proposed total fenestration area as a percent of gross exterior wall area.
- A_{vgt} := The proposed vertical fenestration area with nonmetal framing
- A_{vgmt} := The proposed vertical fenestration area with fixed metal framing
- A_{vgmot} := The proposed vertical fenestration area with operable metal framing
- A_{vgdt} := The proposed entrance door area

NOTE: The vertical fenestration area does not include opaque doors and opaque spandrel panels.

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.

EQUATION 4-4 PROPOSED SHGCA_p

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

Where:

- SHGCA_t := The combined proposed specific heat gain of the proposed fenestration area.
- SHGC_{og} := The solar heat gain coefficient of the skylights.
- A_{og} := The skylight area.
- SHGC_{vg} := The solar heat gain coefficient of the vertical fenestration.
- A_{vg} := The vertical fenestration area.

NOTE: The vertical fenestration area does not include opaque doors and opaque spandrel panels.

C402.2 Specific building thermal envelope insulation requirements (Prescriptive). Insulation in building thermal envelope opaque assemblies shall comply with Sections C402.2.1 through C402.2.6 and Table C402.1.3.

Where this section refers to installing insulation levels as specified in Section C402.1.3, assemblies 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 Multiple layers of continuous insulation.

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

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

Exceptions:

1. Continuously insulated roof assemblies where the thickness of insulation varies 1 inch (25 mm) or less

and where the area-weighted *U*-factor is equivalent to the same assembly with the *R*-value specified in Table C402.1.3.

2. 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).
3. Unit skylight curbs included as a component of skylight listed and labeled in accordance with NFRC 100 shall not be required to be insulated.

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

C402.2.3 Thermal resistance of above-grade walls.

The minimum thermal resistance (*R*-value) of materials installed in the wall cavity between 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.

"Mass walls" shall include walls:

1. Weighing not less than 35 psf (170 kg/m²) of wall surface area.
2. Weighing 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. Having a heat capacity exceeding 7 Btu/ft² × °F (144 kJ/m² × K).
4. Having 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).

C402.2.4 Thermal resistance of below-grade walls.

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

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

Exceptions:

1. The floor framing cavity insulation or structural slab insulation shall be permitted to be in contact with the top side of sheathing or continuous

insulation installed on the bottom side of floor assemblies where combined with insulation that meets or exceeds the minimum *R*-value in Table C402.1.3 for "Metal framed" or "Wood framed and other" values for "Walls, Above Grade" and extends from the bottom of the top of all perimeter floor framing or floor assembly members.

2. Insulation applied to the underside of concrete floor slabs shall be permitted an air space of not more than 1 inch where it turns up and is in contact with the underside of the floor under walls associated with the *building thermal envelope*.

C402.2.6 Slabs-on-grade perimeter insulation. Where the slab-on-grade is in contact with the ground, the minimum thermal resistance (*R*-value) of the insulation around the perimeter of unheated or heated slab-on-grade floors designed in accordance with the *R*-value method of Section C402.1.3 shall be as specified in Table C402.1.3. The insulation shall be

placed on the outside of the foundation or on the inside of the foundation wall. The insulation shall extend downward from the top of the slab for a minimum distance as shown in the table or to the top of the footing, whichever is less, or downward to at least the bottom of the slab and then horizontally to the interior or exterior for the total distance shown in the table. Insulation extending away from the building shall be protected by pavement or by a minimum of 10 inches (254 mm) of soil. Insulation complying with Table C402.1.3 shall be provided under the entire area of heated slabs-on-grade.

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

C402.2.7 Reserved.

C402.2.8 Insulation of radiant heating systems.

Radiant heating system panels and their associated components that are installed in interior or exterior assemblies shall be insulated with a minimum of R-3.5 (0.62 m²/K × W) on all surfaces not facing the space being heated. Radiant heating system panels that are installed in the *building thermal envelope* shall be separated from the exterior of the building or unconditioned or exempt spaces by not less than the *R*-value of the insulation installed in the opaque assembly in which they are installed or the assembly shall comply with Section C402.1.4.

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

C402.3 Reserved.

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

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

CLIMATE ZONE		5 AND MARINE 4	
Vertical Fenestration			
U-factor			
Nonmetal framing (all) ^a		0.30	
Metal framing (fixed) ^b		0.38	
Metal framing (operable) ^c		0.40	
Metal framing (entrance doors) ^d		0.60	
SHGC			
Orientation		SEW	N
PF < 0.2		0.40	0.53
0.2 ≤ PF < 0.5		0.48	0.58
PF ≥ 0.5		0.64	0.64
Skylights			
U-factor		0.50	
SHGC		0.35	

NR = No requirement.

- a. "Nonmetal framing" includes framing materials other than metal, with or without metal reinforcing or cladding.
- b. "Metal framing" includes metal framing, with or without thermal break. "Fixed" includes curtain wall, storefront, picture windows, and other fixed windows.
- c. "Metal framing" includes metal framing, with or without thermal break. "Operable" includes openable fenestration products other than "entrance doors."
- d. "Metal framing" includes metal framing, with or without thermal break. "Entrance door" includes glazed swinging entrance doors. Other doors which are not entrance doors, including sliding glass doors, are considered "operable."

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

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

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

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

C402.4.1.2 Reserved.

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

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

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

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

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

C402.4.2 Minimum skylight fenestration area. For single story buildings only, in an enclosed space greater than 2,500 square feet (232 m²) in floor area, directly under a roof with not less than 75 percent of the ceiling area with a ceiling heights greater than 15 feet (4572 mm), and used as an office, lobby, atrium, concourse, corridor, gymnasium/exercise center, convention center, automotive service, manufacturing, nonrefrigerated warehouse, retail store, distribution/sorting area, transportation, or workshop, skylights are required to provide a total toplight *daylight zone* area not less than half the floor area and shall provide one of the following:

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

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

(Equation 4-5)

where:

Skylight area	=	Total fenestration area of skylights.
Skylight VT	=	Area weighted average visible transmittance of skylights.
WF	=	Area weighted average well factor, where well factor is 0.9 if light well depth is less than 2 feet (610 mm), or 0.7 if light well depth is 2 feet (610 mm) or greater.
Light well depth	=	Measure vertically from the underside of the lowest point of the skylight glazing to the ceiling plane under the skylight.

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

1. Reserved.
2. Spaces where the designed *general lighting* power densities are less than 0.5 W/ft² (5.4 W/m²).

3. Areas where it is documented that existing structures or natural objects block direct beam sunlight on at least half of the roof over the enclosed area for more than 1,500 daytime hours per year between 8 a.m. and 4 p.m.
4. Spaces where the daylight zone under rooftop monitors is greater than 50 percent of the enclosed space floor area.
5. Spaces where the total floor area minus the sidelight daylight zone area is less than 2,500 square feet (232 m²), and where the lighting in the daylight zone is controlled in accordance with Section C405.2.3.1.

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

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

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

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

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

$$PF = A/B$$

(Equation 4-6)

Where:

PF	=	Projection factor (decimal).
A	=	Distance measured horizontally from the furthest continuous extremity of any overhang, eave, or permanently attached shading device to the vertical surface of the glazing.
B	=	Distance measured vertically from the bottom of the glazing to the underside of the overhang, eave, or permanently attached shading device.

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

C402.4.3.1 Reserved

C402.4.3.2 Reserved.

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

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

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

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

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

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

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

1. The air barrier shall be continuous for all assemblies that are the thermal envelope of the building and across the joints and assemblies.
2. Air barrier joints and seams shall be sealed, including sealing transitions in places and changes in materials. The joints and seals shall be securely installed in or on the joint for its entire length so as not to dislodge, loosen or otherwise impair its ability to resist positive and negative pressure from wind, stack effect and mechanical ventilation.

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

C402.5.1.2 Building test. The completed building shall be tested and the air leakage rate of the *building envelope* shall not exceed 0.40 cfm/ft² at a pressure differential of 0.3 inches water gauge (2.0 L/s × m² at 75 Pa) at the upper 95 percent confidence interval in accordance with ASTM E 779 or an equivalent method approved by the code official. A report that includes the tested surface area, floor area, air by volume, stories above grade, and leakage rates shall be submitted to the building owner and the Code Official. If the tested rate exceeds that defined here, a visual inspection of the air barrier shall be conducted and any leaks noted shall be sealed to the extent practicable. An additional report identifying the corrective actions taken to seal air leaks shall be submitted to the building owner and the Code Official and any further requirement to meet the leakage air rate will be waived.

1. Test shall be accomplished using either (1) both pressurization and depressurization or (2) pressurization alone, but not depressurization alone. The test results shall be plotted against the correct P for pressurization in accordance with Section 9.4 of ASTM E779.

2. The test pressure range shall be from 25 Pa to 80 Pa per Section 8.10 of ASTM E779, but the upper limit shall not be less than 50 Pa, and the difference between the upper and lower limit shall not be less than 25 Pa.
3. If the pressure exponent n is less than 0.45 or greater than 0.85 per Section 9.6.4 of ASTM E779, the test shall be rerun with additional readings over a longer time interval.

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

C402.5.2 Reserved.

C402.5.3 Rooms containing fuel-burning appliances. Where open combustion air ducts provide combustion air to open combustion space conditioning fuel-burning appliances, the appliances and combustion air openings shall be located outside of the *building thermal envelope* or enclosed in a room isolated from inside the thermal envelope. Such rooms shall be sealed and insulated in accordance with the envelope requirements of Table C402.1.3 or C402.1.4, where the walls, floors and ceilings shall meet the minimum of the below-grade wall R -value requirement. The door into the room shall be fully gasketed, and any water lines and ducts in the room insulated in accordance with Section C403. The combustion air duct shall be insulated, where it passes through conditioned space, to a minimum of R-8.

Exceptions:

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

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

Exceptions:

1. Door openings required to comply with Section 715 or 715.4 of the *International Building Code*.

2. Doors and door openings required to comply with UL 1784 by the *International Building Code*.

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

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

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

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

Exception: Vestibules are not required for the following:

1. Doors not intended to be used as building entrances.
2. Unfinished ground-level space greater than 3,000 square feet (298 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 a 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 entrance paths to the remainder of the building.
5. Revolving doors.

6. Doors used primarily to facilitate vehicular movement or material handling and adjacent personnel doors.
7. In buildings less than three stories above grade or in spaces that do not directly connect with the building elevator lobby, doors that have an air curtain with a velocity of not less than 6.56 feet per second (2 m/s) at the floor that have been tested in accordance with ANSI/AMCA 220 and installed in accordance with the manufacturer's instructions. Manual or automatic controls shall be provided that will operate the air curtain with the opening and closing of the door. Air curtains and their controls shall comply with Section C408.2.3
8. Building entrances in buildings that are less than four stories above grade and less than 10,000 square feet in area.
9. Elevator doors in parking garages provided that the elevators have an enclosed lobby at each level of the garage.
10. Entrances to semi-heated spaces.

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

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

SECTION C403 MECHANICAL SYSTEMS

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

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

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

C403.2.1 Calculation of heating and cooling loads.

Design loads associated with heating, ventilating and air conditioning of the building shall be determined in accordance with 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.

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

Exceptions:

1. Required standby equipment and systems provided with controls and devices that allow such systems or equipment to operate automatically only when the primary equipment is not operating.
2. Multiple units of the same equipment type with combined capacities exceeding the design load and provided with controls that are configured to sequence the operation of each unit based on load.

C403.2.3 HVAC equipment performance

requirements. Equipment shall meet the minimum efficiency requirements of Tables C403.2.3(1), C403.2.3(2), C403.2.3(3), C403.2.3(4), C403.2.3(5), C403.2.3(6), C403.2.3(7), C403.2.3(8) and C403.2.3(9) when tested and rated in accordance with the applicable test procedure. Plate-type liquid-to-liquid heat exchangers shall meet the minimum requirements of Table C403.2.3(10). The efficiency shall be verified through certification and listed under an *approved* certification program or, if no certification program exists, the equipment efficiency ratings shall be supported by data furnished by the manufacturer. Where multiple rating conditions or performance requirements are provided, the equipment shall satisfy all stated requirements. Where components, such as indoor or outdoor coils, from different manufacturers are used, calculations and supporting data shall be furnished by the designer that demonstrates that the combined efficiency of the specified components meets the requirements herein.

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

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

Exceptions:

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

C403.2.3.1 Water-cooled centrifugal chilling packages. Equipment not designed for operation at AHRI Standard 550/590 test conditions of 44°F (7°C) leaving chilled-water temperature and 2.4 gpm/ton evaporator fluid flow and 85°F (29°C) entering condenser water temperature with 3 gpm/ton (0.054 L/s × kW) condenser water flow shall have maximum full-load kW/ton (*FL*) and part-load ratings adjusted using Equations 4-7 and 4-8.

$$FL_{adj} = FL/K_{adj}$$

(Equation 4-7)

$$PLV_{adj} = IPLV/K_{adj}$$

(Equation 4-8)

Where:

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

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

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

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

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

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

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

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

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

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

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

1. Minimum evaporator leaving temperature: 36°F.
2. Maximum condenser leaving temperature: 115°F.
3. LIFT is not less than 20°F and not greater than 80°F.

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

C403.2.3.3 Packaged electric heating and cooling equipment. Packaged electric equipment providing both heating and cooling with a total cooling capacity greater than 6,000 Btu/h shall be a heat pump.

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

TABLE C403.2.3(1)A
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS

II

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	13.0 SEER	AHRI 210/240
			Single Package	14.0 SEER	
Through-the-wall (air cooled)	≤ 30,000 Btu/h ^b	All	Split system	12.0 SEER	
			Single Package	12.0 SEER	
Small duct high velocity, air cooled	≤ 65,000 Btu/h ^b	All	Split system	11.0 SEER	
Air conditioners, air cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.2 EER 12.9 IEER	AHRI 340/360
		All other	Split System and Single Package	11.0 EER 12.7 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 12.4 IEER	
		All other	Split System and Single Package	10.8 EER 12.2 IEER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.0 EER 11.6 IEER	
		All other	Split System and Single Package	9.8 EER 11.4 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER 11.2 IEER	
		All other	Split System and Single Package	9.5 EER 11.6 IEER	
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	

(continued)

TABLE C403.2.3(1)A—continued
MINIMUM EFFICIENCY REQUIREMENTS:
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE ^a
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 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.
- b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

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

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

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

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency		Test Procedure
				Before 1/1/2017	After 1/1/2017	
VRF Air Cooled, (cooling mode)	<65,000 Btu/h	All	VRF Multi-split System	13.0 SEER	13.0 SEER	AHRI 1230
	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	11.0 EER 12.9 IEER	11.0 EER 14.6 IEER	
	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System with Heat Recovery	10.8 EER 12.7 IEER	10.8 EER 14.4 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	10.6 EER 12.3 IEER	10.6 EER 13.9 IEER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System with Heat Recovery	10.4 EER 12.1 IEER	10.4 EER 13.7 IEER	
	≥240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System	9.5 EER 11.0 IEER	9.5 EER 12.7 IEER	
	≥240,000 Btu/h	Electric Resistance (or none)	VRF Multi-split System with Heat Recovery	9.3 EER 10.8 IEER	9.3 EER 12.5 IEER	

(continued)

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency		Test Procedure
				Before 1/1/2017	After 1/1/2017	
VRF Water source (cooling mode)	<65,000 Btu/h	All	VRF Multi-split systems 86°F entering water	12.0 EER		AHRI 1230
	<65,000 Btu/h	All	VRF Multi-split systems with Heat Recovery 86°F entering water	11.8 EER		
	≥65,000 Btu/h and <135,000 Btu/h	All	VRF Multi-split System 86°F entering water	12.0 EER		
	≥65,000 Btu/h and <135,000 Btu/h	All	VRF Multi-split System with Heat Recovery 86°F entering water	11.8 EER		
	≥135,000 Btu/h	All	VRF Multi-split System 86°F entering water	10.0 EER		
	≥135,000 Btu/h	All	VRF Multi-split System with Heat Recovery 86°F entering water	9.8 EER		
VRF Groundwater source (cooling mode)	<135,000 Btu/h	All	VRF Multi-split System 59°F entering water	16.2 EER		AHRI 1230
	<135,000 Btu/h	All	VRF Multi-split System with Heat Recovery 59°F entering water	16.0 EER		
	≥135,000 Btu/h	All	VRF Multi-split System 59°F entering water	13.8 EER		
	≥135,000 Btu/h	All	VRF Multi-split System with Heat Recovery 59°F entering water	13.6 EER		
VRF Ground source (cooling mode)	<135,000 Btu/h	All	VRF Multi-split System 77°F entering water	13.4 EER		AHRI 1230
	<135,000 Btu/h	All	VRF Multi-split System with Heat Recovery 77°F entering water	13.2 EER		
	≥135,000 Btu/h	All	VRF Multi-split System 77°F entering water	11.0 EER		
	≥135,000 Btu/h	All	VRF Multi-split System with Heat Recovery 77°F entering water	10.8 EER		
VRF Air Cooled (heating mode)	<65,000 Btu/h (cooling capacity)	---	VRF Multi-split System	7.7 HSPF		AHRI 1230
	≥65,000 Btu/h and <135,000 Btu/h (cooling capacity)	---	VRF Multi-split system 47°F db/43°F wb outdoor air 17°F db/15°F wb outdoor air	3.3 COP 2.25 COP		
	≥135,000 Btu/h (cooling capacity)	---	VRF Multi-split System 47°F db/43°F wb outdoor air 17°F db/15°F wb outdoor air	3.2 COP 2.05 COP		
VRF Water source (heating mode)	<135,000 Btu/h (cooling capacity)	---	VRF Multi-split System 68°F entering water	4.2 COP		AHRI 1230
	≥135,000 Btu/h (cooling capacity)	---	VRF Multi-split System 68°F entering water	3.9 COP		

(continued)

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency		Test Procedure
				Before 1/1/2017	After 1/1/2017	
VRF Groundwater source (heating mode)	<135,000 Btu/h (cooling capacity)	---	VRF Multi-split System 50°F entering water	3.6 COP		AHRI 1230
	≥135,000 Btu/h (cooling capacity)	---	VRF Multi-split System 50°F entering water	3.3 COP		
VRF Ground source (heating mode)	<135,000 Btu/h (cooling capacity)	---	VRF Multi-split System 32°F entering water	3.1 COP		AHRI 1230
	≥135,000 Btu/h (cooling capacity)	---	VRF Multi-split System 32°F entering water	2.8 COP		

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

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE ^a
Air cooled (cooling mode)	< 65,000 Btu/h ^b	All	Split System	14.0 SEER	AHRI 210/240
			Single Packaged	14.0 SEER	
Through-the-wall, air cooled (cooling mode)	≤ 30,000 Btu/h ^b	All	Split System	12.0 SEER	
			Single Packaged	12.0 SEER	
Small duct high velocity, air cooled	< 65,000 Btu/h ^b	All	Split System	11.0 SEER	
Air cooled (cooling mode)	≥65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 12.2 IEER	AHRI 340/360
		All other	Split System and Single Package	10.8 EER 12.0 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.6 EER 11.6 IEER	
		All other	Split System and Single Package	10.4 EER 11.4 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 10.6 IEER	
		All other	Split System and Single Package	9.3 EER 10.4 IEER	
Water source (cooling mode)	< 17,000 Btu/h	All	86°F entering water	12.2 EER	ISO 13256-1
	≥17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	13.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F entering water	13.0 EER	
Ground water source (cooling mode)	< 135,000 Btu/h	All	59°F entering water	18.0 EER	
Ground source (cooling mode)	< 135,000 Btu/h	All	77°F entering water	14.1 EER	
Water-source water to water (cooling mode)	< 135,000 Btu/h	All	86°F entering water	10.6 EER	ISO 13256-2
			59°F entering water	16.3 EER	
Ground water source Brine to water (cooling mode)	< 135,000 Btu/h	All	77°F entering fluid	12.1 EER	

(continued)

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

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE ^a
Air cooled (heating mode)	< 65,000 Btu/h ^b	—	Split System	8.2 HSPF	AHRI 210/240
		—	Single Package	8.0 HSPF	
Through-the-wall, (air cooled, heating mode)	≤30,000 Btu/h ^b (cooling capacity)	—	Split System	7.4 HSPF	
		—	Single Package	7.4 HSPF	
Small-duct high velocity (air cooled, heating mode)	< 65,000 Btu/h ^b	—	Split System	6.8 HSPF	
Air cooled (heating mode)	≥65,000 Btu/h and < 135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb Outdoor Air	3.3 COP	AHRI 340/360
			17°F db/15°F wb Outdoor Air	2.25 COP	
	≥ 135,000 Btu/h (cooling capacity)	—	47°F db/43°F wb Outdoor Air	3.2 COP	
			17°F db/15°F wb Outdoor Air	2.05 COP	
Water source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	4.3 COP	ISO 13256-1
Ground water source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	50°F entering water	3.7 COP	
Ground source (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	3.2 COP	
Water-source water to water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	68°F entering water	3.7 COP	ISO 13256-2
		—	50°F entering water	3.1 COP	
Ground source brine to water (heating mode)	< 135,000 Btu/h (cooling capacity)	—	32°F entering fluid	2.5 COP	

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

- a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.
- b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

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

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE ^a
PTAC (cooling mode) new construction	All Capacities	95°F db outdoor air	14.0 - $(0.300 \times \text{Cap}/1000)$ EER	AHRI 310/380
PTAC (cooling mode) replacements ^b	All Capacities	95°F db outdoor air	10.9 - $(0.213 \times \text{Cap}/1000)$ EER	
PTHP (cooling mode) new construction	All Capacities	95°F db outdoor air	14.0 - $(0.300 \times \text{Cap}/1000)$ EER	
PTHP (cooling mode) replacements ^b	All Capacities	95°F db outdoor air	10.8 - $(0.213 \times \text{Cap}/1000)$ EER	
PTHP (heating mode) new construction	All Capacities	—	3.7 - $(0.052 \times \text{Cap}/1000)$ COP	
PTHP (heating mode) replacements ^b	All Capacities	—	2.9 - $(0.026 \times \text{Cap}/1000)$ COP	
SPVAC (cooling mode)	< 65,000 Btu/h	95°F db/ 75°F wb outdoor air	10.0 EER	AHRI 390
	≥65,000 Btu/h and < 135,000 Btu/h	95°F db/ 75°F wb outdoor air	10.0 EER	
	≥135,000 Btu/h and < 240,000 Btu/h	95°F db/ 75°F wb outdoor air	10.0 EER	
SPVHP (cooling mode)	< 65,000 Btu/h	95°F db/ 75°F wb outdoor air	10.0 EER	
	≥65,000 Btu/h and < 135,000 Btu/h	95°F db/ 75°F wb outdoor air	10.0 EER	
	≥135,000 Btu/h and < 240,000 Btu/h	95°F db/ 75°F wb outdoor air	10.0 EER	
SPVHP (heating mode)	<65,000 Btu/h	47°F db/ 43°F wb outdoor air	3.0 COP	AHRI 390
	≥65,000 Btu/h and < 135,000 Btu/h	47°F db/ 43°F wb outdoor air	3.0 COP	
	≥135,000 Btu/h and < 240,000 Btu/h	47°F db/ 43°F wb outdoor air	3.0 COP	
Room air conditioners, with louvered sides	< 6,000 Btu/h	—	9.7 SEER	ANSI/AHA-MRAC-1
	≥ 6,000 Btu/h and < 8,000 Btu/h	—	9.7 SEER	
	≥ 8,000 Btu/h and < 14,000 Btu/h	—	9.8 EER	
	≥ 14,000 Btu/h and < 20,000 Btu/h	—	9.7 SEER	
	≥20,000 Btu/h	—	8.5 EER	
Room air conditioners, without louvered sides	< 8,000 Btu/h	—	9.0 EER	
	≥8,000 Btu/h and < 20,000 Btu/h	—	8.5 EER	
	≥20,000 Btu/h	—	8.5 EER	

(continued)

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

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE ^a
Room air-conditioner heat pumps with louvered sides	< 20,000 Btu/h	—	9.0 EER	ANSI/AHA-MRAC-1
	≥20,000 Btu/h	—	8.5 EER	
Room air-conditioner heat pumps without louvered sides	< 14,000 Btu/h	—	8.5 EER	
	≥14,000 Btu/h	—	8.0 EER	
Room air conditioner casement only	All capacities	—	8.7 EER	
Room air conditioner casement-slider	All capacities	—	9.5 EER	

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

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

- Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
- Replacement unit shall be factory labeled as follows: “MANUFACTURED FOR NONSTANDARD SIZE APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW STANDARD PROJECTS” or MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS.” Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406 mm) in height and less than 42 inches (1067 mm) in width.

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

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY ^{d,e}	TEST PROCEDURE ^a
Warm air furnaces, gas fired	< 225,000 Btu/h	—	78% AFUE or 80% E_t^c	DOE 10 CFR Part 430 or ANSI Z21.47
	≥225,000 Btu/h	Maximum capacity ^c	80% E_t^f	ANSI Z21.47
Warm air furnaces, oil fired	< 225,000 Btu/h	—	78% AFUE or 80% E_t^c	DOE 10 CFR Part 430 or UL 727
	≥ 225,000 Btu/h	Maximum capacity ^b	81% E_t^g	UL 727
Warm air duct furnaces, gas fired	All capacities	Maximum capacity ^b	80% E_c	ANSI Z83.8
Warm air unit heaters, gas fired	All capacities	Maximum capacity ^b	80% E_c	ANSI Z83.8
Warm air unit heaters, oil fired	All capacities	Maximum capacity ^b	80% E_c	UL 731

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

- Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
- Minimum and maximum ratings as provided for and allowed by the unit’s controls.
- Combination units not covered by the National Appliance Energy Conservation Act of 1987 (NAECA) (3-phase power or cooling capacity greater than or equal to 65,000 Btu/h [19 kW]) shall comply with either rating.
- E_t = Thermal efficiency. See test procedure for detailed discussion.
- E_c = Combustion efficiency (100% less flue losses). See test procedure for detailed discussion.
- E_c = Combustion efficiency. Units must also include an IID, have jackets not exceeding 0.75 percent of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.
- E_t = Thermal efficiency. Units must also include an IID, have jacket losses not exceeding 0.75 percent of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.

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

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

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

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

- a. These requirements apply to boilers with rated input of 8,000,000 Btu/h or less that are not packaged boilers and to all packaged boilers. Minimum efficiency requirements for boilers cover all capacities of packaged boilers.
- b. Maximum capacity – minimum and maximum ratings as provided for and allowed by the unit's controls.
- c. Includes oil-fired (residual).

TABLE C403.2.3(6)
RESERVED



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

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	AS OF 1/1/2015 ^b				TEST PROCEDURE ^c
			PATH A		PATH B		
			FULL LOAD	IPLV	FULL LOAD	IPLV	
Air-cooled chillers	< 150 tons	EER	≥ 10.100	≥ 13.700	≥9.700	≥15.800	AHRI 550/590
	≥150 tons	EER	≥ 10.100	≥14.000	≥9.700	≥16.100	
Air cooled without condenser, electrical operated	All capacities	EER	Air-cooled chillers without condensers shall be rated with matching condensers and comply with the air-cooled chiller efficiency requirements				
Water cooled, electrically operated, reciprocating	All capacities	kW/ton	Reciprocating units shall comply with water cooled positive displacement efficiency requirements				
Water cooled, electrically operated, positive displacement	< 75 tons	kW/ton	≤ 0.750	≤ 0.600	≤ 0.780	≤0.500	
	≥75 tons and < 150 tons	kW/ton	≤ 0.720	≤ 0.560	≤ 0.750	≤ 0.490	
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.660	≤0.540	≤ 0.680	≤ 0.440	
	≥ 300 tons and < 600 tons	kW/ton	≤ 0.610	≤ 0.520	≤ 0.625	≤ 0.410	
	≥ 600 tons	kW/ton	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380	
Water cooled, electrically operated, centrifugal	< 150 tons	kW/ton	≤ 0.610	≤ 0.550	≤ 0.695	≤ 0.440	
	≥ 150 tons and < 300 tons	kW/ton					
	≥300 tons and < 400 tons	kW/ton	≤ 0.560	≤ 0.520	≤ 0.595	≤ 0.390	
	≥400 tons	kW/ton	≤0.560	≤ 0.500	≤ 0.585	≤0.380	
Air cooled, absorption single effect	All capacities	COP	≥ 0.600	NR	NA	NA	AHRI 560
Water cooled, absorption single effect	All capacities	COP	≥ 0.700	NR	NA	NA	
Absorption double effect, indirect fired	All capacities	COP	≥1.000	≥ 1.050	NA	NA	
Absorption double effect, direct fired	All capacities	COP	≥ 1.000	≥ 1.000	NA	NA	

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

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

- The centrifugal chiller equipment requirements, after adjustment in accordance with Section C403.2.3.1 or Section C403.2.3.2, do not apply to chillers used in low-temperature applications where the design leaving fluid temperature is less than 36°F. The requirements do not apply to positive displacement chillers with leaving fluid temperatures less than or equal to 32°F. The requirements do not apply to absorption chillers with design leaving fluid temperatures less than 40°F.
- Compliance with this standard can be obtained by meeting the minimum requirements of Path A or B. However, both the full load and IPLV shall be met to fulfill the requirements of Path A or B.
- Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

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

EQUIPMENT TYPE ^a	TOTAL SYSTEM HEAT REJECTION CAPACITY AT RATED CONDITIONS	SUBCATEGORY OR RATING CONDITION ⁱ	PERFORMANCE REQUIRED ^{b, c, d, g, h}	TEST PROCEDURE ^{e, f}
Propeller or axial fan open circuit cooling towers	All	95°F Entering Water 85°F Leaving Water 75°F Entering wb	≥ 38.2 gpm/hp	CTI ATC-105 and CTI STD-201
Centrifugal fan open circuit cooling towers	All	95°F Entering Water 85°F Leaving Water 75°F Entering wb	≥ 20.0 gpm/hp	CTI ATC-105 and CTI STD-201
Propeller or axial fan closed circuit cooling towers	All	102°F Entering Water 90°F Leaving Water 75°F Entering wb	≥ 14.0 gpm/hp	CTI ATC-105S and CTI STD-201
Centrifugal closed circuit cooling towers	All	102°F Entering Water 90°F Leaving Water 75°F Entering wb	≥ 7.0 gpm/hp	CTI ATC-105S and CTI STD-201
Propeller or axial fan evaporative condensers	All	R-507A Test Fluid 165°F Entering Gas Temperature 105°F Condensing Temperature 75°F Entering wb	≥157,000 Btu/h•hp	CTI ATC-106
Propeller or axial fan evaporative condensers	All	Ammonia Test Fluid 140°F Entering Gas Temperature 96.3°F Condensing Temperature 75°F Entering wb	≥134,000 Btu/h•hp	CTI ATC-106
Centrifugal fan evaporative condensers	All	R-507A Test Fluid 165°F Entering Gas Temperature 105°F Condensing Temperature 75°F Entering wb	≥135,000 Btu/h•hp	CTI ATC-106
Centrifugal fan evaporative condensers	All	Ammonia Test Fluid 140°F Entering Gas Temperature 96.3°F Condensing Temperature 75°F Entering wb	≥110,000 Btu/h•hp	CTI ATC-106
Air-cooled condensers	All	125°F Condensing Temperature 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.

- The efficiencies and test procedures for both open and closed circuit cooling towers are not applicable to hybrid cooling towers that contain a combination of wet and dry heat exchange sections.
- For purposes of this table, open circuit cooling tower performance is defined as the water flow rating of the tower at the thermal rating condition listed in Table 403.2.3(8) divided by the fan nameplate rated motor power.
- For purposes of this table, closed circuit cooling tower performance is defined as the water flow rating of the tower at the thermal rating condition listed in Table 403.2.3(8) divided by the sum of the fan nameplate rated motor power and the spray pump nameplate rated motor power.
- For purposes of this table, air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the fan nameplate rated motor power.
- Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
- Where a certification program exists for a covered product, and it includes provisions for verification and challenge of equipment efficiency ratings, then the product shall be listed in the certification program, or, if a certification program exists for a covered product, and it includes provisions for verification and challenge of equipment efficiency ratings, but the product is not listed in the existing certification program, the ratings shall be verified by an independent laboratory test report.
- 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.
- 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.
- Requirements for evaporative condensers are listed with ammonia (R-717) and R-507A as test fluids in this table. Evaporative condensers intended for use with halocarbon refrigerants other than R-507A must meet the minimum efficiency requirements listed above with R-507A as the test fluid.

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

Equipment Type	Net Sensible Cooling Capacity ^a	Minimum SCOP-127 ^b Efficiency Downflow units / Upflow units	Test Procedure
Air conditioners, air cooled	<65,000 Btu/h (<19 kW)	2.20 / 2.09	ANSI / ASHRAE 127
	≥ 65,000 Btu/h and < 240,000 Btu/h (≥19kW and < 70 kW)	2.10 / 1.99	
	≥ 240,000 Btu/h (≥ 70 kW)	1.90 / 1.79	
Air conditioners, water cooled	<65,000 Btu/h (<19 kW)	2.60 / 2.49	ANSI / ASHRAE 127
	≥ 65,000 Btu/h and < 240,000 Btu/h (≥19kW and < 70 kW)	2.50 / 2.39	
	≥ 240,000 Btu/h (≥ 70 kW)	2.40 / 2.29	
Air conditioners, water cooled with fluid economizer	<65,000 Btu/h (<19 kW)	2.55 / 2.44	ANSI / ASHRAE 127
	≥ 65,000 Btu/h and < 240,000 Btu/h (≥19kW and < 70 kW)	2.45 / 2.34	
	≥ 240,000 Btu/h (≥ 70 kW)	2.35 / 2.24	
Air conditioners, glycol cooled (rated at 40% propylene glycol)	<65,000 Btu/h (<19 kW)	2.50 / 2.39	ANSI / ASHRAE 127
	≥ 65,000 Btu/h and < 240,000 Btu/h (≥19kW and < 70 kW)	2.15 / 2.04	
	≥ 240,000 Btu/h (≥ 70 kW)	2.10 / 1.99	
Air conditioners, glycol cooled (rated at 40% propylene glycol) with fluid economizer	<65,000 Btu/h (<19 kW)	2.45 / 2.34	ANSI / ASHRAE 127
	≥ 65,000 Btu/h and < 240,000 Btu/h (≥19kW and < 70 kW)	2.10 / 1.99	
	≥ 240,000 Btu/h (≥ 70 kW)	2.05 / 1.94	

- a. Net sensible cooling capacity: The total gross cooling capacity less the latent cooling less the energy to the air movement system. (Total Gross – latent – Fan Power)
- b. Sensible coefficient of performance (SCOP-127): a ratio calculated by dividing the net sensible cooling capacity in watts by the total power input in watts (excluding re-heaters and humidifiers) at conditions defined in ASHRAE Standard 127. The net sensible cooling capacity is the gross sensible capacity minus the energy dissipated into the cooled space by the fan system.

TABLE C403.2.3(10)
MINIMUM EFFICIENCY REQUIREMENTS: HEAT TRANSFER EQUIPMENT

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

NR = No Requirement

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

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

Exceptions:

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

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

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

Exceptions:

1. Independent perimeter systems that are designed to offset only building envelope heat losses or gains or both serving one or more perimeter *zones* also served by an interior system provided:
 - 1.1 The perimeter system includes at least one thermostatic control *zone* for each building exposure having exterior walls facing only one orientation (within +/-45 degrees) (0.8 rad) for more than 50 contiguous feet (15,240 mm);

- 1.2. The perimeter system heating and cooling supply is controlled by a thermostat located within the *zones* served by the system; and
 - 1.3. Controls are configured to prevent the perimeter system from operating in a different heating or cooling mode from the other equipment within the zones or from neighboring zones connected by openings larger than 10 percent of the floor area of either zone.
2. Any interior zone open to a perimeter zone shall have setpoints and deadbands coordinated so that cooling in the interior zone shall not operate while the perimeter zone is in heating until the interior zone temperature is 5°F (2.8°C) higher than the perimeter zone temperature, unless the interior and perimeter zones are separated by a partition whose permanent openings are smaller than 10 percent of the perimeter zone floor area.

C403.2.4.1.1 Heat pump supplementary heat.

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

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

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

Exceptions:

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

C403.2.4.1.3 Setpoint overlap restriction. Where a *zone* has a separate heating and a separate cooling thermostatic control located within the zone, a limit switch, mechanical stop or direct digital control system with software programming shall be configured to prevent the heating set point from exceeding the cooling setpoint and to maintain a deadband in accordance with Section C403.2.4.1.2.

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

Exceptions:

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

C403.2.4.2.1 Thermostatic setback capabilities. Thermostatic setback controls shall 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).

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

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

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

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

Class I dampers shall have a maximum leakage rate of 4 cfm/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.

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

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

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

Exceptions:

1. Gravity (nonmotorized) dampers shall be permitted to be used as follows:
 - 1.1. Relief dampers serving systems less than 5,000 cfm total supply shall be permitted in buildings less than three stories in height.
 - 1.2. Gravity (nonmotorized) dampers in Group R occupancies where the design outdoor air intake or exhaust capacity does not exceed 400 cfm (189 L/s).
2. Combustion air intakes.

Gravity (nonmotorized) dampers shall have an air leakage rate not greater than 20 cfm/ft² (101.6 L/s × m²) where not less than 24 inches (610 mm) in either dimension and 40 cfm/ft² (203.2 L/s × m²) where less than 24 inches in either dimension. The rate of air leakage shall be determined at 1.0 inch w.g. (249 Pa) when tested in accordance with AMCA 500D for such purpose. The dampers shall be labeled by an approved agency. Gravity dampers for ventilation air intakes shall be protected from direct exposure to wind.

C403.2.4.4 Zone isolation. HVAC systems serving *zones* that are over 25,000 square feet (2323 m²) in floor area or that span more than one floor and are designed to operate or be occupied nonsimultaneously shall be divided into isolation areas. Each isolation area shall be equipped with isolation devices and controls configured to automatically shut off the supply of conditioned air and outdoor air to and exhaust air from the isolation

area. Each isolation area shall be controlled independently by a device meeting the requirements of Section C403.2.4.2.2. Central systems and plants shall be provided with controls and devices that will allow system and equipment operation for any length of time while serving only the smallest isolation area served by the system or plant.

Exceptions:

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

C403.2.4.5 Snow- and ice-melt system controls.

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

C403.2.4.6 Freeze protection system controls.

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

C403.2.4.7 Economizer fault detection and diagnostics (FDD).

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

1. The following temperature sensors shall be permanently installed to monitor system operation:
 - 1.1. Outside air.
 - 1.2. Supply air.
 - 1.3. Return air.
2. Temperature sensors shall have an accuracy of $\pm 2^{\circ}\text{F}$ (1.1°C) over the range of 40°F to 80°F (4°C to 26.7°C).
3. Refrigerant pressure sensors, where used, shall have an accuracy of ± 3 percent of full scale.

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

C403.2.4.8 Combustion heating equipment controls.

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

Exceptions:

1. Boilers.
2. Radiant heaters.

C403.2.4.9 Group R-1 hotel/motel guest rooms.

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

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

C403.2.4.10 Group R-2 and R-3 dwelling units.

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

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

Exceptions:

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

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

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

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

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

Exceptions:

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

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

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

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

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

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

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

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

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

**TABLE C403.2.4.12.1
DDC APPLICATIONS AND QUALIFICATIONS**

Building Status	Application	Qualifications
New Building	Air-handling system and all zones served by the system	All air-handling systems in buildings with building cooling capacity greater than 780,000 Btu/h
	Air-handling system and all zones served by the system	Individual systems supplying more than three zones and with fan system bhp of 10 hp and larger
	Chilled-water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design cooling capacity of 300,000 Btu/h and larger
	Hot-water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design heating capacity of 300,000 Btu/h and larger
Alteration or addition	Zone terminal units such as VAV box	Where existing zones served by the same air-handling, chilled-water, or hot-water system have DDC
	Air-handling system or fan coil	Where existing air-handling system(s) and fan coil(s) served by the same chilled- or hot-water plant have DDC
	New air-handling system and all new zones served by the system	Individual systems with fan system bhp 10 hp and larger and supplying more than three zones and more than 75% of zones are new
	New or upgraded chilled-water plant	Where all chillers are new and plant design cooling capacity is 300,000 Btu/h and larger
	New or upgraded hot-water plant	Where all boilers are new and plant design heating capacity is 300,000 Btu/h and larger

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

Exceptions:

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

C403.2.6.1 Reserved.

C403.2.6.2 Demand controlled ventilation.

Demand control ventilation (DCV) shall be provided for spaces larger than 500 square feet (50 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*) and served by systems with one or more of the following:

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

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

1. Systems with energy recovery complying with Section C403.5.1.
2. Multiple-zone systems without direct digital control of individual zones communicating with a central control panel.
3. System with a design outdoor airflow less than 750 cfm (354 L/s).

4. Spaces where the supply airflow rate minus any makeup or outgoing transfer air requirement is less than 1,200 cfm (566 L/s).
5. Ventilation provided for process loads only.
6. Spaces with one of the following occupancy categories (as defined by the *International Mechanical Code*): Correctional cells, daycare sickrooms, science labs, barbers, beauty and nail salons, and bowling alley seating.

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

C403.2.6.4 Enclosed loading dock and parking garage exhaust ventilation system control.

Mechanical ventilation systems for enclosed loading docks and parking garages shall be designed to exhaust the airflow rates (maximum and minimum) determined in accordance with the *International Mechanical Code*.

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

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

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

C403.2.6.4.1 System activation devices for enclosed loading docks. Ventilation systems for enclosed loading docks shall be activated by one of the following:

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

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

Exception: A parking garage ventilation system having a total design capacity under 8,000 cfm may use occupant sensors.

C403.2.7 Exhaust systems.

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

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

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

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

3. Listed energy recovery devices with a sensible heat recovery effectiveness of not less than 40 percent on not less than 50 percent of the total exhaust airflow.

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

Exceptions:

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

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

Exceptions:

1. Variable air volume laboratory exhaust and room supply systems configured to reduce exhaust and make-up air volume to 50% or less of design values; or
2. Direct make-up (auxiliary) air supply equal to at least 75% of the exhaust rate, heated no warmer than 2°F (1.1°C) below room set point, cooled to no cooler than 3°F (1.7°C) above room set point, no humidification added, and no simultaneous heating and cooling used for dehumidification control; or

3. Combined energy reduction method: VAV exhaust and room supply system configured to reduce exhaust and makeup air volumes and a heat recovery system to precondition makeup air from laboratory exhaust that when combined will produce the same energy reduction as achieved by a heat recovery system with a 50% sensible recovery effectiveness as required above. For calculation purposes, the heat recovery component can be assumed to include the maximum design supply airflow rate at design conditions. The combined energy reduction (Q_{ER}) shall meet the following:

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

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

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

Where:

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

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

$$CFM_S = \text{The maximum design supply airflow rate to conditioned spaces served by the system in cubic feet per minute}$$

$$T_R = \text{Space return air dry bulb at winter design conditions}$$

$$T_O = \text{Outdoor air dry bulb at winter design conditions}$$

$$A = \text{Percentage that the exhaust and makeup air volumes can be reduced from design conditions}$$

$$B = \text{Percentage sensible heat recovery effectiveness}$$

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

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

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

NA = Not Allowed

C403.2.8 Duct and plenum insulation and sealing.

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

Exceptions:

1. Outside air ducts serving individual supply air units with less than 2,800 cfm of total supply air capacity, provided these are insulated to R-7.
2. Unheated equipment rooms with combustion air louvers, provided they are isolated from conditioned space at sides, top and bottom of the room with R-11 nominal insulation.

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

Exceptions:

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

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

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

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

C403.2.8.3 Duct construction. Ductwork shall be constructed and erected in accordance with the *International Mechanical Code*.

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

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

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

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

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

Where:

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

P = The static pressure of the test.

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

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

Exceptions:

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

C403.2.9.1 Protection of piping insulation. Piping insulation exposed to weather shall be protected from damage, including that due to sunlight, moisture, equipment maintenance and wind, and shall provide shielding from solar radiation that can cause degradation of the material. Adhesives tape shall not be permitted.

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

C403.2.11 Air system design and control. Each HVAC system having a total fan system motor nameplate horsepower (hp) exceeding 5 hp (3.7 kW) shall comply with the provisions of Sections C403.2.11.1 through C403.2.11.3.

The airflow requirements of Section C403.2.11.5 shall apply to all fan motors. Group R occupancy exhaust fans shall also comply with Section C403.2.11.4.

**TABLE C403.2.9
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 1½ inch (38 mm) and located in partitions within *conditioned spaces*, reduction of these thicknesses by 1 inch (25 mm) shall be permitted (before thickness adjustment required in footnote b) but not to a thickness less than 1 inch (25 mm).
- b. For insulation outside the stated conductivity range, the minimum thickness (*T*) shall be determined as follows:

$$T = r \{ (1 + t/r)K/k - 1 \}$$
 where:
T = minimum insulation thickness,
r = actual outside radius of pipe,
t = insulation thickness listed in the table for applicable fluid temperature and pipe size,
K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (Btu × in/h × ft² × °F) and
k = the upper value of the conductivity range listed in the table for the applicable fluid temperature.
- c. For direct-buried heating and hot water system piping, reduction of these thicknesses by 1½ inches (38 mm) shall be permitted (before thickness adjustment required in footnote b but not to thicknesses less than 1 inch (25 mm).

C403.2.11.1 Allowable fan motor horsepower.

Each HVAC system at fan system design conditions shall not exceed the allowable *fan system motor nameplate hp* (Option 1) or *fan system bhp* (Option 2) as shown in Table C403.2.11.1(1). This includes supply fans, exhaust fans, return/relief fans, and fan-powered terminal units associated with systems providing heating or cooling capability. Single *zone* variable-air-volume systems shall comply with the constant volume fan power limitation.

Exceptions:

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

C403.2.11.2 Motor nameplate horsepower.

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

Exceptions:

1. For fans less than 6 bhp (4413 W), where the first available motor larger than the brake horsepower has a nameplate rating within 50 percent of the bhp, selection of the next larger nameplate motor size is allowed.
2. For fans 6 bhp (4413 W) and larger, where the first available motor larger than the bhp has a nameplate rating within 30 percent of the bhp, selection of the next larger nameplate motor size is allowed.

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

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

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

1. Fans of 5 hp (3.7 kW) or less as follows:
 - 1.1. Single fan with a motor nameplate horsepower of 5 hp (3.7 kW) or less, unless Exception 1.2 applies.
 - 1.2. Multiple fans in series or parallel that have a combined motor nameplate horsepower of 5 hp (3.7 kW) or less and are operated as the functional equivalent of a single fan.
2. Fans that are part of equipment covered under Section C403.2.3.
3. Fans included in an equipment package certified by an approved agency for air or energy performance.
4. Powered wall/roof ventilators.
5. Fans outside the scope of AMCA 205.
6. Fans that are intended to operate only during emergency conditions.

TABLE C403.2.11.1(1)
FAN POWER LIMITATION

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

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

where:

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

Hp = The maximum combined motor nameplate horsepower.

Bhp = The maximum combined fan brake horsepower.

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

where:

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

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

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

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

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

TABLE C403.2.4.11.4
MECHANICAL VENTILATION SYSTEM FAN EFFICACY

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

**TABLE C403.2.4.11.5
FAN CONTROL**

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

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

Exceptions:

1. Group R heat recovery ventilator and energy recovery ventilator fans that are less than 400 cfm.
2. Where whole house ventilation fans are integrated with forced-air systems that are tested and listed HVAC equipment, they shall be powered by an electronically commutated motor where required by Section C405.8
3. Domestic clothes dryer booster fans, domestic range hood exhaust fans, and domestic range booster fans that operate intermittently.

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

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

of the power at full fan speed. Low or minimum speed shall be used during periods of low cooling load and ventilation-only operation.

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

Exceptions:

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

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

Such heating systems shall be controlled by an occupancy sensing device or a timer switch, so that the system is automatically deenergized when no occupants are present.

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

1. Variable speed drives; or
2. Other controls and devices that will result in fan and pump motor demand of no more than 30 percent of design wattage at 50 percent of design air volume for fans when static

pressure set point equals 1/3 the total design static pressure, and 50 percent of design water flow for pumps, based on manufacturer's certified test data. Variable inlet vanes, throttling valves (dampers), scroll dampers or bypass circuits shall not be allowed.

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

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

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

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

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

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

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

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

C403.3 Economizers (Prescriptive). Air economizers shall be provided on all new systems including those serving computer server rooms, electronic equipment, radio equipment, and telephone switchgear. Economizers shall comply with Sections C403.3.1 through C403.3.4.

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

1. Systems complying with Section C403.6 Dedicated outdoor air systems (DOAS) with year-round cooling loads from lights and equipment of less than 5 watts per square foot.
2. Unitary or packaged systems serving one zone with dehumidification that affect other systems so as to increase the overall building energy consumption. New humidification equipment shall comply with Section C403.2.3.4
3. Unitary or packaged systems serving one zone where the cooling efficiency meets or exceeds the efficiency requirements in Table C403.3.
4. Water-cooled refrigeration equipment serving chilled beams and chilled ceiling space cooling systems only which are provided with a water economizer meeting the requirements of Section C403.3.4.
5. Systems complying with all of the following criteria:
 - 5.1. Consist of multiple water source heat pumps connected to a common water loop.
 - 5.2. Have a minimum of 60 percent air economizer.
 - 5.3. Have water source heat pumps with an EER at least 15 percent higher for cooling and a COP of at least 15 percent higher for heating than that specified in Section C403.2.3.
 - 5.4. Where provided, have a central boiler or furnace efficiency of 90 percent minimum for units up to 199,000 Btu/h.
 - 5.5. Provide heat recovery with a minimum 50 percent heat recovery effectiveness as defined in Section C403.5 to preheat the outside air supply.
6. For Group R occupancies, cooling units installed outdoors or in a mechanical room adjacent to outdoors with a total cooling capacity less than 20,000 Btu/h and other cooling units with a total cooling capacity less than 54,000 Btu/h provided that these are high-efficiency cooling equipment with IEER, SEER, and EER values more than 15 percent higher than minimum efficiencies listed in Tables C403.2.3 (1) through (3), in the appropriate size category, using the same test

procedures. Equipment shall be listed in the appropriate certification program to qualify for this exception. For split systems, compliance is based on the cooling capacity of individual fan coil units.

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

8. Equipment used to cool *Controlled Plant Growth Environments* provided these are high-efficiency cooling equipment with SEER, EER and IEER values a minimum of 20 percent greater than the values listed in Tables C403.2.3(1), (3) and (7).
9. Equipment used to cool any spaces with year-round cooling loads from lights and equipment of greater than 5 watts per square foot, where it can be demonstrated through calculations, to the satisfaction of the code official, that the heat rejection load of the equipment will be recovered and used for on-site space heating or service water heating demands such that the energy use of the building is decreased in comparison to a baseline of the same equipment provided with an air economizer complying with Section C403.3.
10. Equipment used to cool any dedicated server room, electronic equipment room or telecom switch room provided the system complies with Option a, b or c in the table below. The total capacity of all systems 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.

	Equipment Type	Higher Equipment Efficiency	Part-Load Control	Economizer
Option a	Tables C403.2.3(1) and C403.2.3(2) ^a	+15% ^b	Required over 85,000 Btu/h ^c	None Required
Option b	Tables C403.2.3(1) and C403.2.3(2) ^a	+5% ^d	Required over 85,000 Btu/h ^c	Waterside Economizer
Option c	ASHRAE Standard 127 ^f	+0% ^g	Required over 85,000 Btu/h ^c	Waterside Economizer

Notes for Exception 10:

- a. For a system where all of the cooling equipment is subject to the AHRI standards listed in Tables C403.2.3(1) and C403.2.3(2), the system shall comply with all of the following (note that if the system contains any cooling equipment that exceeds the capacity limits in Table C403.2.3(1) or C403.2.3(2), or if the system contains any cooling equipment that is not included in Table C403.2.3(1) or C403.2.3(2), then the system is not allowed to use this option).
- b. The cooling equipment shall have an EER value and an IPLV value that is a minimum of 15 percent greater than the value listed in Tables C403.2.3(1) and C403.2.3(2).
- c. For units with a total cooling capacity over 85,000 Btu/h, the system shall utilize part-load capacity control schemes that are able to modulate to a part-load capacity of 50 percent of the load or less that results in the compressor operating at the same or

higher EER at part loads than at full load (e.g., minimum of two-stages of compressor unloading such as cylinder unloading, two-stage scrolls, dual tandem scrolls, but hot gas bypass is not credited as a compressor unloading system).

- d. The cooling equipment shall have an EER value and an IPLV value that is a minimum of 5 percent greater than the value listed in Tables C403.2.3(1) and C403.2.3(2).
- e. The system shall include a water economizer in lieu of air economizer. Water economizers shall meet the requirements of Sections C403.3.1 and C403.3.2 and be capable of providing the total concurrent cooling load served by the connected terminal equipment lacking airside economizer, at outside air temperatures of 50°F dry-bulb/45°F wet-bulb and below. For this calculation, all factors including solar and internal load shall be the same as those used for peak load calculations, except for the outside temperatures. The equipment shall be served by a dedicated condenser

water system unless a nondedicated condenser water system exists that can provide appropriate water temperatures during hours when waterside economizer cooling is available.

- f. For a system where all cooling equipment is subject to ASHRAE Standard 127.
- g. The cooling equipment subject to ASHRAE Standard 127 shall have an EER value and an IPLV value that is equal or greater than the value listed in Tables C403.2.3(1) and C403.2.3(2) when determined in accordance with the rating conditions in ASHRAE Standard 127 (i.e., not the rating conditions in AHRI Standard 210/240 or 340/360). This information shall be provided by an independent third party.

**TABLE C403.3
EQUIPMENT EFFICIENCY PERFORMANCE
EXCEPTION FOR ECONOMIZERS**

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

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

C403.3.1 Integrated economizer control. Economizer systems shall be integrated with the mechanical cooling system and be 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 C403.3.1.

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

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

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

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

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

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

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

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

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

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

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

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

**TABLE C403.3.3.3
HIGH-LIMIT SHUTOFF CONTROL SETTING FOR AIR ECONOMIZERS^b**

DEVICE TYPE	CLIMATE ZONE	REQUIRED HIGH LIMIT (ECONOMIZER OFF WHEN):	
		EQUATION	DESCRIPTION
Fixed dry bulb	4C, 5B	$T_{OA} > 75^{\circ}\text{F}$	Outdoor air temperature exceeds 75°F
Differential dry bulb	4C, 5B	$T_{OA} > T_{RA}$	Outdoor air temperature exceeds return air temperature
Fixed enthalpy with fixed dry-bulb temperatures	All	$h_{OA} > 28 \text{ Btu/lb}^a$ or $T_{OA} > 75^{\circ}\text{F}$	Outdoor air enthalpy exceeds 28 Btu/lb of dry air ^a or outdoor temperature exceeds 75°F
Differential enthalpy with fixed dry-bulb temperatures	All	$h_{OA} > H_{ra}$ or $T_{OA} > 75^{\circ}\text{F}$	Outdoor air enthalpy exceeds return air enthalpy or outdoor temperature exceeds 75°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 setpoint shall be capable of being set to within 2°F and 2 Btu/lb of the setpoint listed.

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

C403.3.4.1 Design capacity. Water economizer systems shall be configured to 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 in which a water economizer is used and where dehumidification requirements cannot be met using outdoor air temperatures of 50°F dry-bulb (10°C dry-bulb)/45°F wet-bulb (7.2°C wet-bulb) shall satisfy 100 percent of the expected system cooling load at 45°F dry-bulb (7.2°C dry-bulb)/40°F wet-bulb (4.5°C wet-bulb).

C403.3.4.2 Maximum pressure drop. Precooling coils and water-to-water heat exchangers used as part of a water economizer system shall either have a

waterside pressure drop of less than 15 feet (4572 mm) of water or a secondary loop shall be created so that the coil or heat exchanger pressure drop is not seen by the circulating pumps when the system is in the normal cooling (noneconomizer) mode.

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

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

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

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

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

Exception: Systems complying with Section C403.4.1.2.

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

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

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

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

C403.4.2.2 Two-pipe changeover system. Systems that use a common distribution system to supply both heated and chilled water shall be designed to allow a dead band between changeover from one mode to the other of at least 15°F (8.3°C) outside air temperatures; be designed to and provided with controls that will allow operation in one mode for at least 4 hours before changing over to the other mode;

and be provided with controls that allow heating and cooling supply temperatures at the changeover point to be no more than 30°F (16.7°C) apart.

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

C403.4.2.3.1 Temperature dead band. Hydronic heat pumps connected to a common heat pump water loop with central devices for heat rejection and heat addition shall have controls that are configured to provide a heat pump water supply temperature dead band of at least 20°F (11.1°C) between initiation of heat rejection and heat addition by the central devices.

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

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

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

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

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

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

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

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

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

Exception: Hydronic systems serving hydronic heat pumps.

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

Exceptions:

1. Supply-water temperature reset for chilled-water systems supplied by off-site district chilled water or chilled water from ice storage systems.

2. Minimum flow rates other than 50 percent as required by the equipment manufacturer for proper operation of equipment where using flow bypass or end-of-line 3-way valves.
3. Variable pump flow on dedicated equipment circulation pumps where configured in primary/secondary design to provide the minimum flow requirements of the equipment manufacturer for proper operation of equipment.

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

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

**TABLE C403.4.2.5
BOILER TURNDOWN**

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

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

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

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

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

1. For systems having a combined pump motor horsepower less than or equal to 20 hp (15 kW) and without direct digital control of individual coils, pump speed shall be a function of either:

- 1.1. Required differential pressure; or
- 1.2. Reset directly based on zone hydronic demand, or other zone load indicators; or
- 1.3. Reset directly based on pump power and pump differential pressure.
2. For systems having a combined pump motor horsepower that exceeds 20 hp (15 kW) or smaller systems with direct digital control, pump speed shall be a function of either:
 - 2.1. The static pressure set point as reset based on the valve requiring the most pressure; or
 - 2.2. Directly controlled based on zone hydronic demand.

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

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

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

C403.4.3.1.1 Fan motors not less than 7.5 hp.

Each fan powered by a motor of 7.5 hp (5.6 kW) or larger shall have controls that automatically change the fan speed to control the leaving fluid temperature or condensing temperature/pressure of the heat rejection device.

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

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

C403.4.3.2 Limitation on centrifugal fan open-circuit cooling towers. Centrifugal fan open-circuit cooling towers with a combined rated capacity of 1,100 gpm (4164 L/m) or greater at 95°F (35°C) condenser water return, 85°F (29°C) condenser water supply, and 75°F (24°C) outdoor air

wet-bulb temperature shall meet the energy efficiency requirement for axial fan open-circuit cooling towers listed in Table C403.2.3(8).

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

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

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

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

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

1. *Zones* or supply air systems where at least 75 percent of the energy for reheating or for providing warm air in mixing systems is provided from a site-recovered or site-solar energy source.
2. *Zones* where special humidity levels are required to satisfy process needs.
3. *Zones* with a peak supply air quantity of 300 cfm (142 L/s) or less and where the flow rate is less than 10 percent of the total fan system supply airflow rate.

4. *Zones* without DDC for which the volume of air that is reheated, recooled or remixed is less than the larger of the following:
 - 4.1. 30 percent of the zone design peak supply rate.
 - 4.2. The outdoor airflow rate required to meet the ventilation requirements of Chapter 4 of the *International Mechanical Code* for the zone.
 - 4.3. Any higher rate that can be demonstrated, to the satisfaction of the code official, to reduce overall system annual energy usage by offsetting reheat/recool energy losses through a reduction in outdoor air intake for the system.
 - 4.4. The airflow rate required to comply with applicable codes or accreditation standards, such as pressure relationships or minimum air change rates.
5. *Zones* with DDC that comply with all of the following:
 - 5.1. The airflow rate in dead band between heating and cooling does not exceed the larger of the following:
 - 5.1.1. 20 percent of the zone design peak supply rate.
 - 5.1.2. The outdoor airflow rate required to meet the ventilation requirements of Chapter 4 of the *International Mechanical Code* for the zone.
 - 5.1.3. Any higher rate that can be demonstrated, to the satisfaction of the code official, to reduce overall system annual energy usage by offsetting reheat/recool energy losses through a reduction in outdoor air intake for the system.
 - 5.1.4. The airflow rate required to comply with applicable codes or accreditation standards, such as pressure relationships or minimum air change rates.
 - 5.2. The airflow rate that is reheated, recooled or mixed shall be less than 50 percent of the zone design peak supply rate.
 - 5.3. The first stage of heating consists of modulating the zone supply air temperature setpoint up to a maximum setpoint while the airflow is maintained at the dead band flow rate.

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

6. *Zones* or supply air systems with thermostatic and humidistatic controls capable of operating in sequence the supply of heating and cooling energy to the *zones* and which are configured to prevent reheating, recooling, mixing or simultaneous supply of air that has been previously cooled, either mechanically or through the use of economizer systems, and air that has been previously mechanically heated.

C403.4.4.1 Single duct 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.

C403.4.4.2 Dual duct and mixing VAV systems, terminal devices. Systems that have one warm air duct and one cool air duct shall use terminal devices 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.

C403.4.4.3 Multiple-zone VAV system ventilation optimization controls. Multiple-zone VAV systems with direct digital control of individual zone boxes reporting to a central control panel shall have automatic controls configured to reduce outdoor air intake flow below design rates in response to changes in system ventilation efficiency (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 having exhaust air energy recovery complying with Section C403.5.
3. Systems where total design exhaust airflow is more than 70 percent of total design outdoor air intake flow requirements.

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

Exceptions:

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

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

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

**TABLE C403.4.6
MAXIMUM HOT GAS BYPASS CAPACITY**

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

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

** C403.5 Energy recovery.

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

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

1. Where energy recovery systems are restricted per Section 514 of the *International Mechanical Code* to sensible energy, recovery shall comply with one of the following:
 - 1.1. Kitchen exhaust systems where they comply with Section C403.2.7.1.
 - 1.2. Laboratory fume hood systems where they comply with Exception 2 of Section C403.5.1.
 - 1.3. Other sensible energy recovery systems with the capability to provide a change in dry bulb temperature of the outdoor air supply of not less than 50 percent of the difference between the outdoor air and the return air dry bulb temperatures, at design conditions.
2. Laboratory fume hood systems that include at least one of the following features and also comply with Section C403.2.7.2:
 - 2.1. Variable-air-volume hood exhaust and room supply systems capable of reducing exhaust and makeup air volume to 50 percent or less of design values.
 - 2.2. Direct makeup (auxiliary) air supply equal to at least 75 percent of the exhaust rate, heated no warmer than 2°F (1.1°C) above room setpoint, cooled to no cooler than 3°F (1.7°C) below room setpoint, no humidification added, and no simultaneous heating and cooling used for dehumidification control.
3. Systems serving spaces that are heated to less than 60°F (15.5°C) and are not cooled.
4. Where more than 60 percent of the outdoor heating energy is provided from site-recovered or site solar energy.
5. Systems exhausting toxic, flammable, paint or corrosive fumes or dust.
6. Cooling energy recovery in Climate Zones 3C, 4C, 5B, 5C, 6B, 7 and 8.
7. Systems requiring dehumidification that employ energy recovery in series with the cooling coil.
8. Multi-zone systems where the supply airflow rate is less than the values specified in Tables C403.5.1(1) and C403.5.1(2) for the corresponding percent of outdoor air. Where a value of NR is listed, energy recovery shall not be required.

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

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

NR = not required

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

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

NR = not required

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

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

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

C403.5.3 Condenser heat recovery. Facilities having food service, meat or deli departments and having 500,000 Btu/h or greater of remote refrigeration condensers shall have condenser waste heat recovery from freezers and coolers and shall use the waste heat for service water heating, space heating or for dehumidification reheat. Facilities having a gross conditioned floor area of 40,000 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.

C403.5.4 Heat recovery for service water heating.

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

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

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

Exceptions:

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

C403.6 Dedicated outdoor air systems (DOAS). (This section is Optional through 6/30/2017; it becomes Prescriptive as of 7/1/2017). For office, retail, education, libraries and fire stations, outdoor air shall be provided to each occupied space by a dedicated outdoor air system

(DOAS) which delivers 100 percent outdoor air without requiring operation of the heating and cooling system fans for ventilation air delivery.

Exceptions:

1. Occupied spaces that are not ventilated by a mechanical ventilation system and are only ventilated by a natural ventilation system per Section 402 of the *International Mechanical Code*.
2. High efficiency variable air volume (VAV) systems complying with Section C403.7. This exception shall not be used as a substitution for a DOAS per Section C406.6 or as a modification to the requirements for the Standard Reference Design per Section C407

C403.6.1 Energy recovery ventilation with DOAS.

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

Exceptions:

1. Occupied spaces under the threshold of Section C403.5 with an average occupant load greater than 25 people per 1000 square feet (93 m²) of floor area (as established in Table 403.3.1.1 of the *International Mechanical Code*) that include demand control ventilation configured to reduce outdoor air by at least 50% below design minimum ventilation rates when the actual occupancy of the space served by the system is less than the design occupancy.
2. Systems installed for the sole purpose of providing makeup air for systems exhausting toxic, flammable, paint, or corrosive fumes or dust, dryer exhaust, or commercial kitchen hoods used for collecting and removing grease vapors and smoke.

C403.6.2 Heating/cooling system fan controls.

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

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

C403.6.3 Impracticality. Where the *code official* determines full compliance with all of the requirements of Section C403.6.1 and C403.6.2 would be impractical, it is permissible to provide an approved alternate means of compliance that achieves a comparable level of energy efficiency. For the purposes

of this section, impractical means that an HVAC system complying with Section C403.6 cannot effectively be utilized due to an unusual use or configuration of the building.

C403.7 High efficiency variable air volume (VAV)

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

1. The VAV systems are provided with airside economizer per Section 403.3 without exceptions.
2. A direct-digital control (DDC) system is provided to control the VAV air handling units and associated terminal units per Section C403.2.4.12 regardless of sizing thresholds of Table C403.2.4.12.1.
3. Multiple-zone VAV systems with a minimum outdoor air requirement of 2,500 cfm (1180 L/s) or greater shall be equipped with a device capable of measuring outdoor airflow intake under all load conditions. The system shall be capable of increasing or reducing the outdoor airflow intake based on feedback from the VAV terminal units as required by Section C403.4.4.3, without exceptions, and Section C403.2.6.2 demand controlled ventilation.
4. Multiple-zone VAV systems with a minimum outdoor air requirement of 2,500 cfm (1180 L/s) or greater shall be equipped with a device capable of measuring supply airflow to the VAV terminal units under all load conditions.
5. In addition to meeting the zone isolation requirements of C403.2.4.4 a single VAV air handling unit shall not serve more than 50,000 square feet (2323 m²) unless a single floor is greater than 50,000 square feet (2323 m²) in which case the air handler is permitted to serve the entire floor.
6. The primary maximum cooling air for the VAV terminal units serving interior cooling load driven zones shall be sized for a supply air temperature that is a minimum of 5°F greater than the supply air temperature for the exterior zones in cooling.
7. Air terminal units with a minimum primary airflow setpoint of 50% or greater of the maximum primary airflow setpoint shall be sized with an inlet velocity of no greater than 900 feet per minute.
8. DDC systems be designed and configured per the guidelines set by *High Performance Sequences of Operation for HVAC Systems* (ASHRAE GPC 36, RP-1455).

9. Allowable fan motor horsepower shall not exceed 90% of the allowable HVAC *fan system bhp* (Option 2) as defined by Section C403.2.11.1.
10. All fan powered VAV terminal units (series or parallel) shall be provided with electronically commutated motors. The DDC system shall be configured to vary the speed of the motor as a function of the heating and cooling load in the space. Minimum speed shall not be greater than 66 percent of design airflow required for the greater of heating or cooling operation. Minimum speed shall be used during periods of low heating and cooling operation and ventilation-only operation.

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

cooling loads greater than 5 watts/ft² shall be provided with separate, independent HVAC systems to allow the VAV air handlers to turn off during unoccupied hours in the office space and to allow the supply air temperature reset to occur.

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

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

Exception: Heat recovery per exception 9 of Section 403.3 may be in lieu of airside economizer for the separate, independent HVAC system.

15. HVAC system central heating or cooling plant will include a minimum of one of the following options:
 - 15.1. VAV terminal units with hydronic heating coils connected to systems with hot water generation equipment limited to the following types of equipment: gas-fired hydronic boilers with a thermal efficiency, E_t , of not less than 90 percent, air-to-water heat pumps or heat recovery chillers.
 - 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 C403.2.3(7), in the appropriate size category, using the same test procedures. Equipment shall be listed in the appropriate certification program to qualify. The smallest chiller or compressor in the central plant shall not exceed 20% of the total central plant cooling capacity or the chilled water system shall include thermal storage sized for a minimum of 20% of the total central cooling plant capacity.
16. The DDC system shall include a fault detection and diagnostics (FDD) system complying with the following:
 - 16.1. The following temperature sensors shall be permanently installed to monitor system operation:
 - 16.1.1. Outside air.
 - 16.1.2. Supply air.
 - 16.1.3. Return air.
 - 16.2. Temperature sensors shall have an accuracy of $\pm 2^\circ\text{F}$ (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 accessible by day-to-day operating or service personnel or annunciated locally on zone thermostats.
- 16.6. The VAV terminal unit shall be configured to report if the VAV inlet valve has failed by performing the following diagnostic check at a maximum interval of once a month:
 - 16.6.1. Command VAV terminal unit primary air inlet valve closed and verify that primary airflow goes to zero.
 - 16.6.2. Command VAV thermal unit primary air inlet valve to design airflow and verify that unit is controlling to within 10% of design airflow.
- 16.7. The VAV terminal unit shall be configured to report and trend when the zone is driving the following VAV air handling unit reset sequences. The building operator shall have the capability to exclude zones used in the reset sequences from the DDC control system graphical user interface:
 - 16.7.1. Supply air temperature setpoint reset to lowest supply air temperature setpoint for cooling operation.
 - 16.7.2. Supply air duct static pressure setpoint reset for the highest duct static pressure setpoint allowable.
- 16.8. The FDD system shall be configured to detect the following faults:
 - 16.8.1. Air temperature sensor failure/fault.

- 16.8.2. Not economizing when the unit should be economizing.
- 16.8.3. Economizing when the unit should not be economizing.
- 16.8.4. Outdoor air or return air damper not modulating.
- 16.8.5. Excess outdoor air.
- 16.8.6. VAV terminal unit primary air valve failure.

SECTION C404 SERVICE WATER HEATING (MANDATORY)

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

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

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

Exceptions:

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

TABLE C404.2
MINIMUM PERFORMANCE OF WATER-HEATING EQUIPMENT

EQUIPMENT TYPE	SIZE CATEGORY (input)	SUBCATEGORY OR RATING CONDITION	PERFORMANCE REQUIRED ^{a, b}	TEST PROCEDURE
Water heaters, electric	≤ 12 kW	Resistance ≥20 gal	0.97 - 0.00 132V, EF	DOE 10 CFR Part 430
	> 12 kW	Resistance ≥20 gal	0.3 + 27/V _m %h	Section G.2 of ANSI Z21.10.3
	≤ 24 amps and ≤250 volts	Heat pump	0.93 - 0.00132V, EF	DOE 10 CFR Part 430
Instantaneous water heaters, electric	All	Resistance	0.97 - 0.00 132V, EF	DOE 10 CFR Part 430
Storage water heaters, gas	≤ 75,000 Btu/h	≥ 20 gal	0.67 - 0.0019V, EF	DOE 10 CFR Part 430
	> 75,000 Btu/h	< 4,000 Btu/h/gal	80% E _t (Q/800 + 110√V)SL, Btu/h	Section G.1 and G.2 of ANSI Z21.10.3
Instantaneous water heaters, gas	> 50,000 Btu/h and < 200,000 Btu/h	≥ 4,000 (Btu/h)/gal and < 2 gal	0.62 - 0.0019V, EF	DOE 10 CFR Part 430
	≥ 200,000 Btu/h ^c	≥ 4,000 Btu/h/gal and < 10 gal	80% E _t	Section G.1 and G.2 of ANSI Z21.10.3
	≥ 200,000 Btu/h	≥ 4,000 Btu/h/gal and ≥10 gal	80% E _t (Q/800 + 110√V)SL, Btu/h	
Storage water heaters, oil	≤ 105,000 Btu/h	≥20 gal	0.59 - 0.0019V, EF	DOE 10 CFR Part 430
	> 105,000 Btu/h	< 4,000 Btu/h/gal	80% E _t (Q/800 + 110√V)SL, Btu/h	Section G.1 and G.2 of ANSI Z21.10.3
Instantaneous water heaters, oil	≤ 210,000 Btu/h	≥ 4,000 Btu/h/gal and < 2 gal	0.59 - 0.0019V, EF	DOE 10 CFR Part 430
	> 210,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	80% E _t	Section G.1 and G.2 of ANSI Z21.10.3
	> 210,000 Btu/h	≥ 4,000 Btu/h/gal and ≥10 gal	78% E _t (Q/800 + 110√V)SL, Btu/h	
Hot water supply boilers, gas and oil	≥ 300,000 Btu/h and < 12,500,000 Btu/h	≥ 4,000 Btu/h/gal and < 10 gal	80% E _t	Section G.1 and G.2 of ANSI Z21.10.3
Hot water supply boilers, gas	≥ 300,000 Btu/h and < 12,500,000 Btu/h	≥4,000 Btu/h/gal and ≥ 10 gal	80% E _t (Q/800 + 110√V)SL, Btu/h	
Hot water supply boilers, oil	≥300,000 Btu/h and < 12,500,000 Btu/h	≥ 4,000 Btu/h/gal and > 10 gal	78% E _t (Q/800 + 110√V)SL, Btu/h	
Pool heaters, gas and oil	All	—	78% E _t	ASHRAE 146
Heat pump pool heaters	All	—	4.0 COP	AHRI 1160
Unfired storage tanks	All	—	Minimum insulation requirement R-12.5 (h x ft ² x °F)/Btu	(none)

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

- Energy factor (EF) and thermal efficiency (E_t) are minimum requirements. In the EF equation, V is the rated volume in gallons.
- Standby loss (SL) is the maximum Btu/h based on a nominal 70°F temperature difference between stored water and ambient requirements. In the SL equation, Q is the nameplate input rate in Btu/h. In the SL equation for electric water heaters, V is the rated volume in gallons and V_m is the measured volume in gallons. In the SL equation for oil and gas water heaters and boilers, V is the rated volume in gallons.
- Instantaneous water heaters with input rates below 200,000 Btu/h must comply with these requirements if the water heater is designed to heat water to temperatures 180°F or higher.
- Electric water heaters with an input rating of 12kW (40,950 Btu/h) or less that are designed to heat water to temperatures of 180°F or greater shall comply with the requirements for electric water heaters that have an input rating greater than 12 kW.

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

C404.3.1 Maximum allowable pipe length method.

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

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

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. The volume contained within fixture shutoff valves, within flexible water supply connectors to a fixture fitting and within a fixture fitting shall not be included in the water volume determination. Where heated water is supplied by a recirculating system or heat-traced piping, the volume shall include the portion of the fitting on the branch pipe that supplies water to the fixture.

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

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

C404.6 Insulation of piping. Piping from a water heater to the termination of the heated water fixture supply pipe shall be insulated in accordance with Table C403.2.9. On both the inlet and outlet piping of a storage hot water heater or heated water storage tank, the piping to a heat trap or the first 8 feet (2438 mm) of piping, whichever is less, shall be insulated. Piping that is heat traced shall be insulated in accordance with Table C403.2.9 or the heat

**TABLE C404.3.1
PIPING VOLUME AND MAXIMUM PIPING LENGTHS**

NOMINAL PIPE SIZE (inches)	VOLUME (liquid ounces per foot length)	MAXIMUM PIPING LENGTH (feet)	
		Public lavatory faucets	Other fixtures and appliances
1/4	0.33	6	50
5/16	0.5	4	50
3/8	0.75	3	50
1/2	1.5	2	43
5/8	2	1	32
3/4	3	0.5	21
7/8	4	0.5	16
1	5	0.5	13
1 1/4	8	0.5	8
1 1/2	11	0.5	6
2 or larger	18	0.5	4

trace manufacturer's instructions. Tubular pipe insulation shall be installed in accordance with the insulation manufacturer's instructions. Pipe insulation shall be continuous except where the piping passes through a framing member. The minimum insulation thickness requirements of this section shall not supersede any greater insulation thickness requirements necessary for the protection of piping from freezing temperatures or the protection of personnel against external surface temperatures on the insulation.

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

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

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

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

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

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

C404.8 Demand recirculation controls. A water distribution system having one or more recirculation pumps that pump water from a heated-water supply pipe back to the heated-water source through a cold-water supply pipe shall be a *demand recirculation water system*. Pumps shall have controls that comply with both of the following:

1. The control shall start the pump upon receiving a signal from the action of a user of a fixture or appliance, sensing the presence of a user of a fixture or sending the flow of hot or tempered water to a fixture fitting or appliance.
2. The control shall limit the temperature of the water entering the cold water-piping to 104°F (40°C)

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

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

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

C404.10.1 Heaters. Heat pump pool heaters shall have a minimum COP of 4.0 determined in accordance with ASHRAE Standard 146. Other pool heating equipment shall comply with the applicable efficiencies in Section C404.2.

The electric power to all heaters shall be controlled by a readily accessible on-off switch that is an integral part of the heater, mounted on the exterior of the heater, or external to and within 3 feet of the heater. Operation of such switch shall 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.

C404.10.2 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 are required to operate solar- and waste-heat-recovery pool heating systems.

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

C404.10.4 Heat recovery. Heated indoor swimming pools, spas or hot tubs with water surface area greater than 200 square feet shall provide for energy conservation by an exhaust air heat recovery system that heats ventilation air, pool water or domestic hot water. The heat recovery system shall be configured to decrease the exhaust air temperature at design heating conditions (80°F indoor) by 36°F (10°C).

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

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

C404.12 Energy consumption of portable spas

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

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

SECTION C405

ELECTRICAL POWER AND LIGHTING SYSTEMS

C405.1 General (mandatory). This section covers lighting system controls, the maximum lighting power for interior and exterior applications, electrical energy consumption, vertical and horizontal transportation systems, and minimum efficiencies for motors and transformers.

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

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

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

1. Areas designated as security or emergency areas that are required to be continuously lighted.
2. Interior exit stairways, interior exit ramps and exit passageways.
3. Emergency egress lighting that is normally off.
4. Industrial or manufacturing process areas, as may be required for production and safety.
5. Luminaire-level lighting controls (LLLC) that control interior lighting. The LLLC luminaire shall be independently configured to:
 - 5.1. Monitor occupant activity to brighten or dim its lighting when occupied or unoccupied, respectively.
 - 5.2. Monitor ambient light (both electric light and daylight) and brighten or dim electric light to maintain desired light level.
 - 5.3. Configuration and reconfiguration of performance parameters, including bright and dim setpoints, time-outs, dimming, fade rates, sensor sensitivity adjustments, and wireless zoning configurations, for each control strategy.
 - 5.4. Meet the operational and commissioning requirements of Sections C405.2.1, C405.2.2, C405.2.3, C405.2.4, and C408.

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

1. Classrooms/lecture/training rooms.
2. Conference/ meeting/multipurpose rooms.
3. Copy/print rooms.
4. Lounges.
5. Employee lunch and break rooms.
6. Private offices.
7. Restrooms.
8. Storage rooms.
9. Janitorial closets.
10. Locker rooms.
11. Other spaces 300 square feet (28 m²) or less that are enclosed by floor-to- ceiling height partitions.
12. Warehouse spaces.

C405.2.1.1 Occupant sensor control function.

Occupant sensor controls shall comply with the following:

1. Automatically turn off lights within 30 minutes of all occupants leaving the space.
2. Be manual on or shall be controlled to automatically turn the lighting on to not more than 50 percent power.

Exception: Full automatic-on controls shall be permitted to control lighting in public corridors, stairways, restrooms, primary building entrance areas and lobbies, and areas where manual-on operation would endanger the safety or security of the room or building occupants.

3. Shall incorporate a manual control to allow occupants to turn lights off.

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

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

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

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

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

1. Have a minimum 7 day clock.
2. Be capable of being set for 7 different day types per week.
3. Incorporate an automatic holiday "shut-off" feature, which turns off all controlled 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 square feet (465 m²).

Exceptions:

1. Within malls, arcades, auditoriums, single tenant retail spaces, industrial facilities and arenas:
 - 1.1. The time limit shall be permitted to be greater than 2 hours provided the override switch is a captive key device.
 - 1.2. The area controlled by the override switch is permitted to be greater than 5,000 square feet (465 m²), but shall not be greater than 20,000 square feet (1860 m²).
2. Where provided with manual control, the following areas are not required to have light reduction control:
 - 2.1. Spaces that have only one luminaire with a rated power of less than 100 watts.
 - 2.2. Spaces that use less than 0.6 watts per square foot (6.5 W/m²).
 - 2.3. Corridors, equipment rooms, public lobbies, electrical or mechanical rooms.

C405.2.2.2 Light reduction controls. Spaces required to have light reduction controls shall have a manual control that allows the occupant to reduce the connected lighting load in a reasonably *uniform illumination* pattern by at least 50 percent. Lighting reduction shall be achieved by one of the following *approved* methods:

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

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

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

1. Shall be readily accessible to occupants.
2. Shall be located where the controlled lights are visible, or shall identify the area served by the lights and indicate their status.

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

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

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

1. Spaces in health care facilities where patient care is directly provided.
2. Dwelling units and sleeping units.
3. Lighting that is required to have specific application control in accordance with Section C405.2.4.
4. Sidelight daylight zones on the first floor above grade in Group A-2 and Group M occupancies.
5. Daylight zones where the total proposed lighting power density is less than 35 percent of the lighting power allowance per Section C405.4.2.

C405.2.4.1 Daylight responsive controls function.

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

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

Exception: Spaces enclosed by walls or ceiling height partitions with no more than three general lighting fixtures may have combined daylight zone control of primary and secondary daylight zones provided *uniform illumination* can be achieved.

2. Lights in topline daylight zones in accordance with Section C405.2.4.3 shall be controlled independently of lights in sidelight daylight zones in accordance with Section C405.2.4.2.
3. Daylight responsive controls within each space shall be configured so that they can be calibrated from within that space by authorized personnel.
4. Calibration mechanisms shall be readily accessible.

5. Daylight responsive controls shall be configured to completely shut off all controlled lights in that zone.

6. Lights in sidelight daylight zones in accordance with Section C405.2.4.2 facing different cardinal orientations (i.e., within 45 degrees of due north, east, south, west) shall be controlled independently of each other.

Exception: Up to two light fixtures in each space are permitted to be controlled together with lighting in a daylight zone facing a different cardinal orientation.

7. Incorporate time-delay circuits to prevent cycling of light level changes of less than three minutes.
8. The maximum area a single daylight responsive control device serves shall not exceed 2,500 square feet (232 m²).
9. Occupant override capability of daylight dimming controls is not permitted, other than a reduction of light output from the level established by the daylighting controls.

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

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

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

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

1. Where the *fenestration* is located in a wall, the sidelight daylight zone includes the primary and secondary daylight zones. The primary daylight zone shall extend laterally to the nearest full height wall, or up to 1.0 times the

height from the floor to the top of the fenestration, and longitudinally from the edge of the fenestration to the nearest full height wall, or up to 2 feet (610 mm), whichever is less, as indicated in Figure C405.2.4.2(1). The secondary daylight zone begins at the edge of the primary daylight zone and extends laterally to the nearest full height wall, or up to 2.0 times the height from the floor to the top of the fenestration, whichever is less, as indicated in Figure C405.2.4.2(1).

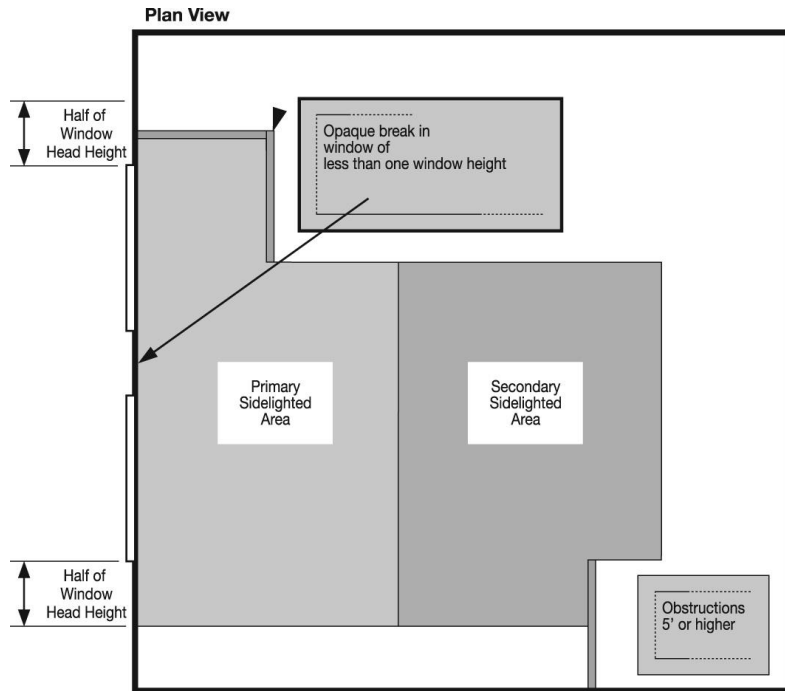
2. Where the fenestration is located in a rooftop monitor, the sidelight daylight zone shall extend laterally to the nearest obstruction that is taller than 0.7 times the ceiling height, or up to 1.0 times the height from the floor to the bottom of the fenestration, whichever is less, and longitudinally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

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

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

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

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



Computing the secondary sidelighted area.

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

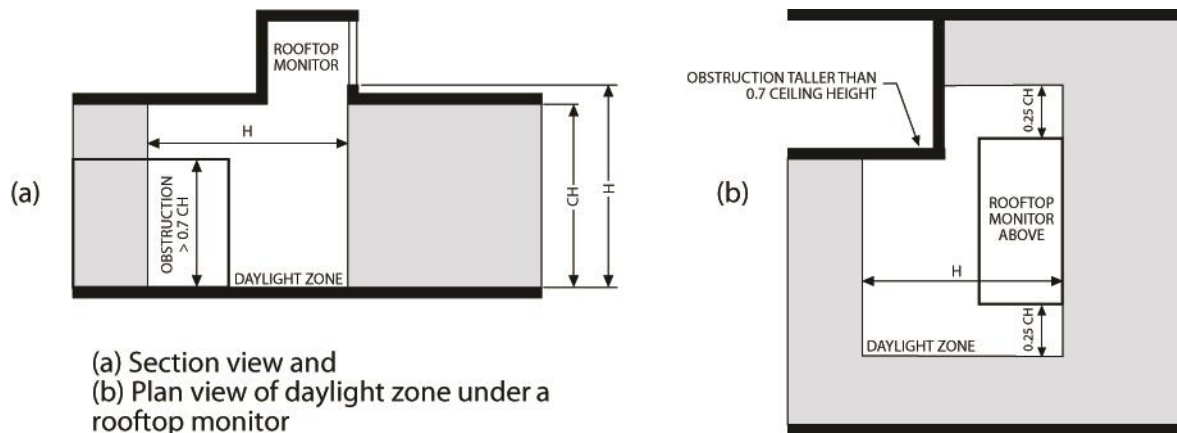
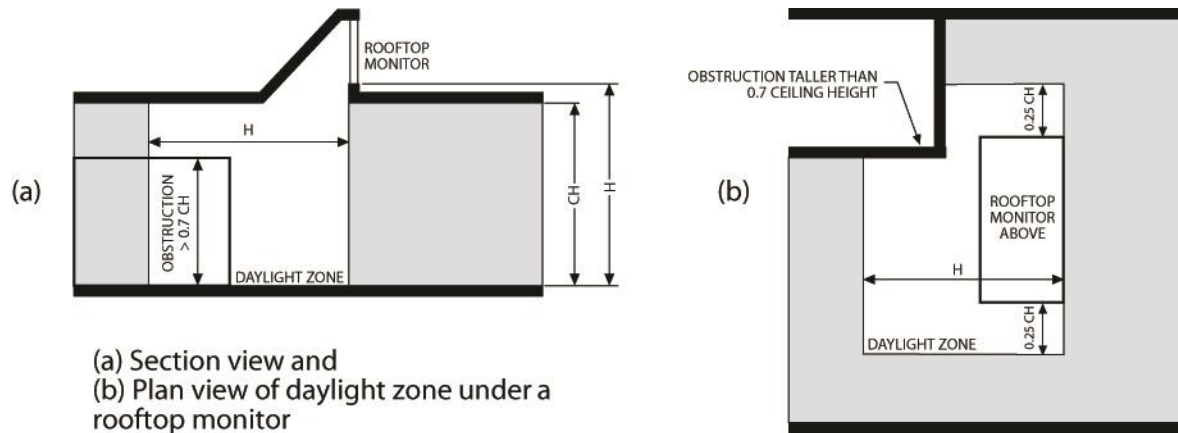
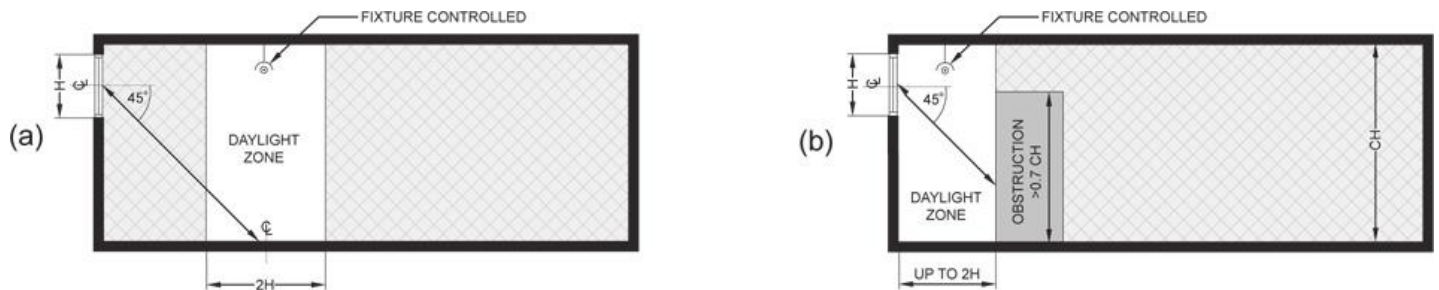


FIGURE C405.2.4.2(3)
DAYLIGHT ZONE UNDER A SLOPED ROOFTOP MONITOR



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

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



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

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

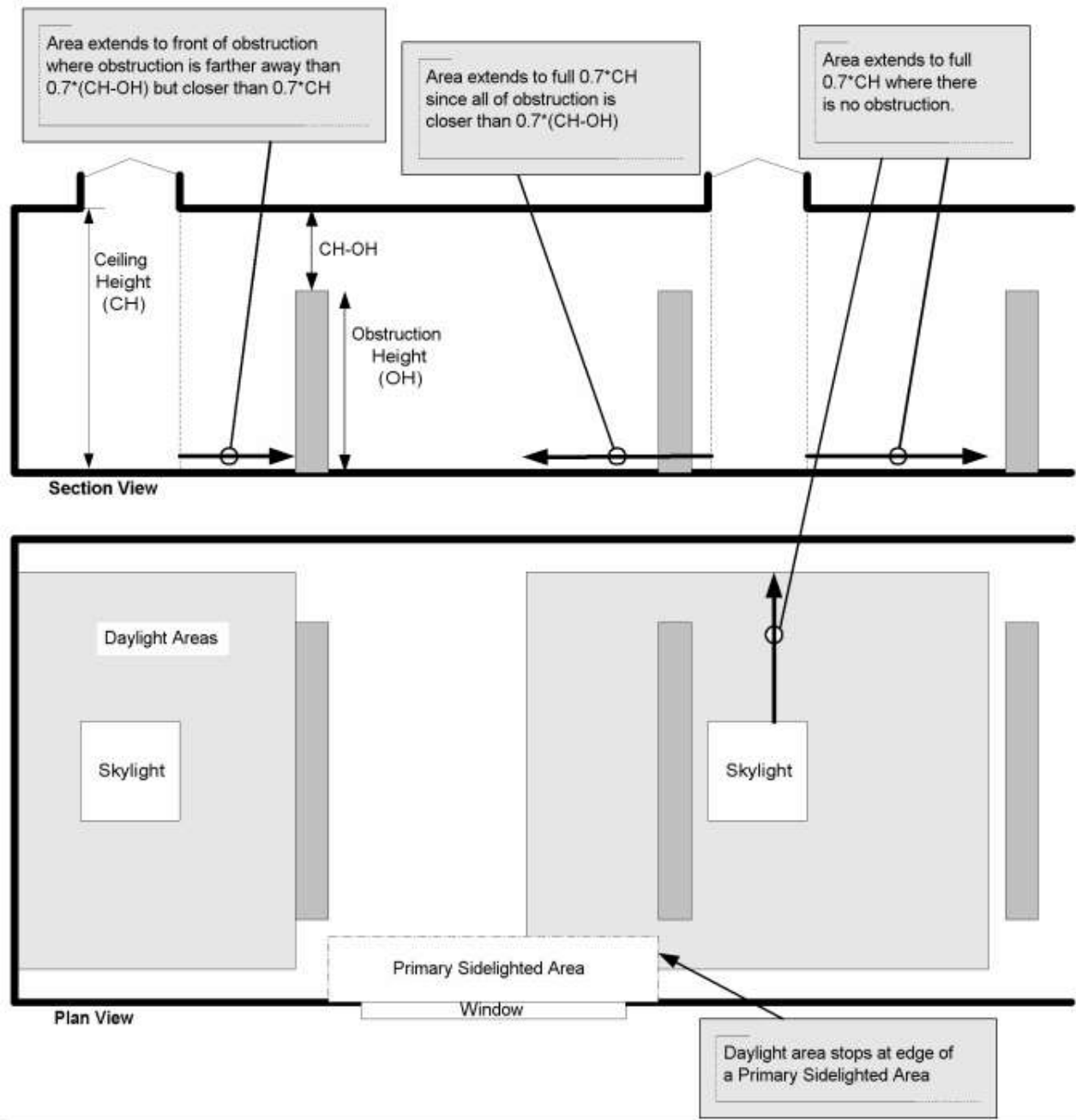
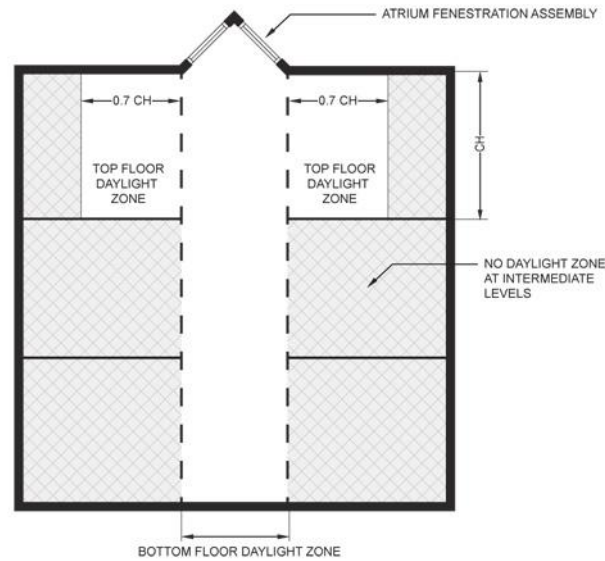


FIGURE C405.2.4.3(2)
DAYLIGHT ZONE UNDER ATRIUM FENESTRATION



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

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

Exception: Lighting and switched receptacles controlled by captive key systems.

4. Supplemental task lighting, including permanently installed under-shelf or under-cabinet lighting, shall be automatically shut off whenever that space is unoccupied and shall have a control device integral to the luminaires or be controlled by a wall-mounted control device provided that the control device is readily accessible.
5. Lighting for nonvisual applications, such as plant growth and food warming, shall be controlled by a dedicated control that is independent of the controls for other lighting

within the room or space. Each control zone shall be no greater than the area served by a single luminaire or 4,000 square feet, whichever is larger.

6. Lighting equipment that is for sale or for demonstrations in lighting education shall be controlled by a dedicated control that is independent of the controls for other lighting within the room or space.
7. Luminaires serving the exit access and providing means of egress illumination required by Section 1006.1 of the *International Building Code*, including luminaires that function as both normal and emergency means of egress illumination shall be controlled by a combination of listed emergency relay and occupancy sensors, or signal from another building control system, that automatically shuts off the lighting when the areas served by that illumination are unoccupied.

Exception: Means of egress illumination serving the exit access that does not exceed 0.02 watts per square foot of building area is exempt from this requirement.

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

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

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

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

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

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

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

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

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

Exception: Areas less than 5 percent of the building footprint for footprints over 100,000 ft².

► **C405.3 Exit signs (Mandatory).** Internally illuminated exit signs shall not exceed 5 watts per side.

C405.4 Interior lighting power requirements

(Prescriptive). A building complies with this section if its total connected lighting power calculated under Section C405.4.1 is no greater than the interior lighting power calculated under Section C405.4.2.

C405.4.1 Total connected interior lighting power.

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

$$TCLP = [SL + LV + LTPB + \text{Other}]$$

(Equation 4-10)

Where:

- TCLP* = Total connected lighting power (watts)
SL = Labeled wattage of luminaires for screw-in lamps.
LV = Wattage of the transformer supplying low voltage lighting.
LTPB = Wattage of line-voltage lighting tracks and plug-in busways as the specified wattage of the luminaires but at least 50 W/lin. ft., or the wattage limit of the system's circuit breaker, or the wattage limit of other permanent current limiting devices on the system.
Other = The wattage of all other luminaires and lighting, sources not covered above and associated with interior lighting verified by data supplied by the manufacturer or other *approved* sources.

Exceptions:

1. The connected power associated with the following lighting equipment is not included in calculating total connected lighting power.
 - 1.1. Professional sports arena playing field lighting.
 - 1.2. Emergency lighting automatically off during normal building operation.
 - 1.3. Lighting in spaces specifically designed for use by occupants with special lighting needs including the visually impaired and other medical and age-related issues.
 - 1.4. Casino gaming areas.
 - 1.5. General area lighting power in industrial and manufacturing occupancies dedicated to the inspection or quality control of goods and products.
 - 1.6. Lighting in sleeping units, provided that the lighting complies with Section R404.1.
 - 1.7. Mirror lighting in dressing rooms.

2. Lighting equipment used for the following shall be exempt provided that it is in addition to general lighting and is controlled by an independent control device:
 - 2.1. Task lighting for medical and dental purposes.
 - 2.2. Display lighting for exhibits in galleries, museums and monuments.
3. Lighting for theatrical purposes, including performance, stage, film production and video production.
4. Lighting for photographic processes.
5. Lighting integral to equipment or instrumentation and is installed by the manufacturer.
6. Task lighting for plant growth or maintenance where the lamp efficacy is not less than 90 lumens per watt.
7. Advertising signage or directional signage.
8. In restaurant buildings and areas, lighting for food warming or integral to food preparation equipment.
9. Lighting equipment that is for sale.
10. Lighting demonstration equipment in lighting education facilities.
11. Lighting *approved* because of safety or emergency considerations, inclusive of exit lights.
12. Lighting integral to both open and glass enclosed refrigerator and freezer cases.
13. Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions.
14. Furniture mounted supplemental task lighting that is controlled by automatic shutoff.
15. Lighting used for aircraft painting.

C405.4.2 Interior lighting power. The total interior lighting power allowance (watts) is determined according to Table C405.4.2(1) using the Building Area Method, or Table C405.4.2(2) using the Space-by-Space Method, for all areas of the building covered in this permit.

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

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

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

C405.4.2.2.1 Additional interior lighting power.

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

$$\text{Additional interior lighting power allowance} = 500 \text{ watts} + (\text{Retail Area 1} \times 0.6 \text{ W/ft}^2) + (\text{Retail Area 2} \times 0.6 \text{ W/ft}^2) + (\text{Retail Area 3} \times 1.4 \text{ W/ft}^2) + (\text{Retail Area 4} \times 2.5 \text{ W/ft}^2)$$

(Equation 4-11)

Where:

- | | | |
|---------------|---|---|
| Retail Area 1 | = | The floor area for all products not listed in Retail Area 2, 3 or 4. |
| Retail Area 2 | = | The floor area used for the sale of vehicles, sporting goods and small electronics. |
| Retail Area 3 | = | The floor area used for the sale of furniture, clothing, cosmetics and artwork. |
| Retail Area 4 | = | The floor area used for the sale of jewelry, crystal and china. |

Exception: Other merchandise categories are permitted to be included in Retail Areas 2 through 4, provided that justification documenting the need for additional lighting

power based on visual inspection, contrast, or other critical display is *approved* by the code official.

C405.5 Exterior lighting (Mandatory). Where the power for exterior lighting is supplied through the energy service to the building, all exterior lighting shall comply with Sections C405.5.1 and C405.5.2.

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

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

C405.5.2 Exterior building lighting power. The total exterior lighting power allowance for all exterior building applications is the sum of the base site allowance plus the individual allowances for areas that are to be illuminated and are permitted in Table C405.5.2(2) for the applicable lighting zone. Tradeoffs are allowed only among exterior lighting applications listed in Table C405.5.2(2), Tradable Surfaces section. The lighting zone for the building exterior is determined from Table C405.5.2(1) unless otherwise specified by the local jurisdiction.

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

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

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

Building Area Type	LPD (w/ft ²)
Automotive facility	0.64
Convention center	0.81
Court house	0.81
Dining: Bar lounge/leisure	0.79
Dining: Cafeteria/fast food	0.72
Dining: Family	0.71
Dormitory	0.46
Exercise center	0.67
Fire station	0.54
Gymnasium	0.75
Health care clinic	0.70
Hospital	0.84
Hotel	0.70
Library	0.94
Manufacturing facility	0.89
Motion picture theater	0.61
Multifamily	0.41
Museum	0.80
Office	0.66
Parking garage	0.16
Penitentiary	0.65
Performing arts theater	1.00
Police station	0.70
Post office	0.70
Religious building	0.80
Retail	1.01
School/university	0.70
Sports arena	0.62
Town hall	0.71
Transportation	0.56
Warehouse	0.40
Workshop	0.95

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

COMMON SPACE-BY-SPACE TYPES^a	LPD^d (w/ft²)
Atrium - First 40 feet in height ^c	0.02 per ft. ht.
Atrium - Above 40 feet in height ^c	0.03 + 0.02 per ft. ht.
Audience/seating area - Permanent	
In an auditorium	0.50
In a convention center	0.66
In a gymnasium	0.34
In an motion picture theater	0.91
In a penitentiary	0.22
In an performing arts theater	1.94
In a religious building	1.22
In a sports arena	0.34
Otherwise	0.34
Banking activity area	0.81
Breakroom (see Lounge/breakroom)	
Classroom/lecture/training	
In a penitentiary	1.07
Otherwise	1.00
Conference/meeting/multipurpose	0.98
Copy/print room	0.58
Corridor	
In a facility for the visually impaired (and not used primarily by the staff) ^b	0.74
In a hospital	0.63
In a manufacturing facility	0.33
Otherwise	0.53
Courtroom	1.38
Computer room	1.37
Dining area	
In a penitentiary	0.77
In a facility for the visually impaired (and not used primarily by the staff) ^b	1.52
In a bar/lounge or leisure dining	0.86
In a family dining area	0.71
Otherwise	0.52
Electrical/mechanical	0.76
Emergency vehicle garage	0.45
Food preparation	0.79
Guest room	0.38
Laboratory	
In or as a classrooms	1.02
Otherwise	1.45
Laundry/washing area	0.48

Loading dock, interior	0.38
Lobby ^c	
In a facility for the visually impaired (and not used primarily by the staff) ^b	1.44
For an elevator	0.51
In a hotel	0.85
In a motion picture theater	0.42
In a performing arts theater	1.60
Otherwise	0.72
Locker room	0.60
Lounge /breakroom	
In a health care facility	0.74
Otherwise	0.58
Office ^f	
Enclosed	0.89
Open plan	0.78
Parking area, interior	0.15
Pharmacy area	0.91
Restroom	
In a facility for the visually impaired (and not used primarily by the staff) ^b	0.97
Otherwise	0.78
Sales area	1.27
Seating area, general	0.43
Stairway (See space containing stairway)	
Stairwell	0.55
Storage room	0.50
Vehicular maintenance	0.54
Workshop	1.27

BUILDING SPECIFIC SPACE-BY-SPACE TYPES

BUILDING SPECIFIC SPACE-BY-SPACE TYPES^a	LPD^d (w/ft²)
Automotive (see Vehicular maintenance, above)	
Convention center - Exhibit space	1.16
Dormitory living quarters	0.30
Facility for the visually impaired ^b	
In a chapel (and not used primarily by the staff) ^b	1.77
In a recreation room (and not used primarily by the staff) ^b	1.93
Fire stations	
Engine rooms	0.45
Sleeping quarters	0.18
Gymnasium/fitness center	
In an exercise area	0.58
In a playing area	0.96

BUILDING SPECIFIC SPACE-BY-SPACE TYPES--Continued

BUILDING SPECIFIC SPACE-BY-SPACE TYPES^a	LPD^d (w/ft²)
Health care facility	
In an exam/treatment room	1.33
In an imaging room	1.06
In a medical supply room	0.59
In a nursery	0.70
In a nurse's station	0.57
In an operating room	1.51
In a patient room	0.50
In a physical therapy room	0.73
In a recovery room	0.92
Library ^f	
In a reading area	0.74
In the stacks	1.37
Manufacturing facility	
In a detailed manufacturing area	1.03
In an equipment room	0.59
In an extra high bay area (> 50-foot floor-ceiling height)	0.84
In a high bay area (25 - 50-foot floor-ceiling height)	0.98
In a low bay area (< 25-foot floor-ceiling height)	0.95
Museum	
In a general exhibition area	0.84
In a restoration room	0.82
Performing arts theater dressing/fitting room	0.32
Post office—Sorting area	0.75
Religious building	
In a fellowship hall	0.51
In a worship pulpit/choir area	1.22
Retail	
In a dressing/fitting room	0.57
In a mall concourse	0.88
Sports arena—Playing area	
For a Class 1 facility	2.41
For a Class 2 facility	1.54
For a Class 3 facility	0.96
For a Class 4 facility	0.58
Transportation	
In a baggage/carousel area	0.42
In an airport concourse	0.29
At a terminal ticket counter	0.64
Warehouse—Storage area	
For medium to bulky palletized items	0.46
For smaller, hand-carried items	0.76

For SI: 1 foot = 304.8 mm, 1 watt per square foot = 11 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. For spaces in which lighting is specified to be installed in addition to, and controlled separately from, the general lighting for the purpose of highlighting art or exhibits, provided that the additional lighting power shall not exceed 0.5 W/ft² of such spaces.
- d. The watts per square foot may be increased by 2 percent per foot of ceiling height above 20 feet, unless specifically directed otherwise by subsequent footnotes.
- e. Footnote d may not be used for these occupancy types.
- f. The watts per square foot may be increased by 2 percent per foot of ceiling height above 9 feet. Footnote d may not be used for these occupancy types.

TABLE C405.5.2(1)
EXTERIOR LIGHTING ZONES

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

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

		LIGHTING ZONES			
		Zone 1	Zone 2	Zone 3	Zone 4
Base Site Allowance (Base allowance is usable in tradable or nontradable surfaces.)		500 W	600 W	750 W	1300 W
Tradable Surfaces (Lighting power densities for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs and outdoor sales areas are tradable.)	Uncovered Parking Areas				
	Parking areas and drives	0.04 W/ft ²	0.06 W/ft ²	0.08 W/ft ²	0.10 W/ft ²
	Building Grounds				
	Walkways less than 10 feet wide	0.7 W/linear foot	0.7 W/linear foot	0.8 W/linear foot	1.0 W/linear foot
	Walkways 10 feet wide or greater, plaza areas special feature areas	0.14 W/ft ²	0.14 W/ft ²	0.16 W/ft ²	0.2 W/ft ²
	Stairways	0.75 W/ft ²	1.0 W/ft ²	1.0 W/ft ²	1.0 W/ft ²
	Pedestrian tunnels	0.15 W/ft ²	0.15 W/ft ²	0.2 W/ft ²	0.3 W/ft ²
	Building Entrances and Exits				
	Main entries	20 W/linear foot of door width	20 W/linear foot of door width	30 W/linear foot of door width	30 W/linear foot of door width
	Other doors	20 W/linear foot of door width	20 W/linear foot of door width	20 W/linear foot of door width	20 W/linear foot of door width
	Entry canopies	0.25 W/ft ²	0.25 W/ft ²	0.4 W/ft ²	0.4 W/ft ²
	Sales Canopies				
	Free-standing and attached	0.6 W/ft ²	0.6 W/ft ²	0.8 W/ft ²	1.0 W/ft ²
	Outdoor Sales				
	Open areas (including vehicle sales lots)	0.25 W/ ft ²	0.25 W/ ft ²	0.5 W/ ft ²	0.7 W/ ft ²
	Street frontage for vehicle sales lots in addition to "open area" allowance	No allowance	10 W/linear foot	10 W/linear foot	30 W/linear foot
Nontradable Surfaces (Lighting power density calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the "Tradable Surfaces" section of this table.)	Building facades	No allowance	0.075 W/ft ² of gross above-grade wall area	0.113 W/ft ² of gross above-grade wall area	0.150 W/ft ² of gross above-grade wall area
	Automated teller machines and night depositories	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location	270 W per location plus 90 W per additional ATM per location
	Entrances and gatehouse inspection stations at guarded facilities	0.75 W/ft ² of covered and uncovered area	0.75 W/ft ² of covered and uncovered area	0.75 W/ft ² of covered and uncovered area	0.75 W/ft ² of covered and uncovered area
	Loading areas for law enforcement, fire, ambulance and other emergency service vehicles	0.5 W/ft ² of covered and uncovered area	0.5 W/ft ² of covered and uncovered area	0.5 W/ft ² of covered and uncovered area	0.5 W/ft ² of covered and uncovered area
	Drive-up windows/doors	400 W per drive-through	400 W per drive-through	400 W per drive-through	400 W per drive-through
	Parking near 24-hour retail entrances	800 W per main entry	800 W per main entry	800 W per main entry	800 W per main entry

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m².

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

Exception: The following transformers are exempt:

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

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

Single Phase Transformers		Three Phase Transformers	
kVA ^a	Efficiency (%) ^b	kVA ^a	Efficiency (%) ^b
15	97.7	15	97.0
25	98.0	30	97.5
37.5	98.2	45	97.7
50	98.3	75	98.0
75	98.5	112.5	98.2
100	98.6	150	98.3
167	98.7	225	98.5
250	98.8	300	98.6
333	98.9	500	98.7
		750	98.8
		1000	98.9

a. kiloVolt-Amp rating.

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

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

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

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

Exceptions:

1. Motors that are an integral part of specialized process equipment.
2. Where the motor is integral to a listed piece of equipment for which no complying motor has been approved.
3. Motors used as a component of the equipment meeting the minimum efficiency requirements of Section C403.2.3 and Tables C403.2.3(1) through C403.2.3(10), provided that the motor input is included when determining the equipment efficiency.
4. Motors in the airstream within fan coils and terminal units that operate only when providing heating to the space served.
5. Fan motors that are not covered by Tables C405.8(1) through C405.8(4) and are used to power heat recovery ventilators, energy recovery ventilators, or local exhaust fans in Group R subject to the high efficacy requirements of Section C403.2.11.4.
6. Domestic clothes dryer booster fans, range hood exhaust fans, and domestic range booster fans that operate intermittently.
7. Radon and contaminated soil exhaust fans.
8. Group R heat recovery ventilator and energy recovery ventilator fans that are less than 400 cfm.

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

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

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

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

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

NR - No requirement.

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

TABLE C405.8(3)
MINIMUM AVERAGE FULL LOAD EFFICIENCY FOR
POLYPHASE SMALL ELECTRIC MOTORS^a

NUMBER OF POLES ►	OPEN MOTORS		
	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 CFR 431.

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

NUMBER OF POLES ►	OPEN MOTORS		
	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 CFR. 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 de-energize ventilation fans and lighting systems when the elevator is stopped, unoccupied and with its doors closed for over 15 minutes.

C405.9.2 Escalators and moving walks. Escalators and moving walks shall comply with ASME A17.1/CSA B44 and shall have automatic controls configured to reduce speed to the minimum permitted speed in accordance with ASME A17.1/CSA B44 or applicable local code when not conveying passengers.

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

C405.9.3 Regenerative drive. An escalators designed either for one-way down operation only or for reversible operation shall have a variable frequency regenerative drive that supplies electrical energy to the building electrical system when the escalator is loaded with passengers whose combined weight exceeds 750 pounds.

C405.10 Controlled receptacles. At least 50 percent of all 125 volt 15- and 20-ampere receptacles installed in private offices, open offices, conference rooms, rooms used primarily for printing and/or copying functions, break rooms, individual workstations and classrooms, including those installed in modular partitions and modular office workstation systems, shall be controlled as required by this section. In rooms larger than 200 square feet (19 m²), a controlled receptacle shall be located within 72 inches (1.8 m) of each uncontrolled receptacle. Controlled receptacles shall be visibly differentiated from standard receptacles and shall be controlled by one of the following automatic control devices:

1. An occupant sensor that turns receptacle power off when no occupants have been detected for a maximum of 20 minutes.
2. A time-of-day operated control device that turns receptacle power off at specific programmed times and can be programmed separately for each day of the week. The control device shall be configured to provide an independent schedule for each portion of the building not to exceed 5,000 square feet (465 m²) and not to exceed one full floor. The device shall be capable of being overridden for periods of up to two hours by a timer accessible to occupants. Any individual override switch shall control the controlled receptacles for a maximum area of 5,000 square feet (465 m²). Override switches for controlled receptacles are permitted to control the lighting within the same area.

Exception: Receptacles designated for specific equipment requiring 24-hour operation, for building maintenance functions, or for specific safety or security equipment are not required to be controlled by an automatic control device and are not required to be located within 72 inches of a controlled receptacle.

C405.11 Electrical power and lighting systems commissioning and completion requirements. Electrical power and lighting systems shall be commissioned and completed in accordance with Section C408.

C405.12 Reserved.

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

SECTION C406 ADDITIONAL EFFICIENCY PACKAGE OPTIONS

C406.1 Requirements. Buildings shall comply with no less than two of the following:

1. More efficient HVAC performance in accordance with Section C406.2.
2. Reduced lighting power in accordance with Section C406.3.
3. Enhanced lighting controls in accordance with Section C406.4.
4. On-site supply of renewable energy in accordance with Section C406.5.
5. Provision of a dedicated outdoor air system for certain HVAC equipment in accordance with Section C406.6.
6. High-efficiency service water heating in accordance with Section C406.7.
7. Enhanced envelope performance in accordance with Section C406.8.
8. Reduced air infiltration in accordance with Section C406.9.

C406.1.1 Tenant spaces. Tenant spaces shall comply with Section C406.2, C406.3, C406.4, C406.6 or C406.7, where applicable. Where an entire building complies with Section C406.5, C406.8 or C406.9, tenant spaces within the building shall be deemed to comply with this section.

C406.2 More efficient HVAC equipment and fan performance. Buildings shall comply with Sections C406.2.1 through C406.2.3.

C406.2.1 HVAC system selection. No less than 90 percent of the total HVAC capacity serving the building shall be provided by equipment that is listed in Tables C403.2.3(1) through C403.2.3(9) or a combination thereof.

Exception: Air-to-water heat pumps or heat recovery chillers are also permitted to be utilized for Option C406.2,

C406.2.2 Minimum equipment efficiency. Equipment shall exceed the minimum efficiency requirements listed in Tables C403.2.3(1) through C403.2.3(9) by 15 percent, in addition to the requirements of Section C403. Where multiple performance requirements are provided, the equipment shall exceed all requirements by 15 percent.

Exception: Equipment that is larger than the maximum capacity range indicated in Tables C403.2.3(1) through C403.2.3(9) shall utilize the values listed for the largest capacity equipment for the associated equipment type shown in the table.

C406.2.3 Minimum fan efficiency. Stand-alone supply, return and exhaust fans designed for operating with motors over 750 watts (1 hp) shall have an energy efficiency classification of not less than FEG 71 as defined in AMCA 205. The total efficiency of the fan at the design point of operation shall be within 10 percentage points of either the maximum total efficiency of the fan or the static efficiency of the fan.

C406.3 Reduced lighting power. Buildings shall comply with Sections C406.3.1 and, where applicable, C406.3.2.

C406.3.1 Reduced lighting power density. The total interior lighting power (watts) of the building shall be 75 percent or less of the lighting power values specified in Table C405.4.2(1) times the floor area for the building types, or by using 75 percent of the interior lighting power allowance calculated by the Space-by-Space Method in Section C405.4.2.

C406.3.2 Lamp fraction. Not less than 95 percent of the interior lighting power (watts) from lamps in permanently installed light fixtures in dwelling units and sleeping units shall be provided by lamps with a minimum efficacy of 60 lumens per watt.

C406.4 Enhanced digital lighting controls. Interior lighting shall be located, scheduled and operated in accordance with Section C405.2 and no less than 90 percent of the total installed interior lighting power shall be configured with the following enhanced control functions.

1. Luminaires shall be configured for continuous dimming.
2. Each luminaire shall be individually addressed.
Exceptions:
 1. Multiple luminaires mounted on no more than 12 linear feet of a single lighting track and addressed as a single luminaire.
 2. Multiple linear luminaires that are ganged together to create the appearance of a single longer fixture and addressed as a single luminaire, where the total length of the combined luminaires is not more than 12 feet.
3. Not more than eight luminaires within a *daylight zone* are permitted to be controlled by a single *daylight responsive control*.
4. Luminaires shall be controlled by a digital control system configured with the following capabilities:
 - 4.1. Scheduling and illumination levels of individual luminaires and groups of luminaires are capable of being reconfigured through the system.
 - 4.2. Load shedding.

- 4.3. In open and enclosed offices, the illumination level of overhead general illumination luminaires are configured to be individually adjusted by occupants.
- 4.4. Occupancy sensors and daylight responsive controls are capable of being reconfigured through the system.
5. Construction documents shall include submittal of a Sequence of Operations, including a specification outlining each of the functions required by this section.

C406.5 On-site renewable energy. Buildings shall be provided with on-site renewable energy systems with an annual energy production per square foot of conditioned floor area of the building of not less than the value specified in Table C406.5.

**TABLE C406.5
ON-SITE RENEWABLE ENERGY
SYSTEM RATING
(PER SQUARE FOOT)**

Building Area Type	kBtu/Year	kWh/Year
Assembly	1.8	0.53
Dining	10.7	3.14
Hospital	3.6	1.06
Hotel/Motel	2.0	0.59
Multi-family residential	0.50	0.15
Office	0.82	0.24
Other	2.02	0.59
Retail	1.31	0.38
School/University	1.17	0.34
Supermarket	5.0	1.47
Warehouse	0.43	0.13

C406.6 Dedicated outdoor air system (DOAS). Not less than 90% of the building conditioned floor area, excluding floor area of unoccupied spaces that do not require ventilation per the *International Mechanical Code*, shall be served by DOAS installed in accordance with Section C403.6. This option is available to both buildings subject to and not subject to the prescriptive requirements of Section C403.6.

C406.7 Reduced energy use in service water heating. Buildings shall comply with Sections C406.7.1 and C406.7.2.

C406.7.1 Building type. Not less than 90 percent of the conditioned floor area shall be of the following types:

1. Group R-1: Boarding houses, hotels or motels.
2. Group I-2: Hospitals, psychiatric hospitals and nursing homes.
3. Group A-2: Restaurants and banquet halls or buildings containing food preparation areas.

4. Group F: Laundries.
5. Group R-2: Buildings with residential occupancies.
6. Group A-3: Health clubs and spas.
7. Buildings with a service hot water load of 10 percent or more of total building energy loads, as shown with an energy analysis as described in Section C407.

C406.7.2 Load fraction. Not less than 60 percent of the annual building service hot water heating energy use, or not less than 100 percent of the annual building service hot water heating energy use in buildings subject to the requirements of Section C403.5.4, shall be provided by one or more of the following:

1. Service hot water system delivering heating requirements using heat pump technology with a minimum COP of 3.0.
2. Waste heat recovery from service hot water, heat recovery chillers, building equipment, process equipment, a combined heat and power system, or other *approved* system.
3. Solar water-heating systems.

C406.8 Enhanced envelope performance. The Proposed Total Envelope UA of the building thermal envelope shall be 15 percent lower than the Allowed Total UA for a building of identical configuration and fenestration area in accordance with Section C402.1.5 and Equation 4-2.

C406.9 Reduced air infiltration. Air infiltration shall be verified by whole building pressurization testing conducted in accordance with ASTM E779 or ASTM E1827 by an independent third party. The measured air leakage rate of the *building envelope* shall not exceed 0.25 cfm/ft² (2.0 L/s•m²) under a pressure differential of 0.3 in. water (75 Pa), with the calculated surface area being the sum of the above and below grade building envelope. A report that includes the tested surface area, floor area, air by volume, stories above grade, and leakage rates shall be submitted to the code official and the building owner.

Exception: Where the *conditioned floor area* of the building is not less than 250,000 ft² (25,000 m²), air leakage testing shall be permitted to be conducted on representative above grade sections of the building provided the conditioned floor area of tested areas is no less than 25 percent of the conditioned floor area of the building and are tested in accordance with this section.

SECTION C407 TOTAL BUILDING PERFORMANCE

C407.1 Scope. This section establishes criteria for compliance using total building performance. All systems and loads shall be included in determining the total building performance including, but not limited to: Heating systems, cooling systems, service water heating, fan systems, lighting power, receptacle loads and process loads.

C407.2 Mandatory requirements. Compliance with this section requires that the criteria of Sections C402.5, C403.2, C404 and C405 be met.

The building permit application for projects utilizing this method shall include in one submittal all building and mechanical drawings and all information necessary to verify that the building envelope and mechanical design for the project corresponds with the annual energy analysis. If credit is proposed to be taken for lighting energy savings, then an electrical permit application shall also be submitted and approved prior to the issuance of the building permit. If credit is proposed to be taken for energy savings from other components, then the corresponding permit application (e.g., plumbing, boiler, etc.) shall also be submitted and approved prior to the building permit application. Otherwise, components of the project that would not be approved as part of a building permit application shall be modeled the same in both the proposed building and the *standard reference design* and shall comply with the requirements of this code.

C407.3 Performance-based compliance. Compliance based on total building performance requires that a proposed building (*proposed design*) be shown to have an annual energy consumption based on site energy expressed in Btu and Btu per square foot of *conditioned floor area* that complies with one of the following three options:

1. Is less than or equal to 87 percent of the annual energy consumption of the *standard reference design*.
2. Is less than or equal to 90 percent of the annual energy consumption of the *standard reference design* and the project complies with one additional energy efficiency package option in Section C406. The standard reference design shall include the selected Section C406 additional efficiency package option unless the option selected is DOAS per Section C406.6. For office, retail, education, libraries and fire stations that comply with the DOAS requirements in Section C403.6 with or without exceptions, the standard reference design shall select the HVAC system per Table C407.5.1(2). Other buildings occupancy types that

comply with the DOAS requirements in Section C403.6 shall select the standard reference design for the HVAC system from Table C407.5.1(3).

3. Is less than or equal to 93 percent of the annual energy consumption of the standard reference design and the project complies with two additional efficiency package options in Section C406. The standard reference design shall include the selected Section C406 additional efficiency package option unless the option selected is DOAS per Section C406.6. For office, retail, education, libraries and fire stations that comply with the DOAS requirements in Section C403.6 with or without exceptions, the standard reference design shall select the HVAC system per Table C407.5.1(2). Other buildings occupancy types that comply with the DOAS requirements in Section C403.6 shall select the standard reference design for the HVAC system from Table C407.5.1(3).

C407.4 Documentation. Documentation verifying that the methods and accuracy of compliance software tools conform to the provisions of this section shall be provided to the *code official*.

C407.4.1 Compliance report. Building permit submittals shall include a report that documents that the *proposed design* has annual energy consumption less than or equal to the annual energy consumption of the *standard reference design*. The compliance documentation shall include the following information:

1. Address of the building;
2. An inspection checklist documenting the building component characteristics of the *proposed design* as listed in Table C407.5.1(1). The inspection checklist shall show the estimated annual energy consumption for both the *standard reference design* and the *proposed design*;
3. Name of individual completing the compliance report; and
4. Name and version of the compliance software tool.

C407.4.2 Additional documentation. The *code official* shall be permitted to require the following documents:

1. Documentation of the building component characteristics of the *standard reference design*;
2. Thermal zoning diagrams consisting of floor plans showing the thermal zoning scheme for *standard reference design* and *proposed design*;
3. Input and output report(s) from the energy analysis simulation program containing the complete input and output files, as applicable.

The output file shall include energy use totals and energy use by energy source and end-use served, total hours that space conditioning loads are not met and any errors or warning messages generated by the simulation tool as applicable;

4. An explanation of any error or warning messages appearing in the simulation tool output; and
5. A certification signed by the builder providing the building component characteristics of the *proposed design* as given in Table C407.5.1(1).

C407.5 Calculation procedure. Except as specified by this section, the *standard reference design* and *proposed design* shall be configured and analyzed using identical methods and techniques.

C407.5.1 Building specifications. The *standard reference design* and *proposed design* shall be configured and analyzed as specified by Table C407.5.1(1). Table C407.5.1(1) shall include by reference all notes contained in Table C402.1.4.

C407.5.2 Thermal blocks. The *standard reference design* and *proposed design* shall be analyzed using identical thermal blocks as specified in Section C407.5.2.1, C407.5.2.2 or C407.5.2.3.

C407.5.2.1 HVAC zones designed. Where HVAC *zones* are defined on HVAC design drawings, each HVAC *zone* shall be modeled as a separate thermal block.

Exception: Different HVAC *zones* shall be allowed to be combined to create a single thermal block or identical thermal blocks to which multipliers are applied provided:

1. The space use classification is the same throughout the thermal block.
2. All HVAC *zones* in the thermal block that are adjacent to glazed exterior walls face the same orientation or their orientations are within 45 degrees (0.79 rad) of each other.
3. All of the *zones* are served by the same HVAC system or by the same kind of HVAC system.

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

1. Separate thermal blocks shall be assumed for interior and perimeter spaces. Interior spaces shall be those located more than 15 feet (4572 mm) from an exterior wall. Perimeter spaces shall be those located closer than 15 feet (4572 mm) from an *exterior wall*.

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

C407.5.2.3 Multifamily residential buildings.

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

C407.5.3 Equipment efficiencies. All HVAC equipment in the standard reference design shall be modeled at the minimum efficiency levels, both part load and full load, in accordance with Section C403.2.3. Chillers shall use Path A efficiencies as shown in Table C403.2.3(7). Where efficiency ratings include supply fan energy, the efficiency rating shall be adjusted to remove the supply fan energy. For Baseline Systems HVAC Systems 3, 4, 6, 8, 9, 10 and 11, calculate the minimum COP_{nfcooling} and COP_{nfheating} using the equation for the applicable performance rating as indicated in Tables C403.2.3(1) through C403.2.3(3). Where a full- and part-load efficiency rating is provided in Tables C403.2.3(1) through C403.2.3(3), use Equation 4-12.

(Equation 4-12)

$$\text{COP}_{\text{nfcooling}} = 7.84\text{E-}8 \times \text{EER} \times Q + 0.338 \times \text{EER}$$

$$\text{COP}_{\text{nfcooling}} = -0.0076 \times \text{SEER}^2 + 0.3796 \times \text{SEER}$$

$$\text{COP}_{\text{nfheating}} = 1.48\text{E-}7 \times \text{COP}_{47} \times Q + 1.062 \times \text{COP}_{47}$$

(applies to heat pump heating efficiency only)

$$\text{COP}_{\text{nfheating}} = -0.0296 \times \text{HSPF}^2 + 0.7134 \times \text{HSPF}$$

Where:

COP_{nfcooling} = The packaged HVAC equipment cooling energy efficiency

COP_{nfheating} = The packaged HVAC equipment heating energy efficiency

Q = The AHRI-rated cooling capacity in Btu/h.

EER, SEER, COP and HSPF shall be at AHRI test conditions. Fan energy shall be modeled separately according to Table C407.5.1(1).

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

Building Component Characteristics	Standard Reference Design	Proposed Design
Space use classification	Same as proposed	The space use classification shall be chosen in accordance with Table C405.4.2 for all areas of the building covered by this permit. Where the space use classification for a building is not known, the building shall be categorized as an office building.
Roofs	Type: Insulation entirely above deck Gross area: Same as proposed <i>U</i> -factor: From Table C402.1.4 Solar absorptance: 0.75 Emittance: 0.90	As proposed As proposed As proposed As proposed As proposed
Walls, above-grade	Type: Mass wall if proposed wall is mass; otherwise steel-framed wall Gross area: Same as proposed <i>U</i> -factor: From Table C402.1.4 Solar absorptance: 0.75 Emittance: 0.90	As proposed As proposed As proposed As proposed As proposed
Walls, below-grade	Type: Mass wall Gross area: Same as proposed <i>U</i> -Factor: From Table C402.1.4 with insulation layer on interior side of walls	As proposed As proposed As proposed
Floors, above-grade	Type: Joist/framed floor Gross area: Same as proposed <i>U</i> -factor: From Table C402.1.4	As proposed As proposed As proposed
Floors, slab-on-grade	Type: Unheated <i>F</i> -factor: From Table C402.1.4	As proposed As proposed
Opaque Doors	Type: Swinging Area: Same as proposed <i>U</i> -factor: From Table C402.1.4	As proposed As proposed As proposed
Vertical Fenestration Other than opaque doors	Area 1. The proposed vertical fenestration area; where the proposed vertical fenestration area is less than 30 percent of above-grade wall area. 2. 30 percent of above-grade wall area; where the proposed vertical fenestration area is 30 percent or more of the above-grade wall area. <i>U</i> -factor: From Table C402.4 for the same framing material as proposed SHGC: From Table C402.4 except that for climates with no requirement (NR) SHGC = 0.40 shall be used External shading and PF: None	As proposed As proposed As proposed As proposed

Building Component Characteristics	Standard Reference Design	Proposed Design
Skylights	<p>Area</p> <ol style="list-style-type: none"> 1. The proposed skylight area; where the proposed skylight area is less than 3 percent of gross area of roof assembly. 2. 3 percent of gross area of roof assembly; where the proposed skylight area is 3 percent or more of gross area of roof assembly. <p><i>U</i>-factor: From Table C402.4 SHGC: From Table C402.4 except that for climates with no requirement (NR) SHGC = 0.40 shall be used</p>	<p>As proposed</p> <p>As proposed</p> <p>As proposed</p>
Air Leakage	<p>For infiltration, the air leakage rate as determined below shall be modeled at 100% when the building fan system is off, and at 25% when the building fan system is on, unless otherwise approved by the building official for unusually pressurized buildings. Per PNNL Report 18898, <i>Infiltration Modeling Guidelines for Commercial Building Energy Analysis</i>, the building air leakage rates as determined in accordance with Section C402.5.1.2 at 0.30 in. w.g. (75 Pa) shall be converted for modeling in annual energy analysis programs by being multiplied by 0.112 unless other multipliers are approved by the building official (e.g., a tested air leakage of 0.40 cfm/ft² of total building envelope area at 0.30 in. w.g. (75 Pa) would be calculated at 0.045 cfm/ft² of building envelope area). The calculated infiltration rate shall be normalized to the input required by the modeling software.</p>	<p>The Proposed Design air-leakage shall be the same as the Standard Design.</p>
Lighting, interior	<p>The interior lighting power shall be determined in accordance with Table C405.4.2. As proposed when the occupancy of the space is not known.</p> <p>Automatic lighting controls (e.g., programmable controls or automatic controls for daylight utilization) shall be modeled in <i>the standard reference design</i> as required by Section C405.</p>	<p>As proposed; where the occupancy of the space is not known, the lighting power density shall be based on the space classification as offices in Table C405.4.2(1).</p>
Lighting, exterior	<p>The lighting power shall be determined in accordance with Table C405.5.2(2). Areas and dimensions of tradable and nontradable surfaces shall be the same as proposed.</p>	<p>As proposed</p>
Internal gains	<p>Same as proposed</p>	<p>Receptacle, motor and process loads shall be modeled and estimated based on the space use classification. All end-use load components within and associated with the building shall be modeled to include, but not be limited to, the following: Exhaust fans, parking garage ventilation fans, exterior building lighting, swimming pool heaters and pumps, elevators, escalators, refrigeration equipment and cooking equipment.</p>

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

Building Component Characteristics	Standard Reference Design	Proposed Design
Schedules	Same as proposed	Operating schedules shall include hourly profiles for daily operation and shall account for variations between weekdays, weekends, holidays and any seasonal operation. Schedules shall model the time-dependent variations in occupancy, illumination, receptacle loads, thermostat settings, mechanical ventilation, HVAC equipment availability, service hot water usage and any process loads. The schedules shall be typical of the proposed building type as determined by the designer and approved by the jurisdiction.
Outdoor airflow rates	Same as proposed, or no higher than those allowed by Section C403.2.6 (without exception 1), whichever is less. Demand Control Ventilation: Shall be modeled as required by Section C403.6 including reduction to the minimum ventilation rate when unoccupied.	As proposed, in accordance with Section C403.2.6. As proposed
Heating systems	Fuel type: Same as proposed design Equipment type ^a : From Tables C407.5.1(2), C407.5.1(3) and C407.5.1(4) Efficiency: From Tables C403.2.3(2), C403.2.3(3), C403.2.3(4) and C403.2.3(5) Preheat coils: For HVAC system numbers 1 through 4, a preheat coil shall be modeled controlled to a fixed setpoint 20°F less than the design room heating temperature setpoint. Capacity ^b : Sized proportionally to the capacities in the proposed design based on sizing runs, i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be the same for both the proposed design and <i>standard reference design</i> , and shall be established such that no smaller number of unmet heating load hours and no larger heating capacity safety factors are provided than in the proposed design. Weather conditions used in sizing runs to determine <i>standard reference design</i> equipment capacities may be based either on hourly historical weather files containing typical peak conditions or on design days developed using 99.6% heating design temperatures and 1% dry-bulb and 1% wet-bulb cooling design temperatures.	As proposed As proposed As proposed As proposed

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

Building Component Characteristics	Standard Reference Design	Proposed Design
Cooling systems	Fuel type: Same as proposed design	As proposed
	Equipment type ^c : From Tables C407.5.1(2), C407.5.1(3) and C407.5.1(4)	As proposed
	Efficiency: From Tables C403.2.3(1), C403.2.3(2) and C403.2.3(3). Chillers shall use Path A efficiency.	As proposed
	Capacity ^b : Sized proportionally to the capacities in the proposed design based on sizing runs, i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be the same for both the proposed design and standard reference design, and shall be established such that no smaller number of unmet cooling load hours and no larger cooling capacity safety factors are provided than in the proposed design.	As proposed
	Economizer ^d : In accordance with Section C403.3. The high-limit shutoff shall be a dry-bulb switch with a setpoint as determined by Table C403.3.3.3.	As proposed
Energy recovery	<i>Standard reference design</i> systems shall be modeled where required in Section C403.5.	As proposed
Fan systems	<p>Airflow rate: System design supply airflow rates for the <i>standard reference design</i> shall be based on a supply-air-to-room-air temperature difference of 20°F or the required ventilation air or makeup air, whichever is greater. If return or relief fans are specified in the proposed design, the <i>standard reference design</i> shall also be modeled with fans serving the same functions and sized for the <i>standard reference design</i> system supply fan air quantity less the minimum outdoor air, or 90% of the supply fan air quantity, whichever is larger.</p> <p>Motor brake horsepower: System fan electrical power for supply, return, exhaust, and relief (excluding power to fan-powered VAV boxes) shall be calculated using the following formulas:</p> <p>For systems 5, 7, 8 and 10 in Table C407.5.1(4), $P_{fan} = CFM_s \times 0.3$</p> <p>For all other systems, including DOAS, $P_{fan} = bhp \times 746 / \text{Fan Motor Efficiency}$</p> <p>Where: P_{fan} = Electric power to fan motor (watts) bhp = Brake horsepower of <i>standard reference design</i> fan motor from Table C403.2.12.1(1) – Option 2 Fan motor = The efficiency from Tables C405.8(1) through C405.8(4) for the efficiency next motor size greater than the bhp using the enclosed motor at 1800 rpm CFM_s = The <i>standard reference design</i> system maximum design supply fan airflow rate in cfm</p>	<p>As proposed</p> <p>As proposed</p>
On-site renewable energy	No on-site renewable energy shall be modeled in the <i>standard reference design</i> .	As proposed.

Building Component Characteristics	Standard Reference Design	Proposed Design
Shading from adjacent structures/terrain	Same as proposed.	For the standard reference design and the proposed building, shading by permanent structures and terrain shall be taken into account for computing energy consumption whether or not these features are located on the building site. A permanent fixture is one that is likely to remain for the life of the proposed design.
Service water heating	<p>Fuel type: Same as proposed</p> <p>Efficiency: From Table C404.2 and per Section C404.2.1</p> <p>Capacity: Same as proposed</p> <p>Demand: Same as proposed</p> <p>Where no service water hot water system exists or is specified in the proposed design, no service hot water heating shall be modeled.</p> <p>Drain water heat recovery: Not required.</p>	<p>As proposed</p> <p>As proposed</p> <p>Service hot-water energy consumption shall be calculated explicitly based upon the volume of service hot water required and the entering makeup water and the leaving service hot water temperatures. Entering water temperatures shall be estimated based upon the location. Leaving temperatures shall be based upon the end-use requirements. Service water loads and usage shall be the same for both the <i>standard reference design</i> and the proposed design and shall be documented by the calculation procedures recommended by the manufacturer's specifications or generally accepted engineering methods.</p> <p>As proposed</p> <p>As proposed. Drain water heat recovery modeling shall take into account manufacturer's rated efficiencies per C404.9, quantity of connected drains, the proportional flow rates between the waste stream and the preheated stream. Reductions in service water heating energy use for drain water heat recovery shall be demonstrated by calculations.</p>

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TABLE C407.5.1(2)
HVAC SYSTEMS MAP FOR BUILDINGS GOVERNED BY SECTION C403.6^d

CONDENSER COOLING SOURCE ^a	HEATING SYSTEM CLASSIFICATION ^b	STANDARD REFERENCE DESIGN HVAC SYSTEM TYPE
Water/ground	Electric resistance	System 5
	Heat pump	System 6
	Fossil fuel	System 7
Air/none	Electric resistance	System 9
	Heat pump	System 9
	Fossil fuel	System 11

- Select "water/ground" if the proposed design system condenser is water or evaporatively cooled; select "air/none" if the condenser is air cooled. Closed-circuit dry coolers shall be considered air cooled. Systems utilizing district cooling shall be treated as if the condenser water type were "water." If no mechanical cooling is specified or the mechanical cooling system in the proposed design does not require heat rejection, the system shall be treated as if the condenser water type were "Air." For proposed designs with ground-source or groundwater-source heat pumps, the standard reference design HVAC system shall be water-source heat pump (System 6).
- Systems utilizing district heating (steam or hot water) or district cooling and systems with no heating capability shall be treated as if the heating system type were "fossil fuel" for the purpose of Standard Reference Design HVAC system selection. Otherwise, select the path that corresponds to the proposed design heat source: Electric resistance, heat pump (including air source and water source), or fuel fired. For systems with mixed fuel heating sources, the system or systems that use the secondary heating source type (the one with the smallest total installed output capacity for the spaces served by the system) shall be modeled identically in the standard reference design and the primary heating source type shall be used to determine *standard reference design* HVAC system type.
- Reserved.
- This table covers those building types required by Section C403.6 to install Dedicated Outdoor Air Systems: office, retail, education, libraries and fire stations.

TABLE C407.5.1(3)
HVAC SYSTEMS MAP

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

- Select "water/ground" if the proposed design system condenser is water or evaporatively cooled; select "air/none" if the condenser is air cooled. Closed-circuit dry coolers shall be considered air cooled. Systems utilizing district cooling shall be treated as if the condenser water type were "water." If no mechanical cooling is specified or the mechanical cooling system in the proposed design does not require heat rejection, the system shall be treated as if the condenser water type were "Air." For proposed designs with ground-source or groundwater-source heat pumps, the standard reference design HVAC system shall be water-source heat pump (System 6).
- Select the path that corresponds to the proposed design heat source: electric resistance, heat pump (including air source and water source), or fuel fired. Systems utilizing district heating (steam or hot water) and systems with no heating capability shall be treated as if the heating system type were "fossil fuel." For systems with mixed fuel heating sources, the system or systems that use the secondary heating source type (the one with the smallest total installed output capacity for the spaces served by the system) shall be modeled identically in the standard reference design and the primary heating source type shall be used to determine *standard reference design* HVAC system type.
- Select the standard reference design HVAC system category: The system under "single-zone residential system" shall be selected if the HVAC system in the proposed design is a single-zone system and serves a residential space. The system under "single-zone nonresidential system" shall be selected if the HVAC system in the proposed design is a single-zone system and serves other than residential spaces. The system under "all other" shall be selected for all other cases.

TABLE C407.5.1(4)
SPECIFICATIONS FOR THE STANDARD REFERENCE DESIGN HVAC SYSTEM DESCRIPTIONS

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

For SI: 1 foot = 304.8 mm, 1 cfm/ft² = 0.0004719, 1 Btu/h = 0.293/W, °C = [(°F) -32]/1.8].

- a. **VAV with parallel boxes:** Fans in parallel VAV fan-powered boxes shall be sized for 50 percent of the peak design flow rate and shall be modeled with 0.35 W/cfm fan power. Minimum volume setpoints for fan-powered boxes shall be equal to the minimum rate for the space required for ventilation consistent with Section C403.4.4, Exception 4. Supply air temperature shall be reset based on zone demand. Design airflow rates shall be sized for the maximum reset supply air temperature. The air temperature for cooling shall be reset higher by 5°F under the minimum cooling load conditions.
- b. **VAV with reheat:** Minimum volume setpoints for VAV reheat boxes shall be 0.4 cfm/ft² of floor area. Supply air temperature shall be reset based on zone demand. Design airflow rates shall be sized for the maximum reset supply air temperature. The air temperature for cooling shall be reset higher by 5°F under the minimum cooling conditions.
- c. **Direct expansion:** The fuel type for the cooling system shall match that of the cooling system in the proposed design.
- d. **VAV:** When the proposed design system has a supply, return or relief fan motor horsepower (hp) requiring variable flow controls as required by Section C403.2.11.5, the corresponding fan in the VAV system of the standard reference design shall be modeled assuming a variable speed drive. For smaller fans, a forward-curved centrifugal fan with inlet vanes shall be modeled. If the proposed design's system has a direct digital control system at the zone level, static pressure setpoint reset based on zone requirements in accordance with Section C403.4.1 shall be modeled.
- e. **Chilled water:** For systems using purchased chilled water, the chillers are not explicitly modeled. Otherwise, the standard reference design's chiller plant shall be modeled with chillers having the number as indicated in Table C407.5.1(5) as a function of standard reference building chiller plant load and type as indicated in Table C407.5.1(6) as a function of individual chiller load. Where chiller fuel source is mixed, the system in the standard reference design shall have chillers with the same fuel types and with capacities having the same proportional capacity as the proposed design's chillers for each fuel type. Chilled water supply temperature shall be modeled at 44°F design supply temperature and 56°F return temperature. Piping losses shall not be modeled in either building model. Chilled water supply water temperature shall be reset in accordance with Section C403.4.2.4. Pump system power for each pumping system shall be the same as the proposed design; if the proposed design has no chilled water pumps, the standard reference design pump power shall be 22 W/gpm (equal to a pump operating against a 75-foot head, 65-percent combined impeller and motor efficiency). The chilled water system shall be modeled as primary-only variable flow with flow maintained at the design rate through each chiller using a bypass. Chilled water pumps shall be modeled as riding the pump curve or with variable-speed drives when required in Section C403.4.2.4. The heat rejection device shall be an axial fan cooling tower with variable speed fans if required in Section C403.4.3. Condenser water design supply temperature shall be 85°F or 10°F approach to design wet-bulb temperature, whichever is lower, with a design temperature rise of 10°F. The tower shall be controlled to maintain a 70°F leaving water temperature where weather permits, floating up to leaving water temperature at design conditions. Pump system power for each pumping system shall be the same as the proposed design; if the proposed design has no condenser water pumps, the standard reference design pump power shall be 19 W/gpm (equal to a pump operating against a 60-foot head, 60-percent combined impeller and motor efficiency). Each chiller shall be modeled with separate condenser water and chilled water pumps interlocked to operate with the associated chiller.
- f. **Fossil fuel boiler:** For systems using purchased hot water or steam, the boilers are not explicitly modeled. Otherwise, the boiler plant shall use the same fuel as the proposed design and shall be natural draft. The standard reference design boiler plant shall be modeled with a single boiler if the standard reference design plant load is 600,000 Btu/h and less and with two equally sized boilers for plant capacities exceeding 600,000 Btu/h. Boilers shall be staged as required by the load. Hot water supply temperature shall be modeled at 180°F design supply temperature and 130°F return temperature. Piping losses shall not be modeled in either building model. Hot water supply water temperature shall be reset in accordance with Section C403.4.2.4. Pump system power for each pumping system shall be the same as the proposed design; if the proposed design has no hot water pumps, the standard reference design pump power shall be 19 W/gpm (equal to a pump operating against a 60-foot head, 60-percent combined impeller and motor efficiency). The hot water system shall be modeled as primary only with continuous variable flow. Hot water pumps shall be modeled as riding the pump curve or with variable speed drives when required by Section C403.4.2.4.

- g. **Electric heat pump and boiler:** Water-source heat pumps shall be connected to a common heat pump water loop controlled to maintain a heating setpoint of 60°F and a cooling setpoint of 90°F. Heat rejection from the loop shall be provided by an axial fan closed-circuit evaporative fluid cooler with variable speed fans if required in Section C403.4.2.1 or C403.2.13. Heat addition to the loop shall be provided by a boiler that uses the same fuel as the proposed design and shall be natural draft. If no boilers exist in the proposed design, the standard reference building boilers shall be fossil fuel. The standard reference design boiler plant shall be modeled with a single boiler if the standard reference design plant load is 600,000 Btu/h or less and with two equally sized boilers for plant capacities exceeding 600,000 Btu/h. Boilers shall be staged as required by the load. Piping losses shall not be modeled in either building model. Pump system power shall be the same as the proposed design; if the proposed design has no pumps, the standard reference design pump power shall be 22 W/gpm, which is equal to a pump operating against a 75-foot head, with a 65-percent combined impeller and motor efficiency. Loop flow shall be variable with flow shutoff at each heat pump when its compressor cycles off as required by Section C403.4.2.3. Loop pumps shall be modeled as riding the pump curve or with variable speed drives when required by Section C403.4.2.4.
- h. **Electric heat pump:** Electric air-source heat pumps shall be modeled with electric auxiliary heat and an outdoor air thermostat. The system shall be controlled to energize auxiliary heat only when outdoor air temperature is less than 40°F. The air-source heat pump shall be modeled to continue to operate while auxiliary heat is energized. The air-source heat pump shall be modeled to operate down to a minimum outdoor air temperature of 35°F for System No. 8 or 0°F for System No. 9. If the Proposed Design utilizes the same system type as the Standard Design (PTHP or PSZ-HP), the Proposed Design shall be modeled with the same minimum outdoor air temperature for heat pump operation as the Standard Design. For temperatures below the stated minimum outdoor air temperatures, the electric auxiliary heat shall be controlled to provide the full heating load.
- i. **Constant volume:** For building types governed by Section C403.6, fans shall be controlled to cycle with load, i.e., fan operation cycled on calls for heating and cooling. If the fan is modeled as cycling and the fan energy is included in the energy efficiency rating of the equipment, fan energy shall not be modeled explicitly. For all other buildings, fans shall be controlled in the same manner as in the proposed design, i.e., fan operation whenever the space is occupied or fan operation cycled on calls for heating and cooling. If the fan is modeled as cycling and the fan energy is included in the energy efficiency rating of the equipment, fan energy shall not be modeled explicitly.
- j. **Fan speed control:** Fans shall operate as one- or two-speed as required by Section C403.2.11.5, regardless of the fan speed control used in the proposed building.
- k. **Outside air:** For building types governed by Section C403.6, outside air shall be supplied by a separate dedicated outside air system (DOAS) operating in parallel with terminal equipment. The terminal equipment fan system cycle calls for heating and cooling. DOAS shall include an Energy Recovery Ventilation System with a minimum effectiveness in accordance with Section C403.5.

**TABLE C407.5.1(5)
NUMBER OF CHILLERS**

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

For SI: 1 ton = 3517 W.

**TABLE C407.5.1(6)
WATER CHILLER TYPES**

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

For SI: 1 ton = 3517 W.

C407.6 Calculation software tools. Calculation procedures used to comply with this section shall be software tools capable of calculating the annual energy consumption of all building elements that differ between the *standard reference design* and the *proposed design* and shall include the following capabilities.

- Building operation for a full calendar year (8,760 hours).
- Climate data for a full calendar year (8,760 hours) and shall reflect *approved* coincident hourly data for temperature, solar radiation, humidity and wind speed for the building location.
- Ten or more thermal zones.
- Thermal mass effects.
- Hourly variations in occupancy, illumination, receptacle loads, thermostat settings, mechanical ventilation, HVAC equipment availability, service hot water usage and any process loads.
- Part-load performance curves for mechanical equipment.
- Capacity and efficiency correction curves for mechanical heating and cooling equipment.

8. Printed *code official* inspection checklist listing each of the *proposed design* component characteristics from Table C407.5.1(1) determined by the analysis to provide compliance, along with their respective performance ratings (e.g., *R*-value, *U*-factor, SHGC, HSPF, AFUE, SEER, EF, etc.).
9. Air-side economizers with integrated control.
10. *Standard reference design* characteristics specified in Table C407.5.1(1).

C407.6.1 Specific approval. Performance analysis tools meeting the applicable subsections of Section C407 and tested according to ASHRAE Standard 140 shall be permitted to be *approved*. Tools are permitted to be *approved* based on meeting a specified threshold for a jurisdiction. The *code official* shall be permitted to approve tools for a specified application or limited scope.

C407.6.2 Input values. Where calculations require input values not specified by Sections C402, C403, C404 and C405, those input values shall be taken from an *approved* source.

C407.6.3 Exceptional calculation methods. Where the *simulation program* does not model a design, material, or device of the *proposed design*, an Exceptional Calculation Method shall be used where *approved* by the *code official*. Where there are multiple designs, materials, or devices that the *simulation program* does not model, each shall be calculated separately and Exceptional Savings determined for each. The total Exceptional Savings shall not constitute more than half of the difference between the *baseline building performance* and the *proposed building performance*. Applications for approval of an exceptional method shall include:

1. Step-by-step documentation of the Exceptional Calculation Method performed detailed enough to reproduce the results.
2. Copies of all spreadsheets used to perform the calculations.
3. A sensitivity analysis of *energy* consumption when each of the input parameters is varied from half to double the value assumed.
4. The calculations shall be performed on a time step basis consistent with the *simulation program* used.
5. The *Performance Rating* calculated with and without the Exceptional Calculation Method.

SECTION C408 SYSTEM COMMISSIONING

C408.1 General. A building commissioning process led by a *certified commissioning professional* shall be completed for mechanical and refrigeration systems in Sections C403 and C410, service water heating systems in Section C404, electrical power and lighting systems in Section C405 and energy metering in Section C409.

Exception: Buildings, or portions thereof, which are exempt from Sections C408.2 through C408.6 may be excluded from the commissioning process.

C408.1.1 Commissioning in construction documents. Construction document notes shall clearly indicate provisions for commissioning and completion requirements in accordance with this section and are permitted to refer to specifications for further requirements.

C408.1.2 Commissioning plan. A *commissioning plan* shall be developed by the project's *certified commissioning professional* and shall outline the organization, schedule, allocation of resources, and documentation requirements of the commissioning process. Items 1 through 4 shall be included with the construction documents, and items 5 through 8 shall be submitted prior to the first mechanical inspection. For projects where no mechanical inspection is required, items 5 through 8 shall be submitted prior to the first electrical inspection:

1. A narrative description of the activities that will be accomplished during each phase of commissioning, including the personnel intended to accomplish each of the activities.
2. Roles and responsibilities of the commissioning team, including statement of qualifications of the commissioning professional.
3. A schedule of activities including systems testing and balancing, functional performance testing, and verification of the building documentation requirements in Section C103.6.
4. Where the certified commissioning professional is an employee of one of the registered design professionals of record or an employee or subcontractor of the project contractor, an In-House Commissioning Disclosure and Conflict Management Plan shall be submitted with the commissioning plan. This plan shall disclose the certified commissioning professional's contractual relationship with other team members and provide a conflict management plan demonstrating that the certified commissioning professional is free to identify any issues discovered and report directly to the owner.

5. A listing of the specific equipment, appliances or systems to be tested and a description of the tests to be performed.
6. Functions to be tested.
7. Conditions under which the test will be performed.
8. Measurable criteria for performance.

C408.1.3 Final commissioning report. A final commissioning report shall be completed and certified by the *certified commissioning professional* and delivered to the building owner or owner's authorized agent. The report shall be organized with mechanical, lighting, service water heating and metering findings in separate sections to allow independent review. The report shall record the activities and results of the commissioning process and be developed from the final commissioning plan with all of its attached appendices. The report shall include:

1. Results of functional performance tests.
2. Disposition of deficiencies found during testing, including details of corrective measures used or proposed.
3. Functional performance test procedures used during the commissioning process including measurable criteria for test acceptance, provided herein for repeatability.

Exception: Deferred tests which cannot be performed at the time of report preparation due to climatic conditions.

**

C408.1.4 Commissioning process completion requirements. Prior to the final mechanical, plumbing and electrical inspections or obtaining a certificate of occupancy, the *certified commissioning professional* or approved agency shall provide evidence of systems *commissioning* and completion in accordance with the provisions of this section.

Copies of all documentation shall be given to the owner and made available to the *code official* upon request in accordance with Section C408.1.4.3

*

C408.1.4.1 Commissioning progress report for code compliance. A preliminary report of commissioning test procedures and results shall be completed and certified by the *certified commissioning professional* or *approved agency* and provided to the building owner or owner's authorized agent. The report shall be organized with mechanical, lighting, service water heating and metering findings in separate sections to allow independent review. The report shall be identified as "Preliminary Commissioning Report" and shall identify:

1. Itemization of deficiencies found during testing required by this code that have not been corrected at the time of report preparation.

2. Deferred tests that cannot be performed at the time of report preparation because of climatic conditions, with anticipated date of completion.
3. Climatic conditions required for performance of the deferred tests.

Status of the project's record documents, manuals and systems operation training with respect to requirements in Section C103.6.

C408.1.4.2 Acceptance of report. Buildings, or portions thereof, shall not be considered acceptable for a final inspection pursuant to Section C104.2 until the *code official* has received a letter of transmittal from the building owner acknowledging that the building owner or owner's authorized agent has received the Preliminary Commissioning Report. Completion of the Commissioning Compliance Checklist (Figure C408.1.4.2) is deemed to satisfy this requirement.

C408.1.4.3 Copy of report. The *code official* shall be permitted to require that a copy of the Preliminary Commissioning Report be made available for review by the code official.

C408.2 Mechanical 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 building's total mechanical equipment capacity is less than 240,000 Btu/h cooling capacity and less than 300,000 Btu/h heating capacity.

C408.2.1 Reserved.

C408.2.2 Systems adjusting and balancing.

HVAC systems shall be balanced in accordance with generally accepted engineering standards. Air and water flow rates shall be measured and adjusted to deliver final flow rates within the tolerances provided in the project specifications. Test and balance activities shall include air system and hydronic system balancing.

C408.2.2.1 Air systems balancing. Each supply air outlet and *zone* terminal device shall be equipped with means for air balancing in accordance with the requirements of Chapter 6 of the *International Mechanical Code*. Discharge dampers used for air system balancing are prohibited on constant volume fans and variable volume fans with motors 10 hp (18.6 kW) and larger. Air systems shall be balanced

**FIGURE C408.1.4.2
COMMISSIONING COMPLIANCE CHECKLIST**

Project Information	Project Name:
	Project Address:
	Certified Commissioning Professional:
	Certifying Body:

Commissioning Plan (Section C408.1.2)	<input type="checkbox"/> Commissioning Plan was used during construction and included items below <ul style="list-style-type: none"> • A narrative description of activities and the personnel intended to accomplish each one • Measurable criteria for performance • Functions to be tested
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Commissioned Systems (Sections C408.2, C408.3, C408.4 and C408.6)	<input type="checkbox"/> Mechanical Systems were included in the commissioning process (Section C408.2) Building mechanical systems have been tested to demonstrate the installation and operation of components, systems and system-to-system interfacing relationships in accordance with approved plans and specifications <input type="checkbox"/> There are unresolved deficiencies with the mechanical systems. These are described in the Preliminary Commissioning Report submitted to the Owner. The following items are not in compliance with energy code:
	<input type="checkbox"/> Service Water Heating Systems were included in the commissioning process (Section C408.3) Service water heating systems have been tested to demonstrate that control devices, components, equipment, and systems are calibrated, adjusted and operate in accordance with approved plans and specifications <input type="checkbox"/> There are unresolved deficiencies with the service water heating systems. These are described in the Preliminary Commissioning Report submitted to the Owner. The following items are not in compliance with energy code:
	<input type="checkbox"/> Electrical Power or Lighting Systems were included in the commissioning process (Section C408.4) Electrical power and automatic lighting controls have been tested to demonstrate the installation and operation of components, systems, and system-to-system interfacing relationships in accordance with approved plans and specifications <input type="checkbox"/> There are unresolved deficiencies with the electrical power and/or automatic lighting controls. These are described in the Preliminary Commissioning Report submitted to the Owner. The following items are not in compliance with energy code:
	<input type="checkbox"/> Additional systems included in the commissioning process (Section C408.5) If additional items were included, list them here: <input type="checkbox"/> There are unresolved deficiencies with systems required by C406 or C407. These are described in the Preliminary Commissioning Report submitted to the Owner. The following items are not in compliance with energy code:
	<input type="checkbox"/> Metering System Functional Testing has been completed (Section C408.6) Energy source meters, energy end-use meters, the energy metering data acquisition system and required display are calibrated adjusted and operate to minimally meet code requirements. <input type="checkbox"/> There are unresolved deficiencies with the metering system. These are described in the Preliminary Commissioning Report submitted to the Owner. The following items are not in compliance with energy code:

FIGURE C408.1.4.2
COMMISSIONING COMPLIANCE CHECKLIST (Continued)

Supporting Documents
 (Section C103.6)

- ☐ **Manuals, record documents and training have been completed or are scheduled**
- System documentation has been provided to the owner or scheduled date: _____
 - Record documents have been submitted to owner or scheduled date: _____
 - Training has been completed or scheduled date: _____

Preliminary Commissioning Report
 (Section C408.1.4.1)

- ☐ **Preliminary Commissioning Report submitted to Owner and includes items below**
- ☐ Itemization of deficiencies found during testing that are part of the energy code and that have not been corrected at the time of report preparation.
 - ☐ Deferred tests that cannot be performed at the time of report preparation with anticipated date of completion.
 - ☐ Status of the project's record documents, manuals, and systems operation training with respect to requirements in Section 103.6.

Certification

- ☐ I hereby certify that all requirements for Commissioning have been completed in accordance with the Washington State Energy Code, including all items above.
- _____
- Building Owner or Owner's Representative Date

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 Functional performance testing. Functional performance testing specified in Sections C408.2.3.1 through C408.2.3.3 shall be conducted. Written procedures which clearly describe the individual systematic test procedures, the expected systems' response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion shall be followed. Testing shall affirm operation during actual or simulated winter and summer design conditions and during full outside air conditions.

C408.2.3.1 Equipment. Equipment functional performance testing shall demonstrate the installation and operation of components, systems, and system-to-system interfacing relationships in accordance with approved plans and specifications such that operation, function, and maintenance serviceability for each of the commissioned systems is confirmed. Testing shall include all modes and *sequence of operation*, including under full-load, part-load and the following emergency conditions:

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

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

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

C408.3 Electrical power and lighting systems

commissioning. Electrical power and lighting systems subject to Section C405 shall be included in the commissioning process required by Section C408.1. The commissioning process shall minimally include all energy code requirements for which the code requires specific daylight responsive controls, "control functions," and where the code states that equipment shall be "configured to" perform specific functions.

Exception: Lighting control systems are exempt from the commissioning process in buildings where:

1. The total installed lighting load is less than 20 kW.
2. Where the lighting load controlled by occupancy sensors or automatic daylighting controls is less than 10 kW.

C408.3.1 Functional testing. Prior to passing final inspection, the *certified commissioning professional* shall provide evidence that the lighting control systems have been tested to ensure that control hardware and software are calibrated, adjusted, programmed and in proper working condition in accordance with the construction documents and manufacturer's instructions. Written procedures which clearly describe the individual systematic test procedures, the expected systems' response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion shall be followed. Functional testing shall comply with Section C408.3.1.1 through C408.3.1.3 for the applicable control type.

C408.3.1.1 Occupant sensor controls. Where occupancy sensors are provided, the following procedures shall be performed:

1. Certify that the occupant sensor has been located and aimed in accordance with manufacturer recommendations.
2. For projects with seven or fewer occupant sensors, each sensor shall be tested. For projects with more than seven occupant sensors, testing shall be done for each unique combination of sensor type and space

geometry. Where multiples of each unique combination of sensor type and space geometry are provided, no fewer than the greater of one or 10 percent of each combination shall be tested unless the code official or design professional requires a higher percentage to be tested. Where 30 percent or more of the tested controls fail, all remaining identical combinations shall be tested.

3. For each occupant sensor to be tested, verify the following:
 - 3.1. Where occupant sensors include status indicators, verify correct operation.
 - 3.2. The controlled lights turn off or down to the permitted level within the required time.
 - 3.3. For auto-on occupant sensors, the lights turn on to the permitted level within the required time.
 - 3.4. For manual on occupant sensors, the lights turn on only when manually activated.
 - 3.5. The lights are not incorrectly turned on by movement in adjacent areas or by HVAC operation.

C408.3.1.2 Time switch controls. Where automatic time switches are provided, the following procedures shall be performed:

1. Confirm that the automatic time switch control is programmed with accurate weekday, weekend and holiday schedules, and set-up and preference program settings.
2. Provide documentation to the owner of automatic time switch programming, including weekday, weekend, holiday schedules and set-up and preference program settings.
3. Verify the correct time and date in the time switch.
4. Verify that any battery backup is installed and energized.
5. Verify that the override time limit is set to not more than two hours.
6. Simulate occupied conditions. Verify and document the following:
 - 6.1. All lights can be turned on and off by their respective area control switch.
 - 6.2. The switch only operates lighting in the enclosed space in which the switch is located.
7. Simulate unoccupied condition. Verify the following:
 - 7.1. All nonexempt lighting turns off.

- 7.2. Manual override switch allows only the lights in the enclosed space where the override switch is located to turn on or remain on until the next scheduled shut off occurs.

8. Additional testing as specified by the *certified commissioning professional*.

C408.3.1.3 Daylight responsive controls. Where *daylight responsive controls* are provided, the following procedures shall be performed:

1. All control devices have been properly located, field-calibrated and set for accurate setpoints and threshold light levels.
2. Daylight controlled lighting loads adjusted to light level setpoints in response to available daylight.
3. The locations of calibration adjustment equipment are *readily accessible* only to authorized personnel.

C408.3.2 Documentation requirements. The construction documents shall specify that documents certifying that the installed lighting controls meet documented performance criteria of Section C405 be provided to the building owner within 90 days from the date of receipt of the certificate of occupancy.

C408.4 Service water heating systems commissioning.

Service water heating equipment and controls subject to Section C404 shall be included in the commissioning process required by Section C408.1. The commissioning process shall minimally include all energy code requirements for which the code states that equipment or controls shall “be capable of” or “configured to” perform specific functions.

Exception: Service water heating systems are exempt from the commissioning process in buildings where the largest service water heating system capacity is less than 200,000 Btu/h (58,562 W) and where there are no pools or permanent spas.

C408.4.1 Functional performance testing. Functional performance testing specified in Sections C408.4.1.1 through C408.4.1.3 shall be conducted. Written procedures which clearly describe the individual systematic test procedures, the expected systems' response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion shall be followed. Testing shall affirm operation with the system under 50 percent water heating load.

C408.4.1.1 Equipment. Equipment functional performance testing shall demonstrate the installation and operation of components, systems, and system-to-system interfacing relationships in accordance with approved plans and specifications such that operation, function, and maintenance

serviceability for each of the commissioned systems is confirmed. Testing shall include all modes and *sequence of operation*, including under full-load, part-load and the following emergency conditions:

1. Redundant or *automatic* back-up mode;
2. Performance of alarms; and
3. Mode of operation upon a loss of power and restoration of power.

C408.4.1.2 Controls. Service water heating controls shall be tested to document that control devices, components, equipment, and systems are calibrated, adjusted and operate in accordance with approved plans and specifications. Sequences of operation shall be functionally tested to document they operate in accordance with *approved* plans and specifications.

C408.4.1.3 Pools and spas. Service water heating equipment, time switches, and heat recovery equipment which serve pools and permanent spas shall undergo a functional test to determine that they operate in accordance with manufacturer's specifications.

C408.5 Systems installed to meet Section C406 or

C407. Equipment, components, controls or configuration settings for mechanical, service water heating, electrical power or lighting systems which are included in the project to comply with Section C406 or C407 shall be included in the commissioning process required by Section C408.1.

C408.6 Metering system commissioning. Energy metering systems required by Section C409 shall comply with Section C408.6 and be included in the commissioning process required by Section C408.1. The commissioning process shall include all energy metering equipment and controls required by Section C409.

C408.6.1 Functional performance testing. Functional performance testing shall be conducted by following written procedures which clearly describe the individual systematic test procedures, the expected systems' response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion. Functional testing shall document that energy source meters, energy end-use meters, the energy metering data acquisition system, and required energy consumption display are calibrated, adjusted and operate in accordance with approved plans and specifications. At a minimum, testing shall confirm that:

1. The metering system devices and components work properly under low and high load conditions.
2. The metered data is delivered in a format that is compatible with the data collection system.
3. The energy display is accessible to building operation and management personnel.

4. The energy display meets code requirements regarding views required in Section C409.4.3. The display shows energy data in identical units (e.g., kWh).

SECTION C409 ENERGY METERING AND ENERGY CONSUMPTION MANAGEMENT

C409.1 General. New buildings and additions with a gross conditioned floor area over 50,000 square feet shall comply with Section C409. Buildings shall be equipped to measure, monitor, record and display energy consumption data for each energy source and end use category per the provisions of this section, to enable effective energy management.

Exceptions:

1. Tenant spaces smaller than 50,000 ft² within buildings if the tenant space has its own utility service and utility meters.
2. Buildings in which there is no gross conditioned floor area over 25,000 square feet, including building common area, that is served by its own utility services and meters.

C409.1.1 Alternate metering methods. Where approved by the building official, energy use metering systems may differ from those required by this section, provided that they are permanently installed and that the source energy measurement, end use category energy measurement, data storage and data display have similar accuracy to and are at least as effective in communicating actionable energy use information to the building management and users, as those required by this section.

C409.1.2 Conversion factor. Any threshold stated in kW shall include the equivalent BTU/h heating and cooling capacity of installed equipment at a conversion factor of 3,412 Btu per kW at 50 percent demand.

C409.2 Energy source metering. Buildings shall have a meter at each energy source. For each energy supply source listed in 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 exception 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.

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.

C409.3 End-use metering. Meters shall be provided to collect energy use data for each end-use category listed in Sections C409.3.1 through C409.3.2. These meters shall collect data for the whole building or for each separately metered portion of the building where not exempted by the exception to Section C409.1. Multiple meters may be used for any end-use category, provided that the data acquisition system totals all of the energy used by that category.

Exceptions:

1. HVAC and water heating equipment serving only an individual dwelling unit or sleeping unit does not require end-use metering.
2. Separate metering is not required for fire pumps, stairwell pressurization fans or other life safety systems that operate only during testing or emergency.
3. End use metering is not required for individual tenant spaces not exceeding 2,500 square feet in floor area when a dedicated source meter meeting the requirements of Section C409.4.1 is provided for the tenant space.

C409.3.1 HVAC system energy use. This category shall include all energy including electrical, gas, liquid fuel, district steam and district chilled water that is used by boilers, chillers, pumps, fans and other equipment used to provide space heating, space cooling, dehumidification and ventilation to the building, but not including energy that serves process loads, water heating or miscellaneous loads as defined in Section C409.3. Multiple HVAC energy sources, such as gas, electric and steam, are not required to be summed together.

Exceptions:

1. All 120 volt equipment.

2. 208/120 volt equipment in a building where the main service is 480/277 volt power.
3. Electrical energy fed through variable frequency drives that are connected to the energy metering data acquisition center.

C409.3.2 Water heating energy use. This category shall include all energy used for heating of domestic and service hot water, but not energy used for space heating.

Exception: Water heating energy use less than 50 kW does not require end-use metering.

C409.4 Measurement devices, data acquisition system and energy display.

C409.4.1 Meters. Meters and other measurement devices required by this section shall have local displays or be configured to automatically communicate energy data to a data acquisition system. Source meters may be any digital-type meters. Current sensors or flow meters are allowed for end use metering, provided that they have an accuracy of $\pm 5\%$. All required metering systems and equipment shall provide at least hourly data that is fully integrated into the data acquisition and display system per the requirements of Section C409.

C409.4.2 Data acquisition system. The data acquisition system shall store the data from the required meters and other sensing devices for a minimum of 36 months. For each energy supply and end use category required by C409.2 and C409.3, it shall provide real-time energy consumption data and logged data for any hour, day, month or year.

C409.4.3 Energy display. For each building subject to Section C409.2 and C409.3, either a readily accessible and visible display, or a web page or other electronic document accessible to building management or to a third-party energy data analysis service shall be provided in the building accessible by building operation and management personnel. The display shall graphically provide the current energy consumption rate for each whole building energy source, plus each end use category, as well as the average and peak values for any day, week or year.

C409.4.4 Commissioning. The entire system shall be commissioned in accordance with Section C408. Deficiencies found during testing shall be corrected and retested and the commissioning report shall be updated to confirm that the entire metering and data acquisition and display system is fully functional.

C409.5 Metering for existing buildings.

C409.5.1 Existing buildings that were constructed subject to the requirements of this section. Where new or replacement systems or equipment are installed in an existing building that was constructed subject to the requirements of this section, metering shall be provided for such new or replacement systems or equipment so that their energy use is included in the corresponding end-use category defined in Section C409.2. This includes systems or equipment added in conjunction with additions or alterations to existing buildings.

C409.5.1.1 Small existing buildings. Metering and data acquisition systems shall be provided for additions over 25,000 square feet to buildings that were constructed subject to the requirements of this section, in accordance with the requirements of sections C409.2 and C409.3.

SECTION C410 REFRIGERATION SYSTEM REQUIREMENTS

C410.1 General (prescriptive). Walk-in coolers, walk-in freezers, refrigerated warehouse coolers, refrigerated warehouse freezers, and refrigerated display cases shall comply with this Section.

Refrigerated warehouse coolers and refrigerated warehouse freezers shall comply with Section C402. Section C402.1.5, Component performance alternative, may be used if granted prior approval by the jurisdiction.

C410.1.1 Refrigeration equipment performance.

Refrigeration equipment shall have an energy use in kWh/day not greater than the values of Tables C410.2(1) and C410.2(2) when tested and rated in accordance with AHRI Standard 1200. The energy use shall be verified through certification under an approved certification program or, where a certification program does not exist, the energy use shall be supported by data furnished by the equipment manufacturer.

**TABLE C410.1.1(1)
MINIMUM EFFICIENCY REQUIREMENTS: COMMERCIAL REFRIGERATION**

EQUIPMENT TYPE	APPLICATION	ENERGY USE LIMITS (kWh per day) ^a	TEST PROCEDURE
Refrigerator with solid doors	Holding Temperature	$0.10 \times V + 2.04$	AHRI 1200
Refrigerator with transparent doors		$0.12 \times V + 3.34$	
Freezers with solid doors		$0.40 \times V + 1.38$	
Freezers with transparent doors		$0.75 \times V + 4.10$	
Refrigerator/freezers with solid doors		The greater of $0.12 \times V + 3.34$ or 0.70	
Commercial refrigerators	Pulldown	$0.126 \times V + 3.51$	

a. V = Volume of the chiller for frozen compartment as defined in AHAM-HRF-1.

**TABLE C410.1.1(2)
MINIMUM EFFICIENCY REQUIREMENTS: COMMERCIAL REFRIGERATORS AND FREEZERS**

EQUIPMENT TYPE				ENERGY USE LIMITS (kWh per day) ^{a,b}	TEST PROCEDURE
Equipment Class ^c	Family Code	Operating Mode	Rating Temperature		
VOP.RC.M	Vertical open	Remote condensing	Medium	$0.82 \times TDA + 4.07$	AHRI 1200
SVO.RC.M	Semivertical open	Remote condensing	Medium	$0.83 \times TDA + 3.18$	
HZO.RC.M	Horizontal open	Remote condensing	Medium	$0.35 \times TDA + 2.88$	
VOP.RC.L	Vertical open	Remote condensing	Low	$2.27 \times TDA + 6.85$	
HZO.RC.L	Horizontal open	Remote condensing	Low	$0.57 \times TDA + 6.88$	
VCT.RC.M	Vertical transparent door	Remote condensing	Medium	$0.22 \times TDA + 1.95$	
VCT.RC.L	Vertical transparent door	Remote condensing	Low	$0.56 \times TDA + 2.61$	
SOC.RC.M	Service over counter	Remote condensing	Medium	$0.51 \times TDA + 0.11$	

TABLE C410.1.1(2) (Continued)
MINIMUM EFFICIENCY REQUIREMENTS: COMMERCIAL REFRIGERATORS AND FREEZERS

Equipment Class ^c	EQUIPMENT TYPE			ENERGY USE LIMITS (kWh per day) ^{a,b}	TEST PROCEDURE
	Family Code	Operating Mode	Rating Temperature		
VOP.SC.M	Vertical open	Self-contained	Medium	1.74 x TDA + 4.71	AHRI 1200
SVO.SC.M	Semivertical open	Self-contained	Medium	1.73 x TDA + 4.59	
HZO.SC.M	Horizontal open	Self-contained	Medium	0.77 x TDA + 5.55	
HZO.SC.L	Horizontal open	Self-contained	Low	1.92 x TDA + 7.08	
VCT.SC.I	Vertical transparent door	Self-contained	Ice cream	0.67 x TDA + 3.29	
VCS.SC.I	Vertical solid door	Self-contained	Ice cream	0.38 x V + 0.88	
HCT.SC.I	Horizontal transparent door	Self-contained	Ice cream	0.56 x TDA + 0.43	
SVO.RC.L	Semivertical open	Remote condensing	Low	2.27 x TDA + 6.85	
VOP.RC.I	Vertical open	Remote condensing	Ice cream	2.89 x TDA + 8.7	
SVO.RC.I	Semivertical open	Remote condensing	Ice cream	2.89 x TDA + 8.7	
HZO.RC.I	Horizontal open	Remote condensing	Ice cream	0.72 x TDA + 8.74	
VCT.RC.I	Vertical transparent door	Remote condensing	Ice cream	0.66 x TDA + 3.05	
HCT.RC.M	Horizontal transparent door	Remote condensing	Medium	0.16 x TDA + 0.13	
HCT.RC.L	Horizontal transparent door	Remote condensing	Low	0.34 x TDA + 0.26	
HCT.RC.I	Horizontal transparent door	Remote condensing	Ice cream	0.4 x TDA + 0.31	
VCS.RC.M	Vertical solid door	Remote condensing	Medium	0.11 x V + 0.26	
VCS.RC.L	Vertical solid door	Remote condensing	Low	0.23 x V + 0.54	
VCS.RC.I	Vertical solid door	Remote condensing	Ice cream	0.27 x V + 0.63	
HCS.RC.M	Horizontal solid door	Remote condensing	Medium	0.11 x V + 0.26	
HCS.RC.L	Horizontal solid door	Remote condensing	Low	0.23 x V + 0.54	
HCS.RC.I	Horizontal solid door	Remote condensing	Ice cream	0.27 x V + 0.63	
SOC.RC.L	Service over counter	Remote condensing	Low	1.08 x TDA + 0.22	
SOC.RC.I	Service over counter	Remote condensing	Ice cream	1.26 x TDA + 0.26	
VOP.SC.L	Vertical open	Self-contained	Low	4.37 x TDA + 11.82	

TABLE C410.1.1(2) (Continued)
MINIMUM EFFICIENCY REQUIREMENTS: COMMERCIAL REFRIGERATORS AND FREEZERS

EQUIPMENT TYPE				ENERGY USE LIMITS (kWh per day) ^{a,b}	TEST PROCEDURE
Equipment Class ^c	Family Code	Operating Mode	Rating Temperature		
VOP.SC.I	Vertical open	Self-contained	Ice cream	5.55 x TDA + 15.02	AHRI 1200
SVO.SC.L	Semivertical open	Self-contained	Low	4.34 x TDA + 11.51	
SVO.SC.I	Semivertical open	Self-contained	Ice cream	5.52 x TDA + 14.63	
HZO.SC.I	Horizontal open	Self-contained	Ice cream	2.44 x TDA + 9.0	
SOC.SC.I	Service over counter	Self-contained	Ice cream	1.76 x TDA + 0.36	
HCS.SC.I	Horizontal solid door	Self-contained	Ice cream	0.38 x V + 0.88	

a V = Volume of the case, as measured in accordance with Appendix C of AHRI 1200.

b TDA = Total display area of the case, as measured in accordance with Appendix D of AHRI 1200.

c Equipment class designations consist of a combination [(in sequential order separated by periods (AAA).(BB).(C))]:

(AAA) An equipment family code where:

VOP = Vertical open

SVO = Semi-vertical open

HZO = Horizontal open

VCT = Vertical transparent doors

VCS = Vertical solid doors

HCT = Horizontal transparent doors

HCS = Horizontal solid doors

SOC = Service over counter

(BB) An operating mode code:

RC = Remote condensing

SC = Self-contained

(C) A rating temperature code:

M = Medium temperature (38°F)

L = Low temperature (0°F)

I = Ice cream temperature (15°F)

For example, "VOP.RC.M" refers to the "vertical-open, remote-condensing, medium-temperature" equipment class.

C410.2 Walk-in coolers, walk-in freezers, refrigerated warehouse coolers and refrigerated warehouse freezers. Refrigerated warehouse coolers, refrigerated warehouse freezers and all walk-in coolers and walk-in freezers including site assembled, site constructed and prefabricated units shall comply with the following:

- 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.

- Doorways shall be provided with strip doors, curtains, spring-hinged doors or other method of minimizing infiltration when doors are open.
- 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 frames.

- 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.
- Transparent 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.
- Transparent reach-in doors for walk-in coolers and windows for walk-in cooler doors shall be provided with double-pane or triple-pane glass, with interstitial spaces filled with inert gas, or be provided with heat-reflective treated glass.
- 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.

C410.2.1 Reserved.

C410.2.2 Refrigerated display cases. Site-assembled or site-constructed refrigerated display cases shall comply with the following:

1. Lighting and glass doors in refrigerated display cases shall be controlled by one of the following:
 - 1.1. Time switch controls to turn off lights during nonbusiness hours. Timed overrides for display cases shall turn the lights on for up to 1 hour and shall automatically time out to turn the lights off.
 - 1.2. Motion sensor controls on each display case section that reduce lighting power by at least 50 percent within 3 minutes after the area within the sensor range is vacated.
2. Low-temperature display cases shall incorporate temperature-based defrost termination control with a time-limit default. The defrost cycle shall terminate first on an upper temperature limit breach and second upon a time limit breach.
3. Antisweat heater controls shall reduce the energy use of the antisweat heater as a function of the relative humidity in the air outside the door or to the condensation on the inner glass pane.

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C410.3 Refrigeration systems. Refrigerated display cases, *walk-in coolers* or *walk-in freezers* that are served by remote compressor and remote condensers not located in a *condensing unit*, shall comply with Sections C410.4.1, C410.4.2 and C403.5.3.

Exception: Systems where the working fluid in the refrigeration cycle goes through both subcritical and supercritical states (transcritical) or that use ammonia refrigerant are exempt.

C410.3.1 Condensers serving refrigeration systems. Fan-powered condensers shall comply with the following:

1. The design *saturated condensing temperatures* for air-cooled condensers shall not exceed the design dry-bulb temperature plus 10°F (5.6°C) for *low-temperature refrigeration systems*, and the design dry-bulb temperature plus 15°F (8°C) for *medium temperature refrigeration systems* where the *saturated condensing temperature* for blend refrigerants shall be determined using the average of liquid and vapor temperatures as converted from the condenser drain pressure.
2. Condenser fan motors that are less than 1 hp (0.75 kW) shall use electronically commutated motors, permanent split-capacitor-type motors or 3-phase motors.
3. Condenser fans for air-cooled condensers, evaporatively cooled condensers, air- or water-cooled fluid coolers or cooling towers shall reduce fan motor demand to not more than 30 percent of design wattage at 50 percent of design air volume, and incorporate one of the following continuous variable speed fan control approaches:
 - 3.1. Refrigeration system condenser control for air-cooled condensers shall use variable setpoint control logic to reset the condensing temperature setpoint in response to ambient dry-bulb temperature.
 - 3.2. Refrigeration system condenser control for evaporatively cooled condensers shall use variable setpoint control logic to reset the condensing temperature setpoint in response to ambient wet-bulb temperature.
4. Multiple fan condensers shall be controlled in unison.
5. The minimum condensing temperature setpoint shall be not greater than 70°F (21°C).

C410.3.2 Compressor systems. Refrigeration compressor systems shall comply with the following:

1. Compressors and multiple-compressor system suction groups shall include control systems that use floating suction pressure control logic to reset the target suction pressure temperature based on the temperature requirements of the attached refrigeration display cases or walk-ins.

Exception: Controls are not required for the following:

1. 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.

CHAPTER 5

EXISTING BUILDINGS

SECTION C501 GENERAL

C501 General.

C501.1 Scope. The provisions of this chapter shall control the *alteration, repair, addition* and change of occupancy of existing buildings and structures.

C501.2 Existing buildings. Except as specified in this chapter, this code shall not be used to require the removal, *alteration* or abandonment of, nor prevent the continued use and maintenance of, an existing building or building system lawfully in existence at the time of adoption of this code.

C501.3 Maintenance. Buildings and structures, and parts thereof, shall be maintained in a safe and sanitary condition. Devices and systems which are required by this code shall be maintained in conformance with the code edition under which installed. The owner or the owner's authorized agent shall be responsible for the maintenance of buildings and structures. The requirements of this chapter shall not provide the basis for removal or abrogation of energy conservation, fire protection and safety systems and devices in existing structures.

C501.4 Compliance. *Alterations, repairs, additions* and changes of occupancy to, or relocation of, existing buildings and structures shall comply with the provisions for *alterations, repairs, additions* and changes of occupancy or relocation, respectively, in the *International Building Code, International Fire Code, International Fuel Gas Code, International Mechanical Code, Uniform Plumbing Code*, and NFPA 70.

C501.5 New and replacement materials. Except as otherwise required or permitted by this code, materials permitted by the applicable code for new construction shall be used. Like materials shall be permitted for *repairs*, provided no hazard to life, health or property is created. Hazardous materials shall not be used where the code for new construction would not permit their use in buildings of similar occupancy, purpose and location.

C501.6 Historic buildings. The building official may modify the specific requirements of this code for historic buildings and require alternate provisions which will result in a reasonable degree of energy efficiency. This modification may be allowed for those buildings or structures that are listed in the state or national register of historic places; designated as a historic property under local or state designation law or survey; certified as a

contributing resource with a national register listed or locally designated historic district; or with an opinion or certification that the property is eligible to be listed on the national or state registers of historic places either individually or as a contributing building to a historic district by the state historic preservation officer or the keeper of the national register of historic places.

SECTION C502 ADDITIONS

C502.1 General. *Additions* to an existing building, building system or portion thereof shall conform to the provisions of this code as they relate to new construction without requiring the unaltered portion of the existing building or building system to comply with this code. Additions shall not create an unsafe or hazardous condition or overload existing building systems. An addition shall be deemed to comply with this code if the addition alone complies or if the existing building and addition comply with this code as a single building. Additions shall comply with Section C502.2.

C502.2 Prescriptive compliance. *Additions* shall comply with Sections C502.2.1 through C502.2.6.2.

C502.2.1 Vertical fenestration. Additions with *vertical fenestration* that results in a total building vertical fenestration area less than or equal to that specified in Section C402.4.1 shall comply with Section C402.4. Additions with vertical fenestration that results in a total building vertical fenestration area greater than that specified in Section C402.4.1 shall comply with one of the following:

1. Vertical fenestration alternate per Section C402.4.1.1 or C402.4.1.3 for the addition only.
2. Component performance option with target area adjustment per Section C402.1.5 or the total building performance option in Section C407 for the whole building.

C502.2.2 Skylight area. *Additions* with *skylights* that result in a total building skylight area less than or equal to that specified in Section C402.4.1 shall comply with Section C402.4. Additions with skylights that result in a total building skylight area greater than that specified in Section C402.4.1 shall comply with the component performance option with the target area adjustment per Section C402.1.5 or the total building performance option in Section C407 for the whole building.

C502.2.3 Building mechanical systems. New mechanical systems and equipment serving the building heating, cooling or ventilation needs, that are part of the addition, shall comply with Section C403.

C502.2.4 Service water heating systems. New service water-heating equipment, controls and service water heating piping shall comply with Section C404.

C502.2.5 Pools and permanent spas. New pools and permanent spas shall comply with Section C404.11.

C502.2.6 Lighting and power systems. New lighting systems that are installed as part of the addition shall comply with Section C405.

C502.2.6.1 Interior lighting power. The total interior lighting power for the addition shall comply with Section C405.4.2 for the addition alone, or the existing building and the addition shall comply as a single building.

C502.2.6.2 Exterior lighting power. The total exterior lighting power for the addition shall comply with Section C405.5.1 for the addition alone, or the existing building and the addition shall comply as a single building.

C502.2.7 Refrigeration systems. New refrigerated spaces and refrigeration equipment shall comply with Section C410.

SECTION C503 ALTERATIONS

C503.1 General. Alterations to any building or structure shall comply with the requirements of the code for new construction. Alterations shall be such that the existing building or structure is no less conforming with the provisions of this code than the existing building or structure was prior to the alteration. Alterations to an existing building, building system or portion thereof shall conform to the provisions of this code as they relate to new construction without requiring the unaltered portions of the existing building or building system to comply with this code. Alterations shall not create an unsafe or hazardous condition or overload existing building systems.

Exception: The following alterations need not comply with the requirements for new construction provided the energy use of the building is not increased:

1. Storm windows installed over existing fenestration.
2. Surface applied window film installed on existing single pane fenestration assemblies to reduce solar heat gain provided the code does not require the glazing fenestration to be replaced.
3. Existing ceiling, wall or floor cavities exposed during construction provided that these cavities are insulated to full depth with insulation having a minimum nominal value of R-3.0 per inch installed per Section C402.

4. Construction where the existing roof, wall or floor cavity is not exposed.
5. *Roof recover.*
6. *Air barriers* shall not be required for roof recover and roof replacement where the alterations or renovations to the building do not include alterations, renovations or repairs to the remainder of the building envelope.
7. Replacement of existing doors that separate conditioned space from the exterior shall not require the installation of a vestibule or revolving door, provided however that an existing vestibule that separates a conditioned space from the exterior shall not be removed.

C503.2 Change in space conditioning. Any nonconditioned space that is altered to become *conditioned space* or *semi-heated space* shall be required to be brought into full compliance with this code. Any semi-heated space that is altered to become conditioned space shall be required to be brought into full compliance with this code.

Exception: Where the component performance building envelope option in Section C402.1.5 is used to comply with this Section, the Proposed Total Envelope UA is allowed to be up to 110 percent of the Allowed Total Envelope UA. Where the total building performance option in Section C407 is used to comply with this section, the annual energy consumption of the proposed design is allowed to be 110 percent of the annual energy consumption otherwise allowed by Section C407.3.

C503.3 Building envelope. New building envelope assemblies that are part of the alteration shall comply with Sections C402.1 through C402.5 as applicable.

Exception: Air leakage testing is not required for alterations and repairs, unless the project includes a change in space conditioning according to Section C503.2 or a change of occupancy or use according to Section C505.1.

C503.3.1 Roof replacement. *Roof replacements* shall comply with Table C402.1.3 or C402.1.4 where the existing roof assembly is part of the *building thermal envelope* and contains insulation entirely above the roof deck.

C503.3.2 Vertical fenestration. The addition of *vertical fenestration* that results in a total building vertical fenestration area less than or equal to that specified in Section C402.4.1 shall comply with Section C402.4. Alterations that result in a total building vertical fenestration area greater than specified in Section C402.4.1 shall comply with one of the following:

1. Vertical fenestration alternate per Section C402.1.3 for the new vertical fenestration added.

2. Vertical fenestration alternate per Section C402.4.1.1 for the area adjacent to the new vertical fenestration added.
3. Component performance option with target area adjustment per Section C402.1.5 or the total building performance option in Section C407 for the whole building.

C503.3.2.1 Application to replacement

fenestration products. Where some or all of an existing *fenestration* unit is replaced with a new *fenestration* product, including sash and glazing, the replacement *fenestration* unit shall meet the applicable requirements for *U*-factor and *SHGC* in Table C402.4.

Exception: An area-weighted average of the *U*-factor of replacement fenestration products being installed in the building for each fenestration product category listed in Table C402.4 shall be permitted to satisfy the *U*-factor requirements for each fenestration product category listed in Table C402.4. Individual fenestration products from different product categories listed in Table C402.4 shall not be combined in calculating the area-weighted average *U*-factor.

C503.3.3 Skylight area. The addition of *skylights* that results in a total building skylight area less than or equal to that specified in Section C402.4.1 shall comply with Section C402.4. *Alterations* that result in a total building skylight area greater than that specified in Section C402.4.1 shall comply with the component performance option with target area adjustment per Section C402.1.5 or the total building performance option in Section C407 for the whole building.

C503.4 Mechanical systems. Those parts of systems which are altered or replaced shall comply with Section C403. Additions or alterations shall not be made to an existing mechanical system that will cause the existing mechanical system to become out of compliance.

Exception: Existing mechanical systems which are altered or where parts of the system are replaced are not required to be modified to comply with Section C403.6 as long as mechanical cooling is not added to the system.

All new systems in existing buildings, including packaged unitary equipment and packaged split systems, shall comply with Section C403.

Where mechanical cooling is added to a space that was not previously cooled, the mechanical system shall comply with either Section C403.6 or C403.3.

Exceptions:

1. Alternate designs that are not in full compliance with this code may be approved when the code official determines that existing building constraints including, but not limited to, available mechanical space, limitations of the

existing structure, or proximity to adjacent air intakes/exhausts make full compliance impractical. Alternate designs shall provide alternate energy savings strategies including, but not limited to, Demand Control Ventilation or increased mechanical cooling or heating efficiency above that required by Tables C403.2.3(1) through C403.2.3(10).

2. Qualifying small equipment: This exception shall not be used for unitary cooling equipment installed outdoors or in a mechanical room adjacent to the outdoors. This exception is allowed to be used for other cooling units and split systems serving one zone with a total cooling capacity rated in accordance with Section C403.2.3 of less than 33,000 Btu/h (hereafter referred to as qualifying small systems) provided that these are high-efficiency cooling equipment with SEER and EER values more than 15 percent higher than minimum efficiencies listed in Tables C403.2.3 (1) through (3), in the appropriate size category, using the same test procedures. Equipment shall be listed in the appropriate certification program to qualify for this exception. The total capacity of all qualifying small equipment without economizers shall not exceed 72,000 Btu/h per building, or 5 percent of its air economizer capacity, whichever is greater. That portion of the equipment serving Group R occupancies is not included in determining the total capacity of all units without economizers in a building. Redundant units are not counted in the capacity limitations. This exception shall not be used for the shell-and-core permit or for the initial tenant improvement or for Total Building Performance.
3. Chilled water terminal units connected to systems with chilled water generation equipment with IPLV values more than 25 percent higher than minimum part load efficiencies listed in Table C403.2.3(7), in the appropriate size category, using the same test procedures. Equipment shall be listed in the appropriate certification program to qualify for this exception. The total capacity of all systems without economizers shall not exceed 480,000 Btu/h per building, or 20 percent of its air economizer capacity, whichever is greater. That portion of the equipment serving Group R occupancy is not included in determining the total capacity of all units without economizers in a building. This exception shall not be used for the initial permit (this includes any initial permit for the space including, but not limited to, the shell-and-core permit, built-to-suit permit, and tenant improvement permit) or for Total Building Performance Method.

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Alterations to existing mechanical cooling systems shall not decrease economizer capacity unless the system complies with either Section C403.2.6 or C403.3. In addition, for existing mechanical cooling systems that do not comply with either Section C403.2.6 or C403.3, including both the individual unit size limits and the total building capacity limits on units without economizer; other alterations shall comply with Table C503.4.

When space cooling equipment is replaced, controls shall comply with all requirements under Section C403.6 and related subsections or provide for integrated operation with economizer in accordance with Section C403.3.1.

Existing equipment currently in use may be relocated within the same floor or same tenant space if removed and reinstalled within the same permit.

C503.5 Service hot water systems. New service hot water systems that are part of the alteration shall comply with Section C404.

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C503.6 Lighting and motors. Alterations that replace 50 percent or more of the luminaires in a space enclosed by walls or ceiling-height partitions, replace 50 percent or more of parking garage luminaires, or replace 50 percent or more of the total installed wattage of exterior luminaires shall comply with Sections C405.4 and C405.5. Where less than 50 percent of the fixtures in an interior space enclosed by walls or ceiling-height partitions or parking garage are new, or less than 50 percent of the installed exterior wattage is altered, the installed lighting wattage shall be maintained or reduced.

Where new wiring is being installed to serve added fixtures and/or fixtures are being relocated to a new circuit, controls shall comply with Sections C405.2.1, C405.2.3, C405.2.4, C405.2.5, C405.2.7, C405.3, and as applicable C408.3. In addition, office areas less than 300 ft² enclosed by walls or ceiling-height partitions, and all meeting and conference rooms, and all school classrooms, shall be equipped with occupancy sensors that comply with Section C405.2.1 and C408.3. Where a new lighting panel (or a moved lighting panel) with all new raceway and conductor wiring from the panel to the fixtures is being installed, controls shall also comply with the other requirements in Sections C405.2 and C408.3.

Where new walls or ceiling-height partitions are added to an existing space and create a new enclosed space, but the lighting fixtures are not being changed, other than being relocated, the new enclosed space shall have controls that comply with Sections C405.2.1, C 405.2.2, C405.2.3, C405.2.4, C405.2.5 and C408.3.

Those motors which are altered or replaced shall comply with Section C405.8.

C503.7 Refrigeration systems. Those parts of systems which are altered or replaced shall comply with Section C410. Additions or alterations shall not be made to an existing refrigerated space or system that will cause the existing mechanical system to become out of compliance. All new refrigerated spaces or systems in existing buildings, including refrigerated display cases, shall comply with Section C410.

**TABLE C503.4
ECONOMIZER COMPLIANCE OPTIONS FOR MECHANICAL ALTERATIONS**

**

Unit Type	Option A	Option B (alternate to A)	Option C (alternate to A)	Option D (alternate to A)
	Any alteration with new or replacement equipment	Replacement unit of the same type with the same or smaller output capacity	Replacement unit of the same type with a larger output capacity	New equipment added to existing system or replacement unit of a different type
1. Packaged Units	Efficiency: min. ¹ Economizer: C403.4.1 ²	Efficiency: min. ¹ Economizer: C403.4.1 ^{2,3}	Efficiency: min. ¹ Economizer: C403.4.1 ^{2,3}	Efficiency: min. ¹ Economizer: C403.4.1 ^{2,4}
2. Split Systems	Efficiency: min. ¹ Economizer: C403.4.1 ²	Efficiency: + 10/5% ⁵ Economizer: shall not decrease existing economizer capability	Only for new units < 54,000 Btuh replacing unit installed prior to 1991 (one of two): Efficiency: + 10/5% ⁵ Economizer: 50% ⁶	Efficiency: min. ¹ Economizer: C403.4.1 ^{2,4}
			For units > 54,000 Btuh or any units installed after 1991: Option A	
3. Water Source Heat Pump	Efficiency: min. ¹ Economizer: C403.4.1 ²	(two of three): Efficiency: + 10/5% ⁵ Flow control valve ⁷	(three of three): Efficiency: + 10/5% ⁵ Flow control valve ⁷	Efficiency: min. ¹ Economizer: C403.4.1 ^{2,4}

Unit Type	Option A	Option B (alternate to A)	Option C (alternate to A)	Option D (alternate to A)
	Any alteration with new or replacement equipment	Replacement unit of the same type with the same or smaller output capacity	Replacement unit of the same type with a larger output capacity	New equipment added to existing system or replacement unit of a different type
		Economizer: 50% ⁶	Economizer: 50% ⁶ (except for certain pre-1991 systems ⁸)	(except for certain pre-1991 systems ⁸)
4. Hydronic Economizer using Air-Cooled Heat Rejection Equipment (Dry Cooler)	Efficiency: min. ¹ Economizer: 1433 ²	Efficiency: + 10/5% ⁵ Economizer: shall not decrease existing economizer capacity	Option A	Efficiency: min. ¹ Economizer: C403.4.1 ^{2,4}
5. Air-Handling Unit (including fan coil units) where the system has an air-cooled chiller	Efficiency: min. ¹ Economizer: C403.4.1 ²	Economizer: shall not decrease existing economizer capacity	Option A (except for certain pre-1991 systems ⁸)	Option A (except for certain pre-1991 systems ⁸)
6. Air- Handling Unit (including fan coil units) and Water-cooled Process Equipment, where the system has a water-cooled chiller ¹⁰	Efficiency: min. ¹ Economizer: C403.4.1 ²	Economizer: shall not decrease existing economizer capacity	Option A (except for certain pre-1991 systems ⁸ and certain 1991-2004 systems ⁹ .)	Efficiency: min. ¹ Economizer: C403.4.1 ^{2,4} (except for certain pre-1991 systems ⁸ and certain 1991-2004 systems ⁹)
7. Cooling Tower	Efficiency: min. ¹ Economizer: C403.4.1 ²	No requirements	Option A	Option A
8. Air-Cooled Chiller	Efficiency: min. ¹ Economizer: C403.4.1 ²	Efficiency: + 5% ¹¹ Economizer: shall not decrease existing economizer capacity	Efficiency (two of two): (1) + 10% ¹² and (2) multistage Economizer: shall not decrease existing economizer capacity	Efficiency: min. ¹ Economizer: C403.4.1 ^{2,4}
9. Water-Cooled Chiller	Efficiency: min. ¹ Economizer: C403.4.1 ²	Efficiency (one of two): (1) + 10% ¹³ or (2) plate frame heat exchanger ¹⁵ Economizer: shall not decrease existing economizer capacity	Efficiency (two of two): (1) + 15% ¹⁴ and (2) plate-frame heat exchanger ¹⁵ Economizer: shall not decrease existing economizer capacity	Efficiency: min. ¹ Economizer: C403.4.1 ^{2,4}
10. Boiler	Efficiency: min. ¹ Economizer: C403.4.1 ²	Efficiency: + 8% ¹⁶ Economizer: shall not decrease existing economizer capacity	Efficiency: + 8% ¹⁶ Economizer: shall not decrease existing economizer capacity	Efficiency: min. ¹ Economizer: C403.4.1 ^{2,4}

1. Minimum equipment efficiency shall comply with Section C403.2.3 and Tables C403.2.3(1) through C403.2.3(9).
2. System and building shall comply with Section C403.4.1 (including both the individual unit size limits and the total building capacity limits on units without economizer). It is acceptable to comply using one of the exceptions to Section C403.4.1.
3. All equipment replaced in an existing building shall have air economizer complying with Sections C403.3.1 and C403.4.1 unless both the individual unit size and the total capacity of units without air economizer in the building is less than that allowed in Exception 1 to Section C403.3.1.
4. All separate new equipment added to an existing building shall have air economizer complying with Sections C403.3.1 and C403.4.1 unless both the individual unit size and the total capacity of units without air economizer in the building is less than that allowed in Exception 1 to Section C403.4.1.
5. Equipment shall have a capacity-weighted average cooling system efficiency:
 - a. for units with a cooling capacity below 54,000 Btuh, a minimum of 10% greater than the requirements in Tables C403.2.3(1) and C403.2.3(2) (1.10 x values in Tables C403.2.3(1) and C403.2.3(2)).
 - b. for units with a cooling capacity of 54,000 Btuh and greater, a minimum of 5% greater than the requirements in Tables C403.2.3(1) and C403.2.3(2) (1.05 x values in Tables C403.2.3(1) and C403.2.3(2)).
6. Minimum of 50% air economizer that is ducted in a fully enclosed path directly to every heat pump unit in each zone, except that ducts may terminate within 12 inches of the intake to an HVAC unit provided that they are physically fastened so that the outside air duct is directed into the unit intake. If this is an increase in the amount of outside air supplied to this unit, the outside air supply system shall be capable of providing this additional outside air and equipped with economizer control.
7. Have flow control valve to eliminate flow through the heat pumps that are not in operation with variable speed pumping control complying with Section C403.4.3 for that heat pump.
 - When the total capacity of all units with flow control valves exceeds 15% of the total system capacity, a variable frequency drive shall be installed on the main loop pump.
 - As an alternate to this requirement, have a capacity-weighted average cooling system efficiency that is 5% greater than the requirements in note 5 (i.e. a minimum of 15%/10% greater than the requirements in Tables C403.2.3(1) and C403.2.3(2) (1.15/1.10 x values in Tables C403.2.3(1) and C403.2.3(2)).
8. Systems installed prior to 1991 without fully utilized capacity are allowed to comply with Option B, provided that the individual unit cooling capacity does not exceed 90,000 Btuh.
9. Economizer not required for systems installed with water economizer plate and frame heat exchanger complying with previous codes between 1991 and June 2013, provided that the total fan coil load does not exceed the existing or added capacity of the heat exchangers.
10. For water-cooled process equipment where the manufacturers specifications require colder temperatures than available with waterside economizer, that portion of the load is exempt from the economizer requirements.
11. The air-cooled chiller shall have an IPLV efficiency that is a minimum of 5% greater than the IPLV requirements in Table C403.2.3(7) (1.05 x IPLV values in Table C403.2.3(7)).
12. The air-cooled chiller shall:
 - a. have an IPLV efficiency that is a minimum of 10% greater than the IPLV requirements in Table C403.2.3(7) (1.10 x IPLV values in Table C403.2.3(7)), and
 - b. be multistage with a minimum of two compressors.
13. The water-cooled chiller shall have an IPLV efficiency that is a minimum of 10% greater than the IPLV requirements in Table C403.2.3(7) (1.10 x IPLV values in Table C403.2.3(7)).
14. The water-cooled chiller shall have an IPLV efficiency that is a minimum of 15% greater than the IPLV requirements in Table C403.2.3(7), (1.15 x IPLV values in Table C403.2.3(7)).
15. Economizer cooling shall be provided by adding a plate-frame heat exchanger on the waterside with a capacity that is a minimum of 20% of the chiller capacity at standard AHRI rating conditions.
16. The replacement boiler shall have an efficiency that is a minimum of 8% higher than the value in Table C403.2.3(5) (1.08 x value in Table C403.2.3(5)), except for electric boilers.

SECTION C504 REPAIRS

C504.1 General. Buildings and structures, and parts thereof, shall be repaired in compliance with Section C501.3 and this section. Work on nondamaged components that is necessary for the required *repair* of damaged components shall be considered part of the *repair* and shall not be subject to the requirements for *alterations* in this chapter. Routine maintenance required by Section C501.3, ordinary repairs exempt from *permit*, and abatement of wear due to normal service conditions shall not be subject to the requirements for *repairs* in this section.

C504.2 Application. For the purposes of this code, the following shall be considered repairs.

1. Glass only replacements in an existing sash and frame.
2. *Roof repairs.*
3. Air barriers shall not be required for *roof repair* where the repairs to the building do not include *alterations*, renovations or *repairs* to the remainder of the building envelope.
4. Replacement of existing doors that separate conditioned space from the exterior shall not require the installation of a vestibule or revolving door, provided however that an existing vestibule that separates a conditioned space from the exterior shall not be removed.
5. *Repairs* where only the bulb and/or ballast within the existing luminaires in a space are replaced provided that the replacement does not increase the installed interior lighting power.

SECTION C505 CHANGE OF OCCUPANCY OR USE

C505.1 General. Spaces undergoing a change in occupancy shall be brought up to full compliance with this code in the following cases:

1. Any space that is converted from an F, S or U occupancy to an occupancy other than F, S or U.
2. Any space that is converted to a Group R dwelling unit or portion thereof, from another use or occupancy.
3. Any Group R dwelling unit or portion thereof permitted prior to July 1, 2002, that is converted to a commercial use or occupancy.

Where the use in a space changes from one use in Table C405.4.2 (1) or (2) to another use in Table C405.4.2 (1) or (2), the installed lighting wattage shall comply with Section C405.4.

Exception: Where the component performance alternative in Section C402.1.5 is used to comply with this section, the Proposed Total Envelope UA is allowed to be up to 110 percent of the Allowed Total Envelope UA. Where the total building performance option in Section C407 is used to comply with this section, the annual energy consumption of the proposed design is allowed to be 110 percent of the annual energy consumption otherwise allowed by Section C407.3.

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CHAPTER 6

REFERENCED STANDARDS

This chapter lists the standards that are referenced in various sections of this document. The standards are listed herein by the promulgating agency of the standard, the standard identification, the effective date and title, and the section or sections of this document that reference the standard. The application of the referenced standards shall be as specified in Section 106.

AAMA

American Architectural Manufacturers Association
1827 Walden Office Square
Suite 550
Schaumburg, IL 60173-4268

Standard reference number	Title	Referenced in code section number
AAMA/WDMA/CSA 101/1.S.2/A C440—11	North American Fenestration Standard/ Specifications for Windows, Doors and Unit Skylights	Table C402.4.3

AHAM

Association of Home Appliance Manufacturers
1111 19th Street, NW, Suite 402
Washington, DC 20036

Standard reference number	Title	Referenced in code section number
ANSI/ AHAM RAC-1—2008	Room Air Conditioners	Table C403.2.3(3)

AHRI

Air Conditioning, Heating, and Refrigeration Institute
4100 North Fairfax Drive
Suite 200
Arlington, VA 22203

Standard reference number	Title	Referenced in code section number
ISO/AHRI/ASHRAE 13256-1 (2011)	Water-source Heat Pumps—Testing and Rating for Performance— Part 1: Water-to-air and Brine-to-air Heat Pumps	Table C403.2.3(2)
ISO/AHRI/ASHRAE 13256-2 (2011)	Water-source Heat Pumps—Testing and Rating for Performance— Part 2: Water-to-water and Brine-to-water Heat Pumps	Table C403.2.3(2)
210/240—08	Unitary Air Conditioning and Air-source Heat Pump Equipment.....	Table C403.2.3(1), Table C403.2.3(2)
310/380—04	Standard for Packaged Terminal Air Conditioners and Heat Pumps.....	Table C403.2.3(3)
340/360—2007	Commercial and Industrial Unitary Air-conditioning and Heat Pump Equipment.....	Table C403.2.3(1), Table C403.2.3(2)
365—09	Commercial and Industrial Unitary Air-conditioning Condensing Units	Table C403.2.3(1), Table C403.2.3(6)
390—2011	Performance Rating of Single Package Vertical Air Conditioners and Heat Pumps.....	Table C403.2.3(3)
400—01	Liquid to Liquid Heat Exchangers with Addendum 2	Table C403.2.3(9)
440—08	Room Fan Coil	C403.2.8
460—05	Performance Rating Remote Mechanical Draft Air-cooled Refrigerant Condensers	Table C403.2.3(8)
550/590—03	Water Chilling Packages Using the Vapor Compression Cycle—with Addenda.....	C403.2.3.1, Table C403.2.3(7), Table C406.2(6)
560—00	Absorption Water Chilling and Water-heating Packages	Table C403.2.3(7)
1160—08	Performance Rating of Heat Pump Pool Heaters	Table C404.2

AMCA

Air Movement and Control Association International
30 West University Drive
Arlington Heights, IL 60004-1806

Standard reference number	Title	Referenced in code section number
205-12	Energy Efficiency Classification for Fans.....	C403.2.11.3
220-08 (R2012)	Laboratory Methods of Testing Air Curtain Units	C402.5.6
500D—10	Laboratory Methods for Testing Dampers for Rating	C402.4.5.1, C402.4.5.2

ANSI

American National Standards Institute
25 West 43rd Street
Fourth Floor
New York, NY 10036

Standard reference number	Title	Referenced in code section number
Z21.10.3/CSA 4.3—11	Gas Water Heaters, Volume III—Storage Water Heaters with Input Ratings Above 75,000 Btu per Hour, Circulating Tank and Instantaneous	Table C404.2
Z21.47/CSA 2.3—12	Gas-fired Central Furnaces.....	Table C403.2.3(4), Table C406.2.(4)
Z83.8/CSA 2.6—09	Gas Unit Heaters, Gas Packaged Heaters, Gas Utility Heaters and Gas-fired Duct Furnaces	Table C403.2.3(4), Table C406.2.(4)

APSP

The Association of Pool and Spa Professionals
2111 Eisenhower Avenue
Alexandria, VA 22314

Standard reference number	Title	Referenced in code section number
14-11	American National Standard for Portable Electric Spa Efficiency	C404.8

ASHRAE

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle, NE
Atlanta, GA 30329-2305

Standard reference number	Title	Referenced in code section number
ANSI/ASHRAE/ACCA Standard 127-2007 Standard 183—2007	Method of Testing for Rating Computer and Data Processing Room Unitary Air Conditioners..... Peak Cooling and Heating Load Calculations in Buildings, Except Low-rise Residential Buildings	C403.4.1 C403.2.1 C403.2.1
ASHRAE—2012 ISO/AHRI/ASHRAE 13256-1 (2011)	ASHRAE HVAC Systems and Equipment Handbook—2004	C403.2.1
	Water-source Heat Pumps—Testing and Rating for Performance— Part 1: Water-to-air and Brine-to-air Heat Pumps	Table C403.2.3(2)
ISO/AHRI/ASHRAE 13256-2 (2011)	Water-source Heat Pumps—Testing and Rating for Performance— Part 2: Water-to-water and Brine-to-water Heat Pumps	Table C403.2.3(2)
90.1—2013	Energy Standard for Buildings Except Low-rise Residential Buildings.....	C401.2, C401.2.1, C402.1.1, Table C402.1.2, Table C402.2, Table C407.6.1
140—2011	Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs	C407.6.1
146—2011	Testing and Rating Pool Heaters	Table C404.2

ASME

American Society Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990

Standard reference number	Title	Referenced in code section number
ASME A17.1/ CSA B44—2013	Safety Code for Elevators and Escalators.....	C405.9.2

ASTM

ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428-2859

Standard reference number	Title	Referenced in code section number
C 90—13	Specification for Load-bearing Concrete Masonry Units	Table C402.2
C 1371—10	Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers	Table C402.2.1.1
C 1549—09	Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using A Portable Solar Reflectometer	Table C405.2.1.1
D 1003—11e1	Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics	C402.3.2.2
E 283—04	Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls and Doors Under Specified Pressure Differences Across the Specimen	Table C402.2.1.1, C402.4.1.2.2, Table C402.4.3, C402.4.4, C402.4.8
E 408—71(2008)	Test Methods for Total Normal Emittance of Surfaces Using Inspection-meter Techniques	Table C402.2.1.1
E 779—10	Standard Test Method for Determining Air Leakage Rate by Fan Pressurization	C402.4.1.2.3
E 903—96	Standard Test Method Solar Absorptance, Reflectance and Transmittance of Materials Using Integrating Spheres (Withdrawn 2005)	Table C402.2.1.1
E 1677—11	Standard Specification for an Air-retarder (AR) Material or System for Low-rise Framed Building Walls	C402.4.1.2.2
E 1918—06	Standard Test Method for Measuring Solar Reflectance of Horizontal or Low-sloped Surfaces in the Field	Table C402.2.1.1
E 1980—(2011)	Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-sloped Opaque Surfaces	Table C402.2.1.1
E 2178—13	Standard Test Method for Air Permanence of Building Materials	C402.4.1.2.1
E 2357—11	Standard Test Method for Determining Air Leakage of Air Barriers Assemblies	C404.1.2.2

CSA

Canadian Standards Association
5060 Spectrum Way
Mississauga, Ontario, Canada L4W 5N6

Standard reference number	Title	Referenced in code section number
AAMA/WDMA/CSA 101/1.S.2/A440—11	North American Fenestration Standard/Specification for Windows, Doors and Unit Skylights	Table C402.5.2
CSA B55.1—2012	Test Method for Measuring Efficiency and Pressure Loss of DWHR Units	C404.8
CSA B55.2—2012	Drain Water Heat Recovery Units	C404.8

CTI

Cooling Technology Institute
2611 FM 1960 West, Suite A-101
Houston, TX 77068

Standard reference number	Title	Referenced in code section number
ATC 105 (00)	Acceptance Test Code for Water Cooling Tower	Table C403.2.3(8)
ATC 105S—2011	Acceptance Test Code for Closed Circuit Cooling Towers	Table C403.2.3(8)
ATC 106—2011	Acceptance Test for Mechanical Draft Evaporative Vapor Condensers	Table C403.2.3(8)
STD 201—09	Standard for Certification of Water Cooling Towers Thermal Performances	Table C403.2.3(8)

DASMA

Door and Access Systems Manufacturers Association
1300 Sumner Avenue
Cleveland, OH 44115-2851

Standard reference number	Title	Referenced in code section number
105—92 (R2004)—13	Test Method for Thermal Transmittance and Air Infiltration of Garage Doors.....	Table C402.5.2

DOE

U.S. Department of Energy
c/o Superintendent of Documents
U.S. Government Printing Office
Washington, DC 20402-9325

Standard reference number	Title	Referenced in code section number
10 CFR, Part 430—1998	Energy Conservation Program for Consumer Products: Test Procedures and Certification and Enforcement Requirement for Plumbing Products; and Certification and Enforcement Requirements for Residential Appliances; Final Rule	Table C403.2.3(4), Table C403.2.3(5), Table C404.2, Table C406.2(4), Table C406.2(5)
10 CFR, Part 430, Subpart B, Appendix N—1998	Uniform Test Method for Measuring the Energy Consumption of Furnaces and Boilers	
10 CFR, Part 431—2004	Energy Efficiency Program for Certain Commercial and Industrial Equipment: Test Procedures and Efficiency Standards; Final Rules	Table C403.2.3(5), Table C406.2(5)
NAECA 87—(88)	National Appliance Energy Conservation Act 1987 [(Public Law 100-12 (with Amendments of 1988-P.L. 100-357)).....	Tables C403.2.3(1), (2), (4)

IAPMO

International Association of Plumbing and Mechanical Officials
4755 E. Philadelphia Street
Ontario, CA 91761

Standard reference number	Title	Referenced in code section number
UPC—2015	Uniform Plumbing Code	C201.3

ICC

International Code Council, Inc.
500 New Jersey Avenue, NW
6th Floor
Washington, DC 20001

Standard reference number	Title	Referenced in code section number
IBC—15	International Building Code	C201.3, C303.2, C402.4.4
IFC—15	International Fire Code	C201.3
IFGC—15	International Fuel Gas Code.....	C201.3
IMC—15	International Mechanical Code.....	C403.2.5, C403.2.5.1, C403.2.6, C403.2.7, C403.2.7.1, C403.2.7.1.1, C403.2.7.1.2, C403.2.7.1.3, C403.4.5, C408.2.2.1

IEEE

The Institute of Electrical and Electronic Engineers
Three Park Avenue
New York, NY 10016

Standard reference number	Title	Referenced in code section number
IEEE 515.1—2012	Standard for the Testing, Design, Installation and Maintenance of Electrical Resistance Trace Heating for Commercial Applications	C404.6.2

IESNA

Illuminating Engineering Society of North America
120 Wall Street, 17th Floor
New York, NY 10005-4001

Standard reference number	Title	Referenced in code section number
ANSI/ASHRAE/IESNA 90.1—2013	Energy Standard for Buildings Except Low-rise Residential Buildings	C401.2, C401.2.1, C402.1.1, Table C402.1.2, Table C402.2, Table C407.6.1

ISO

International Organization for Standardization
1, rue de Varembe, Case postale 56, CH-1211
Geneva, Switzerland

Standard reference number	Title	Referenced in code section number
ISO/AHRI/ASHRAE 13256-1 (2011)	Water-source Heat Pumps—Testing and Rating for Performance— Part 1: Water-to-air and Brine-to-air Heat Pumps	C403.2.3(2)
ISO/AHRI/ASHRAE 13256-2 (2011)	Water-Source Heat Pumps—Testing and Rating for Performance— Part 2: Water-to-water and Brine-to-water Heat Pumps	C403.2.3(2)

NEMA

National Electric Manufacturer's Association
1300 North 17th Street
Suite 1753
Rosslyn, VA 22209

Standard reference number	Title	Referenced in code section number
TP-1-2002	Guide for Determining Energy Efficiency for Distribution Transformers	C405.9
MG1-1993	Motors and Generators	C202

NFRC

National Fenestration Rating Council, Inc.
6305 Ivy Lane, Suite 140
Greenbelt, MD 20770

Standard reference number	Title	Referenced in code section number
100—2009	Procedure for Determining Fenestration Products U-factors—Second Edition	C303.1.2, C402.2.1
200—2009	Procedure for Determining Fenestration Product Solar Heat Gain Coefficients and Visible Transmittance at Normal Incidence—Second Edition	C303.1.3, C402
400—2009	Procedure for Determining Fenestration Product Air Leakage—Second Edition	Table C402.4.3

SMACNA

Sheet Metal and Air Conditioning Contractors National Association, Inc.
4021 Lafayette Center Drive
Chantilly, VA 20151-1209

Standard reference number	Title	Referenced in code section number
SMACNA—2012	HVAC Air Duct Leakage Test Manual	C403.2.7.1.3

UL

Underwriters Laboratories
333 Pfingsten Road
Northbrook, IL 60062-2096

Standard reference number	Title	Referenced in code section number
710—12	Exhaust Hoods for Commercial Cooking Equipment	C403.2.8
727—06	Oil-fired Central Furnaces—with Revisions through April 2010.....	Table C403.2.3(4), Table C406.2(4)
731—95	Oil-fired Unit Heaters—with Revisions through April 2010.....	Table C403.2.3(4), Table C406.2(4)
1784—01 (R2009)	Air Leakage Tests of Door Assemblies	C402.5.3

US-FTC

United States-Federal Trade Commission
600 Pennsylvania Avenue NW
Washington, DC 20580

Standard reference number	Title	Referenced in code section number
CFR Title 16 (May 31, 2005)	R-value Rule	C303.1.4

WDMA

Window and Door Manufacturers Association
1400 East Touhy Avenue, Suite 470
Des Plaines, IL 60018

Standard reference number	Title	Referenced in code section number
AAMA/WDMA/CSA 101/I.S.2/A440—11	North American Fenestration Standard/Specification for Windows, Doors and Unit Skylights	Table C402.4.3