

2017

CITY OF BOULDER ENERGY CONSERVATION CODE



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First Printing: March 2017
Second Printing: October 2017

ISBN: 978-1-60983-701-3

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PRINTED IN THE U.S.A.

PREFACE

Introduction

The 2017 *City of Boulder Energy Conservation Code* (COBECC) prescribes minimum energy efficiency and conservation standards for new buildings and for additions and alterations to existing buildings. The requirements of the COBECC are intended to promote public health, safety and welfare by requiring design and construction of buildings in the City of Boulder consistent with the city's energy, climate and sustainability goals; national safety standards and best practices for engineering and construction technology.

The COBECC introduces new energy efficiency measures and improves the energy performance requirements for residential buildings and prescriptive requirements for commercial buildings.

The COBECC is based on the 2012 edition of the *International Energy Conservation Code*® (IECC®), published by the International Code Council® (ICC®), and incorporates local amendments to the model code. In the past, the City of Boulder has adopted various editions of the IECC with local amendments to the model code set forth in Chapter 10, "Structures," of the Boulder Revised Code (B.R.C.) 1981. This new COBECC is more user-friendly than previous energy code adoptions and their local amendments because it eliminates portions of the model code that do not apply to Boulder and incorporates Boulder's local energy conservation requirements in one document.

Since 1996, the city has adopted local amendments to the IECC to impose more stringent energy efficiency requirements than the model code. Like previous local amendments, the COBECC imposes more stringent energy efficiency requirements than the model code. The COBECC requirements support the climate commitment goals adopted by City Council on Dec. 6, 2016:

- 80 percent reduction of the community's greenhouse gas emissions below 2005 levels by 2050,
- 100 percent renewable electricity by 2030, and
- 80 percent reduction in organizational greenhouse gas emissions below 2008 levels by 2030.

In support of these goals, Boulder has set a target of reaching net zero energy construction for new buildings and major alterations through building and energy code requirements by 2031. Boulder has developed a strategy to achieve that target; adopting increasingly aggressive energy codes is a key part of the strategy.

Adoption

The 2017 *City of Boulder Energy Conservation Code* was adopted at third reading by the City Council of the City of Boulder on March 7, 2017, with the passage of City of Boulder Ordinance No. 8166, and amended on October 3, 2017, with passage of City of Boulder Ordinance No. 8209.

Information regarding the adoption of Ordinance No. 8166 can be reviewed at the City of Boulder Central Records Office as part of the City Council agenda materials for Feb. 7, 2017; Feb. 21, 2017; March 7, 2017; and October 3, 2017.

Marginal Markings

- || = Indicates a City of Boulder amendment has been made to the 2012 *International Energy Conservation Code*.
- > = Indicates model code language deleted by the City of Boulder.

Italicized Terms

Selected terms set forth in Chapter 2, Definitions, for both the Commercial and Residential Provisions are italicized where they appear in code text. Such terms are not italicized where the definition set forth in Chapter 2 does not impart the intended meaning in the use of the term. The terms selected have definitions which the user should read carefully to facilitate better understanding of the code.

Effective Use of the City of Boulder Energy Conservation Code

The 2017 *City of Boulder Energy Conservation Code* (2017 COBECC) is a code that regulates minimum energy conservation requirements for new buildings. This code addresses energy conservation requirements for all aspects of energy uses in both commercial and residential construction, including heating and ventilating, lighting, water heating, and power usage for appliances and building systems.

This code is a design document. For example, before one constructs a building, the designer must determine the minimum insulation *R*-values and fenestration *U*-factors for the building exterior envelope. Depending on whether the building is for residential use or for commercial use, this code sets forth minimum requirements for exterior envelope insulation, window and door *U*-factors and SHGC ratings, duct insulation, lighting and power efficiency, and water distribution insulation.

Arrangement and Format of the 2017 COBECC

The COBECC contains two separate sets of provisions—one for commercial buildings and one for residential buildings. Each set of provisions are applied separately to buildings within their scope. The Commercial Provisions apply to all buildings except for residential buildings. The Residential Provisions apply to detached one- and two-family dwelling units, attached multiple single-family dwelling units with a separate means of egress from each dwelling unit and no common area in the building, and Group R-3 and R-4 buildings three stories or less in height. These scopes are based on the definitions of “commercial building” and “residential building,” respectively, in Chapter 2 of each set of provisions. Note that the Commercial Provisions therefore contain provisions for multi-family buildings. Each set of provisions is divided into four different parts:

Chapters	Subjects
1–2	Administration and definitions
3	General materials requirements
4	Energy efficiency requirements
5	Referenced standards

The following is a chapter-by-chapter synopsis of the scope and intent of the provisions of the 2017 *City of Boulder Energy Conservation Code* and applies to both the commercial and residential energy provisions:

Chapter 1 Administration. This chapter contains provisions for the application, enforcement and administration of subsequent requirements of the code. In addition to establishing the scope of the code, Chapter 1 identifies which buildings and structures come under its purview. Chapter 1 is largely concerned with maintaining “due process of law” in enforcing the energy conservation criteria contained in the body of the code. Only through careful observation of the administrative provisions can the building official reasonably expect to demonstrate that “equal protection under the law” has been provided.

Chapter 2 Definitions. All terms that are defined in the code are listed alphabetically in Chapter 2. While a defined term may be used in one chapter or another, the meaning provided in Chapter 2 is applicable throughout the code.

Where understanding of a term’s definition is especially key to or necessary for understanding of a particular code provision, the term is shown in *italics* wherever it appears in the code. This is true only for those terms that have a meaning that is unique to the code. In other words, the generally understood meaning of a term or phrase might not be sufficient or consistent with the meaning prescribed by the code; therefore, it is essential that the code-defined meaning be known.

Guidance regarding tense, gender and plurality of defined terms as well as guidance regarding terms not defined in this code is provided.

Chapter 3 General Requirements. Chapter 3 provides interior design conditions that are used as a basis for assumptions in heating and cooling load calculations, and provides basic material requirements for insulation materials and fenestration materials.

Chapter 4 Energy Efficiency. Chapter 4 of each set of provisions contains the technical requirements for energy efficiency.

Commercial Energy Efficiency. Chapter 4 of the Commercial Provisions contains the energy-efficiency-related requirements for the design and construction of most types of commercial buildings and multifamily buildings that are not included in the definition of residential buildings. Residential buildings, as defined in this code, are covered in the Residential Provisions. This chapter defines requirements for the portions of the building and building systems that impact energy use in new commercial construction and promotes the effective use of energy. The provisions within the chapter promote energy efficiency in the building envelope, the heating and cooling system and the service water heating system of the building.

Residential Energy Efficiency. Chapter 4 of the Residential Provisions contains the energy-efficiency-related requirements for the design and construction of residential buildings regulated under this code. It should be noted that the definition of a *residential building* in this code is unique for this code. In this code, a *residential building* includes detached one- and two-family dwelling units, attached multiple single-family dwelling units with a separate means of egress and no common area in the building, and a Group R-3 or R-4 building three stories or less in height. All other buildings are regulated by the energy conservation requirements in the Commercial Provisions. The applicable portions of a residential building must comply with the provisions within this chapter for energy efficiency. This chapter defines requirements for the portions of the building and building systems that impact energy use in new residential construction and promotes the effective use of energy. The provisions within the chapter promote energy efficiency in the building envelope, the heating and cooling system and the service water heating system of the building.

Chapter 5 Referenced Standards. The code contains numerous references to standards that are used to regulate materials and methods of construction. Chapter 5 contains a comprehensive list of all standards that are referenced in the code. The standards are part of the code to the extent of the reference to the standard. Compliance with the referenced standard is necessary for compliance with this code. By providing specifically adopted standards, the construction and installation requirements necessary for compliance with the code can be readily determined. The basis for code compliance is, therefore, established and available on an equal basis to the code official, contractor, designer and owner.

Chapter 5 is organized in a manner that makes it easy to locate specific standards. It lists all of the referenced standards, alphabetically, by acronym of the promulgating agency of the standard. Each agency's standards are then listed in either alphabetical or numeric order based upon the standard identification. The list also contains the title of the standard; the edition (date) of the standard referenced; any addenda included as part of the ICC adoption; and the section or sections of this code that reference the standard.

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CHAPTER 1

SCOPE AND ADMINISTRATION

PART 1—SCOPE AND APPLICATION

SECTION C101 SCOPE AND GENERAL REQUIREMENTS

C101.1 Title. This code shall be known as the 2017 *City of Boulder Energy Conservation 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.

C101.3 Intent. This code shall regulate the design and construction of buildings for the effective use and conservation of energy over the useful 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 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.

C101.4.2 Historic buildings. Any building or structure that is listed in the State or National Register of Historic Places; locally designated as an individual landmark; 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 in the National or State Registers of Historic Places either individually or as a contributing building or structure to a historic district by the State Historic Preservation Officer or the Keeper of the National Register of Historic Places; or has been found, through a historic building inventory, to be eligible for local designation as a landmark or to be listed as a contributing building or structure to a local historic district, shall comply with the requirements of this code. The *code official* may approve an alteration or modification to the requirements of this code where the requirement would have a detrimental impact on the special character or special historical, architectural, aesthetic interest or value of the building or structure individually or of the historic district to which the building or structure is contributing or, if the alteration would require a landmark alteration certificate under Chapter 9-11, “Historic Preservation,” B.R.C.

1981, but would not meet the applicable standards of Section 9-11-18, “Standards for Landmark Alteration Certificate Applications,” B.R.C. 1981.

C101.4.3 Additions, alterations, or repairs. Additions, alterations, or repairs 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(s) of the existing building or building system to comply with this code except where explicitly required in this code. Additions, alterations, or repairs 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.

Exception: The following need not comply provided the energy use of the building is not increased:

1. Storm windows installed over existing fenestration.
2. Glass only replacements in an existing sash and frame.
3. Construction where the existing roof, wall or floor cavity is not exposed.
4. Reroofing for roofs where neither the sheathing nor the insulation is exposed. Roofs without insulation in the cavity and where the sheathing or insulation is exposed during reroofing shall be insulated either above or below the sheathing.
5. 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,
6. Alterations that replace less than 50 percent of the luminaires in a space, provided that such alterations do not increase the installed interior lighting power.
7. Alterations that replace only the bulb and ballast within the existing luminaires in a space provided that the *alteration* does not increase the installed interior lighting power.

C101.4.4 Change in occupancy or use. Spaces undergoing a change in occupancy that would result in an increase in demand for either fossil fuel or electrical energy shall comply with this code. Where the use in a space changes from one use in Table C405.5.2(1) to another use in Table C405.5.2(1), the installed lighting wattage shall comply with Section C405.5.

C101.4.5 Change in space conditioning. Any nonconditioned space that is altered to become *conditioned space*

shall be required to be brought into full compliance with this code.

C101.4.6 Mixed occupancy. Where a building includes both *residential* and *commercial* occupancies, the building shall meet the requirements of this code for *commercial buildings*.

C101.5 Compliance. *Residential buildings* shall meet the Residential Provisions of this code, Sections R101 through R404. *Commercial buildings* shall meet the Commercial Provisions of this code, Sections C101 through C407.

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.

C101.5.2 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 the *building thermal envelope* provisions of this code:

1. Those 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*.

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.

C102.1.1 Above code programs. The *code official* or other authority having jurisdiction shall be permitted to deem a national, state or local energy efficiency program to exceed the energy efficiency required by this code. Buildings *approved* in writing by such an energy efficiency program shall be considered in compliance with this code. The requirements identified as “mandatory” in Chapter 4 shall be met.

PART 2—ADMINISTRATION AND ENFORCEMENT

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 and designs submitted under the provisions of this code shall be prepared by and bear the stamp of a Colorado licensed professional engineer or architect. Where special conditions

exist, the *code official* is authorized to require additional construction documents to be prepared by a Colorado licensed professional engineer or architect.

Exception: The *code official* may waive the submission of construction documents and other supporting data if the official finds that the nature of the work does not require review of the documents or data to obtain compliance. This waiver authority does not apply to documents required to be prepared by a Colorado licensed architect or engineer.

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, insulation materials and their *R*-values; fenestration *U*-factors and SHGCs; area-weighted *U*-factor and SHGC calculations; mechanical system design criteria; mechanical and service water heating system and equipment types, sizes and efficiencies; economizer description; equipment and systems controls; fan motor horsepower (hp) and controls; duct sealing, duct and pipe insulation and location; lighting fixture schedule with wattage and control narrative; air sealing details; and any details related to energy savings modeled in the performance modeling described in Section C401.2.

SECTION C104 INSPECTIONS

C104.1 General. Construction or work for which a permit is required shall be subject to inspection by the *code official*.

C104.2 Required approvals. Work shall not be done beyond the point indicated in each successive inspection without first obtaining the approval of the *code official*. The *code official*, upon notification, shall make the requested inspections and shall either indicate the portion of the construction that is satisfactory as completed, or notify the permit holder or his or her agent wherein the same fails to comply with this code. Any portions that do not comply shall be corrected and such portion shall not be covered or concealed until authorized by the *code official*.

C104.3 Final inspection. The building shall have a final inspection and not be occupied until *approved*. The applicant must provide at time of final inspection of a commercial building written verification that bears the stamp of a licensed architect or engineer or special inspector as described in Section 107.3.4 of the Building Code of the City of Boulder that the structure conforms with the provisions of Chapter 4.

C104.4 Reinspection. A building shall be reinspected when determined necessary by the *code official*.

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 conflicts 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 Conflicting requirements. Where the provisions of this code and the referenced standards conflict, the provisions of this code shall take precedence.

C106.3 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.

C106.4 Other laws. The provisions of this code shall not be deemed to nullify any provisions of local, state or federal law. This code is intended to comply with and be interpreted and enforced so as to comply with 42 U.S.C. Section 6297(f)(3) and any other federal requirements to avoid pre-emption. For purposes of 42 U.S.C. Section 6297(f)(3), “new construction” shall be interpreted to include all work that triggers the requirements established in this code.

SECTION C107 ADMINISTRATION

C107.1 Administration. This code shall be administered in accordance with and as part of Chapter 10-5, “Building Code,” B.R.C. 1981.

CHAPTER 2

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*, *International 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

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.

ALTERATION. Any construction or renovation to an existing structure other than repair or addition that requires a permit. Also, a change in a mechanical 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*.

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”).

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 basement walls, exterior walls, floor, roof, and any other building elements that enclose *conditioned space* or provides a boundary between *conditioned 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 ($\text{Btu/h ft}^2 \times ^\circ\text{F}$) [$\text{W}/(\text{m}^2 \times \text{K})$].

CODE OFFICIAL. The code official is the city manager.

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 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 that are not included in the definition of “Residential buildings.”

CONDITIONED FLOOR AREA. The *floor area* associated with the *conditioned space*.

CONDITIONED SPACE. An area or room within a building being heated or cooled, containing uninsulated ducts, or with a fixed opening directly into an adjacent *conditioned space*.

CONSTRUCTION VALUATION. The total value of work requiring building, mechanical, plumbing and electrical permits, to be determined consistent with the standards of Subsection 4-20-4(d), B.R.C. 1981. The higher of the two valuations considered under Subsection 4-20-4(d), B.R.C. 1981, shall be the total value of work.

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

DEFINITIONS

CRAWL SPACE WALL. The opaque portion of a wall that encloses a crawl space and is partially or totally below grade.

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

DAYLIGHT ZONE.

1. **Under skylights.** The area under skylights whose horizontal dimension, in each direction, is equal to the skylight dimension in that direction plus either the floor-to-ceiling height or the dimension to a ceiling height opaque partition, or one-half the distance to adjacent skylights or vertical fenestration, whichever is least.
2. **Adjacent to vertical fenestration.** The area adjacent to vertical fenestration which receives daylight through the fenestration. For purposes of this definition and unless more detailed analysis is provided, the daylight *zone* depth is assumed to extend into the space a distance of 15 feet (4572 mm) or to the nearest ceiling height opaque partition, whichever is less. The daylight *zone* width is assumed to be the width of the window plus 2 feet (610 mm) on each side, or the window width plus the distance to an opaque partition, or the window width plus one-half the distance to adjacent skylight or vertical fenestration, whichever is least.

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 pump(s) prime the service hot water piping with heated water upon demand for hot water.

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.

[B] 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 openable devices such as doors and operable windows.

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.

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 basement 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 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. Skylights, roof windows, vertical windows (fixed or moveable), opaque doors, glazed doors, glazed block and combination opaque/glazed doors. Fenestration includes products with glass and nonglass glazing materials.

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-assem-

bled 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 \times ft \times °F) [W/(m \times K)].

FLOOR AREA. The total square footage of all levels as measured from the inside finished surface of the walls, but excluding courts, unconditioned garages, and uninhabitable crawl spaces and attics.

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 Btu's per year.

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

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

HEATED SLAB. Slab-on-grade 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-EFFICACY LAMPS. Compact fluorescent lamps, T-8 or smaller diameter linear fluorescent lamps, or lamps with a minimum efficacy of:

1. 60 lumens per watt for lamps over 40 watts;
2. 50 lumens per watt for lamps over 15 watts to 40 watts; and
3. 40 lumens per watt for lamps 15 watts or less.

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.

INSULATING SHEATHING. An insulating board with a core material having a minimum *R*-value of *R*-2.

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.

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 SLOPE. Low slopes are defined as slopes up to and including 2:12 (rise:run).

LOW-VOLTAGE LIGHTING. Lighting equipment powered through a transformer such as a cable conductor, a rail conductor and track lighting.

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

MECHANICAL COOLING. Mechanical cooling is lowering the temperature within a space using refrigerant compressors or absorbers, desiccant dehumidifiers, or other systems that require energy to directly condition the space. In nonresidential, high-rise residential, and hotel/motel buildings, cooling of a space by direct or indirect evaporation of water alone is not considered mechanical cooling.

MECHANICAL HEATING. Mechanical heating is raising the temperature within a space using electric resistance heaters, fossil fuel burners, heat pumps, or other systems that require energy to directly condition the space.

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.

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.

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

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").

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

RESIDENTIAL BUILDING. For this code, includes detached one- and two-family *dwelling units*, attached multiple single-family *dwelling units* with a separate means of egress from each *dwelling unit* and no common area in the building, and Group R-3 and R-4 buildings three stories or less in height above grade plane, and accessory structures to such *residential buildings*.

ROOF ASSEMBLY. A system designed to provide weather protection and resistance to design loads. The system consists

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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.

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 ($h \times \text{ft}^2 \times ^\circ\text{F}/\text{Btu}$) [$(\text{m}^2 \times \text{K})/\text{W}$].

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

SERVICE WATER HEATING. Supply of hot water for purposes other than comfort heating.

SHADING. Shading is the protection from heat gains because of direct solar radiation by permanently attached exterior devices or building elements, interior shading devices, glazing material, or adherent materials.

SKYLIGHT. Glass or other transparent or translucent glazing material installed at a slope of less than 60 degrees (1.05 rad) from horizontal. Glazing material in skylights, including unit skylights, solariums, sunrooms, roofs and sloped walls is included in this definition.

SKYLIGHT AREA. Skylight area is the area of the rough opening for the skylight.

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*.

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 that is then reradiated, conducted or convected into the space.

SOLAR ZONE. A solar zone is a section of the roof designated and reserved for the future installation of a solar electric or solar thermal system.

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.

STANDARD TEST CONDITIONS. A fixed set of conditions for which PV module performance is rated. These conditions are 1000 W/m² incident solar radiation, 25°C cell temperature, 0.0 wind speed, and air mass 1.5 spectrum.

STEEP SLOPE. Steep slopes are defined as slopes greater than 2:12 (rise:run).

STOREFRONT. A nonresidential system of doors and windows mulled 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 mulled windows and doors.

SUNROOM. A one-story structure attached to a dwelling with a glazing area in excess of 40 percent of the gross area of the structure's exterior walls and roof.

THERMAL ISOLATION. Physical and space conditioning separation from *conditioned space(s)*. The *conditioned space(s)* shall be controlled as separate zones for heating and cooling or conditioned by separate equipment.

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

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 ($\text{Btu}/\text{h} \times \text{ft}^2 \times ^\circ\text{F}$) [$\text{W}/(\text{m}^2 \times \text{K})$].

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.

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.

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

GENERAL REQUIREMENTS

SECTION C301 DESIGN CONDITIONS

C301.1 Interior design conditions. The interior design temperatures used for heating and cooling load calculations shall be a maximum of 70°F (21°C) for heating and a minimum of 75°F (24°C) for cooling.

SECTION C302 MATERIALS, SYSTEMS AND EQUIPMENT

C302.1 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.

C302.1.1 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. The insulation installer shall sign, date and post the certification in a conspicuous location on the job site.

C302.1.1.1 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 a minimum of 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.

C302.1.2 Insulation mark installation. Insulating materials shall be installed such that the manufacturer's *R*-value mark is readily observable upon inspection.

C302.1.3 Fenestration product rating. *U*-factors of fenestration products (windows, doors and skylights) shall be determined in accordance with NFRC 100 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 C302.1.3(1) or C302.1.3(2). 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 C302.1.3(3).

C302.1.4 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 (CFR Title 16, Part 460) in units of h × ft² × °F/Btu at a mean temperature of 75°F (24°C).

C302.2 Installation. All materials, systems and equipment shall be installed in accordance with the manufacturer's installation instructions and the *International Building Code*.

C302.2.1 Protection of exposed foundation insulation. Insulation applied to the exterior of basement walls, crawl-space 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 a minimum of 6 inches (153 mm) below grade.

C302.3 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 C302.1.3(1)
DEFAULT GLAZED FENESTRATION *U*-FACTOR

FRAME TYPE	SINGLE PANE	DOUBLE PANE	SKYLIGHT	
			Single	Double
Metal	1.20	0.80	2.00	1.30
Metal with Thermal Break	1.10	0.65	1.90	1.10
Nonmetal or Metal Clad	0.95	0.55	1.75	1.05
Glazed Block	0.60			

GENERAL REQUIREMENTS

TABLE C302.1.3(2)
DEFAULT DOOR *U*-FACTORS

DOOR TYPE	<i>U</i> -FACTOR
Uninsulated Metal	1.20
Insulated Metal	0.60
Wood	0.50
Insulated, nonmetal edge, max 45% glazing, any glazing double pane	0.35

TABLE C302.1.3(3)
DEFAULT GLAZED FENESTRATION SHGC AND VT

	SINGLE GLAZED		DOUBLE GLAZED		GLAZED BLOCK
	Clear	Tinted	Clear	Tinted	
SHGC	0.8	0.7	0.7	0.6	0.6
VT	0.6	0.3	0.6	0.3	0.6

CHAPTER 4

COMMERCIAL ENERGY EFFICIENCY

SECTION C401 GENERAL

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

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

C401.2.1 Application to new buildings and additions. New buildings and *additions* to existing buildings shall comply with the following:

1. New buildings and *additions* with a *construction valuation* of \$500,000 or more shall have annual energy operating costs for the *proposed design* that are at least 30 percent less than the *standard reference design* of Appendix G of ASHRAE/IESNA Standard 90.1-2010 Energy Standard for Buildings Except for Low-rise Residential Buildings. Compliance shall be demonstrated through performance modeling that complies with all requirements of ASHRAE 90.1-2010 Appendix G, performed by a *registered design professional*. In addition, new buildings and additions shall comply with all mandatory requirements of this chapter.
 - 1.1. Commercial core and shell buildings may take credit for energy efficiency that is part of the future interior tenant finish design provided the efficiency measures are shown on the final tenant build-out drawings. The *code official* will issue a temporary certificate of occupancy until the final tenant drawings are submitted showing the efficiency measures. If all efficiency measures are shown on the final tenant drawings, a permanent certificate of occupancy will be issued.

2. New buildings and *additions* with a *construction valuation* less than \$500,000 shall comply with Sections C402, C403, C404, C405, C406, and C407.

C401.2.2 Application to alterations and repairs. *Alterations* and *repairs* to existing buildings shall comply with all mandatory requirements of this chapter and the requirements specified in Table C401.2.2. The applicable requirements in Table C401.2.2 are determined by *construction valuation*.

SECTION C402 BUILDING ENVELOPE REQUIREMENTS

C402.1 General (Prescriptive). The building thermal envelope shall comply with Section C402.1.1. Section C402.1.2 shall be permitted as an alternative to the *R*-values specified in Section C402.1.1.

C402.1.1 Insulation and fenestration criteria. The *building thermal envelope* shall meet the requirements of Tables C402.2 and C402.3. *Commercial buildings* or portions of *commercial buildings* enclosing Group R occupancies shall use the *R*-values from the “Group R” column of Table C402.2. *Commercial buildings* or portions of *commercial buildings* enclosing occupancies other than Group R shall use the *R*-values from the “All other” column of Table C402.2.

C402.1.2 U-factor alternative. An assembly with a *U*-factor, *C*-factor, or *F*-factor equal or less than that specified in Table C402.1.2 shall be permitted as an alternative to the *R*-value in Table C402.2. *Commercial buildings* or portions of *commercial buildings* enclosing Group R occupancies shall use the *U*-factor, *C*-factor, or *F*-factor from the “Group R” column of Table C402.1.2. *Commercial buildings* or portions of *commercial buildings* enclosing occupancies other than Group R shall use the *U*-factor, *C*-factor or *F*-factor from the “All other” column of Table C402.1.2.

TABLE C401.2.2
ALTERATION AND REPAIR GENERAL ENERGY EFFICIENCY REQUIREMENTS

CONSTRUCTION VALUATION IS < 26% OF VALUE ^a OF EXISTING BUILDING	CONSTRUCTION VALUATION IS 26 – 50% OF VALUE ^a OF EXISTING BUILDING	CONSTRUCTION VALUATION IS > 50% OF VALUE ^a OF EXISTING BUILDING
All prescriptive requirements of this chapter for the scope of the <i>alteration</i> or <i>repair</i> .	The entire building shall have annual energy operating costs for the proposed design that are equal to or less than the standard reference design of Appendix G of ASHRAE/IESNA Standard 90.1-2010 Energy Standard for Buildings Except for Low-rise Residential Buildings. ^{b, c}	The entire building shall have annual energy operating costs for the proposed design that are at least 30% less than the standard reference design of Appendix G of ASHRAE/IESNA Standard 90.1-2010 Energy Standard for Buildings Except for Low-rise Residential Buildings. ^{b, c}

- a. The applicant shall demonstrate the value of the existing building by submitting the actual value of the structure determined by the Boulder County Assessor's Office or the fair market value of the building determined by a real estate appraiser licensed in Colorado. An appraisal by a licensed real estate appraiser shall include both a sales comparison approach and cost approach. The City of Boulder must be an authorized user of the appraisal. The appraisal is subject to review and approval by the city manager.
- b. These projects must demonstrate compliance through performance modeling that complies with all requirements of ASHRAE 90.1-2010 Appendix G, performed by a registered design professional.
- c. If the alteration or repair is limited to some but not all dwelling units, tenant spaces or common areas of a building, this energy performance requirement may be met by showing compliance for each dwelling unit, tenant space and common area being altered or repaired rather than compliance of the entire building.

TABLE C402.1.2
OPAQUE THERMAL ENVELOPE ASSEMBLY REQUIREMENTS^a

Roofs	
Insulation entirely above deck	U-0.030
Metal buildings	U-0.035
Attic and other	U-0.020
Walls, Above Grade	
Mass	U-0.078
Metal building	U-0.048
Metal framed	U-0.052
Wood framed and other	U-0.048
Walls, Below Grade	
Below-grade wall ^a	C-0.113
Floors	
Mass	U-0.054
Joist/framing	U-0.031
Slab-on-Grade Floors	
Unheated slabs	F-0.494
Heated slabs	F-0.58

a. Where heated slabs are below grade, below-grade walls shall comply with the *F*-factor requirements for heated slabs.

C402.2 Specific insulation requirements (Prescriptive). Opaque assemblies shall comply with Table C402.2. Where two or more layers of continuous insulation board are used in a construction assembly, the continuous insulation boards shall be installed in accordance with Section C302.2. 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.

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

Exceptions:

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

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

C402.2.2 Classification of walls. Walls associated with the building envelope shall be classified in accordance with Section C402.2.2.1 or C402.2.2.2.

C402.2.2.1 Above-grade walls. Above-grade walls are those walls covered by Section C402.2.3 on the exterior of the building and completely above grade or walls that are more than 15 percent above grade.

C402.2.2.2 Below-grade walls. Below-grade walls covered by Section C402.2.4 are basement or first-story walls associated with the exterior of the building that are at least 85 percent below grade.

TABLE C402.2
OPAQUE THERMAL ENVELOPE REQUIREMENTS^a

	All Other	Group R
Roofs		
Insulation entirely above deck	R-32.9ci	R-32.9ci
Metal buildings (with R-5 thermal blocks) ^{a, b}	R-19 + R-11 LS	R-19 + R-11 LS
Attic and other	R-50.1	R-50.1
Walls, Above Grade		
Mass ^c	R-12.8ci	R-13.3ci
Metal building	R-13 + R-13ci	R-13 + R-13ci
Metal framed	R-13 + R-8.1ci	R-13 + R-8.1ci
Wood framed and other	R-13 + R-6.1ci or R-20	R-13 + R-6.1ci or R-20
Walls, Below Grade		
Below-grade wall ^d	R-8.8ci	R-8.8ci
Floors		
Mass	R-18.5ci	R-18.5ci
Joist/framing	R-31.9	R-31.9
Slab-on-Grade Floors		
Unheated slabs	R-15 for 24" below	R-15 for 24" below
Heated slabs ^d	R-15 for 36" below	R-15 for 36" below
Opaque Doors		
Swinging	U-0.37	U-0.37
Roll-up or sliding	R-4.75	R-4.75

For SI: 1 inch = 25.4 mm. ci = Continuous insulation. NR = No requirement. LS = Liner System—A continuous membrane installed below the purlins and uninterrupted by framing members. Uncompressed, unfaced insulation rests on top of the membrane between the purlins.

- Assembly descriptions can be found in ANSI/ASHRAE/IESNA Appendix A.
- Where using *R*-value compliance method, a thermal spacer block shall be provided, otherwise use the *U*-factor compliance method in Table C402.1.2.
- R-5.7ci is allowed to be substituted with concrete block walls complying with ASTM C90, ungrouted or partially grouted at 32 inches or less on center vertically and 48 inches or less on center horizontally, with ungrouted cores filled with materials having a maximum thermal conductivity of 0.44 Btu-in/h-*f*² °F.
- Where heated slabs are below grade, below-grade walls shall comply with the exterior insulation requirements for heated slabs.

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

“Mass walls” shall include walls weighing not less than:

1. 35 psf (170 kg/m²) of wall surface area; or
2. 25 psf (120 kg/m²) of wall surface area if the material weight is not more than 120 pounds per cubic foot (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 C402.2, and shall extend to a depth of 10 feet (3048 mm) below the outside finished ground level, or to the level of the floor, whichever is less.

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

“Mass floors” shall include floors weighing not less than:

1. 35 psf (170 kg/m²) of floor surface area; or
2. 25 psf (120 kg/m²) of floor surface area if the material weight is not more than 120 pcf (1,900 kg/m³).

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

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

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

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

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

**TABLE C402.3
BUILDING ENVELOPE REQUIREMENTS: FENESTRATION**

Vertical fenestration	
U-factor	
Fixed fenestration	0.38
Operable fenestration	0.45
Entrance doors	0.73
SHGC	
SHGC	0.38
Skylights	
U-factor	0.475
SHGC	0.38

C402.3.1 Maximum area. The vertical fenestration area (not including opaque doors and opaque spandrel panels) shall not exceed 30 percent of the gross above-grade wall area. The skylight area shall not exceed 3 percent of the gross roof area.

C402.3.1.1 Increased vertical fenestration area with daylighting controls. A maximum of 40 percent of the gross above-grade wall area shall be permitted to be vertical fenestration, provided:

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

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

C402.3.1.2 Increased skylight area with daylighting controls. The skylight area shall be permitted to be a maximum of 5 percent of the roof area provided automatic daylighting controls are installed in daylight zones under skylights.

C402.3.2 Minimum skylight fenestration area. In an enclosed space greater than 10,000 square feet (929 m²), directly under a roof with ceiling heights greater than 15 feet (4572 mm), and used as an office, lobby, atrium, concourse, corridor, storage, gymnasium/exercise center, convention center, automotive service, manufacturing, non-refrigerated warehouse, retail store, distribution/sorting

area, transportation, or workshop, the total daylight zone under skylights shall be not less than half the floor area and shall provide a minimum skylight area to daylight zone under skylights of either:

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

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

(Equation C4-1)

where:

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

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

- 1. Spaces where the designed *general lighting* power densities are less than 0.5 W/ft² (5.4 W/m²).
- 2. Areas where it is documented that existing structures or natural objects block direct beam sunlight on at least half of the roof over the enclosed area for more than 1,500 daytime hours per year between 8 am and 4 pm.
- 3. Spaces where the daylight zone under rooftop monitors is greater than 50 percent of the enclosed space floor area.

C402.3.2.1 Lighting controls in daylight zones under skylights. All lighting in the daylight zone shall be controlled by multilevel lighting controls that comply with Section C405.2.2.3.3.

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

- 1. Spaces where the designed *general lighting* power densities are less than 0.5 W/ft² (5.4 W/m²).
- 2. Areas where it is documented that existing structures or natural objects block direct beam sunlight on at least half of the roof over the enclosed area for more than 1,500 daytime hours per year between 8 am and 4 pm.

- 3. Spaces where the daylight zone under rooftop monitors is greater than 50 percent of the enclosed space floor area.

C402.3.2.2 Haze factor. Skylights in office, storage, automotive service, manufacturing, nonrefrigerated warehouse, retail store, and distribution/sorting area spaces shall have a glazing material or diffuser with a measured haze factor greater than 90 percent when tested in accordance with ASTM D1003.

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

C402.3.3 Maximum U-factor and SHGC. For vertical fenestration, the maximum *U-factor* and *solar heat gain coefficient* (SHGC) shall be as specified in Table C402.3, based on the window projection factor. For skylights, the maximum *U-factor* and *solar heat gain coefficient* (SHGC) shall be as specified in Table C402.3.

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

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

where:

PF = Projection factor (decimal).

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

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

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

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

TABLE C402.3.3.1
SHGC ADJUSTMENT MULTIPLIERS

PROJECTION FACTOR	ORIENTED WITHIN 45 DEGREES OF TRUE NORTH	ALL OTHER ORIENTATION
0.2 ≤ PF < 0.5	1.1	1.2
PF ≥ 0.5	1.2	1.6

C402.3.3.2 Increased skylight SHGC. Skylights shall be permitted a maximum SHGC of 0.60 where located above daylight zones provided with automated daylighting controls.

C402.3.3.3 Increased skylight U-factor. Where skylights are installed above daylight zones provided with

- > automatic daylighting controls, a maximum *U*-factor of
 > 0.75 shall be permitted.

|| **C402.3.3.4 Dynamic glazing.** For compliance with Section C402.3.3, the SHGC for dynamic glazing shall be determined using the manufacturer's lowest-rated SHGC, and the VT/SHGC ratio shall be determined using the maximum VT and maximum SHGC. Dynamic glazing shall be considered separately from other fenestration, and area-weighted averaging with other fenestration that is not dynamic glazing shall not be permitted.

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

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

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

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

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

|| **Exception:** Buildings that comply with Section C402.4.1.2.1 are not required to comply with Items 1 and 3.

|| **C402.4.1.2 Air barrier compliance.** A continuous air barrier for the opaque building envelope shall comply with Section C402.4.1.2.1. In addition, all dwelling units must comply with C402.4.1.2.2.

> **C402.4.1.2.1 Commercial 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) in accordance with ASTM E779 or an equivalent method approved by the *code official*.

Testing and inspection shall be conducted by a third-party *registered design professional*. A written report of the test results shall be signed by the party conducting the test and provided to the *code official*. Testing shall be performed at any time after completion of all penetrations of the building thermal envelope.

C402.4.1.2.2 Dwelling unit air infiltration. A sampling of *dwelling units* shall be tested and the air leakage rate of each tested dwelling unit's enclosure surface area shall not exceed 0.25 cfm/ft² of surface area. For purposes of this section, enclosure surface area of a unit means the total surface area of all walls, floors, and ceiling. Testing shall be conducted with a blower door at a pressure of 0.2 inches water gauge (50 Pascals).

Testing and inspection shall be conducted by a third-party *registered design professional*. A written report of the test results shall be signed by the party conducting the test and provided to the *code official*. Testing shall be performed at any time after completion of all penetrations of the building thermal envelope.

The sampling of *dwelling units* tested shall include at least 20 percent of the dwelling units in each building, including at least one of each unit type (a unit type is distinct if it has a different floor plan or a different exterior exposure) and approximately an equal number of units on each floor level. Each of these units must be tested and pass without a failure. If a failure occurs, items causing the failure must be diagnosed, and corrected, and the unit retested until it passes. A minimum of at least two additional units of this type in the same building must also be tested and pass.

During testing:

1. Exterior windows and doors, fireplace doors and stove doors shall be closed, but not sealed beyond the intended weather stripping or other infiltration control measures.
2. Dampers, including exhaust, intake, makeup air, backdraft and flue dampers, shall be closed, but not sealed beyond intended infiltration control measures.
3. Interior doors, if installed at the time of the test, shall be open.
4. Exterior doors for continuous ventilation systems and heat recovery ventilators shall be closed and sealed.
5. Heating and cooling systems, if installed at the time of the test, shall be turned off.
6. Supply and return registers, if installed at the time of the test, shall be fully open.

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

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

Exceptions:

1. Field-fabricated fenestration assemblies that are sealed in accordance with Section C402.4.1.
2. Fenestration in buildings that comply with Section C402.4.1.2.1 are not required to meet the air leakage requirements in Table C402.4.3.

**TABLE C402.4.3
MAXIMUM AIR INFILTRATION RATE
FOR FENESTRATION ASSEMBLIES**

FENESTRATION ASSEMBLY	MAXIMUM RATE(CFM/FT ²)	TEST PROCEDURE
Windows	0.20 ^a	AAMA/WDMA/ CSA101/I.S.2/A440 or NFRC 400
Sliding doors	0.20 ^a	
Swinging doors	0.20 ^a	
Skylights – with condensation weepage openings	0.30	
Skylights – all other	0.20 ^a	
Curtain walls	0.06	NFRC 400 or ASTM E283 at 1.57 psf (75 Pa)
Storefront glazing	0.06	
Commercial glazed swinging entrance doors	1.00	
Revolving doors	1.00	
Garage doors	0.40	ANSI/DASMA 105, NFRC 400, or ASTM E283 at 1.57 psf (75 Pa)
Rolling doors	1.00	

For SI: 1 cubic foot per minute = 0.47L/s, 1 square foot = 0.093 m².

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

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

Exception: Door openings required to comply with Section 716 or 716.4 of the *International Building Code*; or doors and door openings required by the *Inter-*

national Building Code to comply with UL 1784 shall not be required to comply with Section C402.4.4.

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

C402.4.5.1 Stairway and shaft vents. Stairway and shaft vents shall be provided with Class I motorized dampers with a maximum leakage rate of 4 cfm/ft² (20.3 L/s × m²) at 1.0 inch water gauge (w.g.) (249 Pa) when tested in accordance with AMCA 500D.

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

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

C402.4.5.2 Outdoor air intakes and exhausts. *Outdoor air* supply and exhaust openings shall be provided with Class IA motorized dampers with 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.

Exceptions:

1. Gravity (nonmotorized) dampers having a maximum leakage rate of 20 cfm/ft² (101.6 L/s × m²) at 1.0 inch water gauge (w.g.) (249 Pa) when tested in accordance with AMCA 500D are permitted to be used as follows:
 - 1.1. In buildings for exhaust and relief dampers.
 - 1.2. In buildings less than three stories in height above grade.
 - 1.3. Where the design *outdoor air* intake or exhaust capacity does not exceed 300 cfm (141 L/s).
 - 1.4. Gravity (nonmotorized) dampers for ventilation air intakes shall be protected from direct exposure to wind.
2. Dampers smaller than 24 inches (610 mm) in either dimension shall be permitted to have a leakage of 40 cfm/ft² (203.2 L/s × m²) at 1.0 inch water gauge (w.g.) (249 Pa) when tested in accordance with AMCA 500D.

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

C402.4.7 Vestibules. All building entrances shall be protected with an enclosed vestibule, with all doors opening into and out of the vestibule equipped with self-closing devices. Vestibules shall be designed so that in passing through the vestibule it is not necessary for the interior and exterior doors to open at the same time. The installation of one or more

revolving doors in the building entrance shall not eliminate the requirement that a vestibule be provided on any doors adjacent to revolving doors.

Exceptions:

1. Doors not intended to be used by the public, such as doors to mechanical or electrical equipment rooms, or intended solely for employee use.
2. Doors opening directly from a *sleeping unit* or dwelling unit.
3. Doors that open directly from a space less than 3,000 square feet (298 m²) in area.
4. Revolving doors.
5. Doors used primarily to facilitate vehicular movement or material handling and adjacent personnel doors.

C402.4.8 Recessed lighting. Recessed luminaires installed in the *building thermal envelope* shall be sealed to limit air leakage between conditioned and unconditioned spaces. All recessed luminaires shall be IC-rated and *labeled* as having an air leakage rate of not more than 2.0 cfm (0.944 L/s) when tested in accordance with ASTM E283 at a 1.57 psf (75 Pa) pressure differential. All recessed luminaires shall be sealed with a gasket or caulk between the housing and interior wall or ceiling covering.

SECTION C403 BUILDING MECHANICAL SYSTEMS

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

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

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

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

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

Exceptions:

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

C403.2.3 HVAC equipment performance requirements (Prescriptive). Equipment shall meet the minimum efficiency requirements of Tables C403.2.3(1), C403.2.3(2), C403.2.3(3), C403.2.3(4), C403.2.3(5), C403.2.3(6), C403.2.3(7) and C403.2.3(8) when tested and rated in accordance with the applicable test procedure. Plate-type liquid-to-liquid heat exchangers shall meet the minimum requirements of Table C403.2.3(9). The efficiency shall be verified through certification 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.

C403.2.3.1 Water-cooled centrifugal chilling packages. Equipment not designed for operation at AHRI Standard 550/590 test conditions of 44°F (7°C) leaving chilled-water temperature and 85°F (29°C) entering condenser water temperature with 3 gpm/ton (0.054 l/s · kW) condenser water flow shall have maximum full-load kW/ton and *NPLV* ratings adjusted using Equations C4-3 and C4-4.

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

(Equation C4-3)

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

(Equation C4-4)

where:

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

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

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

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

$$L_{vg}^{\text{Cond}} = \text{Full-load condenser leaving water temperature } (^\circ\text{C})$$

$$L_{vg}^{\text{Evap}} = \text{Full-load leaving evaporator temperature } (^\circ\text{C})$$

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

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

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

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

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

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

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE ^a
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 11.0 IEER	
	< 65,000 Btu/h ^b	All	Split System and Single Package	12.1 EER 12.3 IEER	
Air conditioners, water cooled	≥ 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	12.0 EER 13.5 IEER	
		All other	Split System and Single Package	12.0 EER 13.3 IEER	
	< 65,000 Btu/h ^b	All	Split System and Single Package	12.1 EER 12.3 IEER	

(continued)

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

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE ^a
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	12.2 EER 11.9 IEER	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.7 EER 11.9 IEER	
		All other	Split System and Single Package	11.5 EER 11.7 IEER	
Condensing units, air cooled	≥ 135,000 Btu/h			10.5 EER 14.0 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(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 Package	14.0 SEER	
Through-the-wall, air cooled	≤ 30,000 Btu/h ^b	All	Split System	13.0 SEER	
			Single Package	13.0 SEER	
Single-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	
		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	
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	

(continued)

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

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE ^a
Air cooled (heating mode)	≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity)	—	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	

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

EQUIPMENT TYPE	SIZE CATEGORY (INPUT)	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE ^a
PTAC (cooling mode) new construction	All Capacities	95°F db outdoor air	13.8 - (0.300 × Cap/1000) EER	AHRI 310/380
PTAC (cooling mode) replacements ^b	All Capacities	95°F db outdoor air	10.9 - (0.213 × Cap/1000) EER	
PTHP (cooling mode) new construction	All Capacities	95°F db outdoor air	14.0 - (0.300 × Cap/1000) EER	
PTHP (cooling mode) replacements ^b	All Capacities	95°F db outdoor air	10.8 - (0.213 × Cap/1000) EER	
PTHP (heating mode) new construction	All Capacities	—	3.2 - (0.026 × Cap/1000) COP	
PTHP (heating mode) replacements ^b	All Capacities	—	2.9 - (0.026 × Cap/1000) COP	
SPVAC (cooling mode)	< 65,000 Btu/h	95°F db/ 75°F wb outdoor air	9.0 EER	AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h	95°F db/ 75°F wb outdoor air	8.9 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95°F db/ 75°F wb outdoor air	8.6 EER	
SPVHP (cooling mode)	< 65,000 Btu/h	95°F db/ 75°F wb outdoor air	9.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	95°F db/ 75°F wb outdoor air	8.9 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95°F db/ 75°F wb outdoor air	8.6 EER	
SPVHP (heating mode)	< 65,000 Btu/h	47°F db/ 43°F wb outdoor air	3.0 COP	AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h	47°F db/ 43°F wb outdoor air	3.0 COP	
	≥ 135,000 Btu/h and < 240,000 Btu/h	47°F db/ 75°F wb outdoor air	2.9 COP	

(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 conditioners, with louvered slides	< 6,000 Btu/h	—	9.7 SEER	ANSI/AHAM RAC-1
	≥ 6,000 Btu/h and < 8,000 Btu/h	—	9.7 EER	
	≥ 8,000 Btu/h and < 14,000 Btu/h	—	9.8 EER	
	≥ 14,000 Btu/h and < 20,000 Btu/h	—	9.7 SEER	
	≥ 20,000 Btu/h	—	8.5 EER	
Room air conditioners, without louvered slides	< 8,000 Btu/h	—	9.0 EER	
	≥ 8,000 Btu/h and < 20,000 Btu/h	—	8.5 EER	
	≥ 20,000 Btu/h	—	8.5 EER	
Room air-conditioner heat pumps with louvered sides	< 20,000 Btu/h	—	9.0 EER	
	≥ 20,000 Btu/h	—	8.5 EER	
Room air-conditioner heat pumps without louvered sides	< 14,000 Btu/h	—	8.5 EER	
	≥ 14,000 Btu/h	—	8.0 EER	
Room air conditioner casement only	All capacities	—	8.7 EER	
Room air conditioner casement-slider	All capacities	—	9.5 EER	

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

“Cap” = The rated cooling capacity of the project in Btu/h. If the unit’s capacity is less than 7,000 Btu/h, use 7,000 Btu/h in the calculation. If the unit’s capacity is greater than 15,000 Btu/h, use 15,000 Btu/h in the calculations.

- a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
- b. Replacement unit shall be factory labeled as follows: “MANUFACTURED FOR 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
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h ^b	80% E_t	10 CFR Part 431
		> 2,500,000 Btu/h ^a	82% E_c	
	Oil-fired ^c	< 300,000 Btu/h	84% AFUE	10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h ^b	82% E_t	10 CFR Part 431
		> 2,500,000 Btu/h ^a	84% E_c	
Boilers, steam	Gas-fired	< 300,000 Btu/h	80% AFUE	10 CFR Part 430
	Gas-fired- all, except natural draft	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h ^b	79% E_t	10 CFR Part 431
		> 2,500,000 Btu/h ^a	79% E_t	
	Gas-fired-natural draft	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h ^b	77% E_t	
		> 2,500,000 Btu/h ^a	77% E_t	
	Oil-fired ^c	< 300,000 Btu/h	82% AFUE	10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h ^b	81% E_t	10 CFR Part 431
		> 2,500,000 Btu/h ^a	81% E_t	

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

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

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

TABLE C403.2.3(6)
MINIMUM EFFICIENCY REQUIREMENTS:
CONDENSING UNITS, ELECTRICALLY OPERATED

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

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

- a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
- b. IPLVs are only applicable to equipment with capacity modulation.

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

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	PATH A ^b		PATH B ^b		TEST PROCEDURE ^c
			FULL LOAD	IPLV	FULL LOAD	IPLV	
Air-cooled chillers	< 150 tons	EER	≥ 9.562	≥ 12.500	NA	NA	AHRI 550/590
	≥ 150 tons	EER	≥ 9.562	≥ 12.750	NA	NA	
Air cooled without condenser, electrically 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	≤ 0.780	≤ 0.630	≤ 0.800	≤ 0.600	
	≥ 75 tons and < 150 tons	kW/ton	≤ 0.775	≤ 0.615	≤ 0.790	≤ 0.586	
	≥ 150 tons and < 300 tons	kW/ton	≤ 0.680	≤ 0.580	≤ 0.718	≤ 0.540	
	≥ 300 tons	kW/ton	≤ 0.620	≤ 0.540	≤ 0.639	≤ 0.490	
Water cooled, electrically operated, centrifugal	< 150 tons	kW/ton	≤ 0.634	≤ 0.596	≤ 0.639	≤ 0.450	
	≥ 150 tons and < 300 tons	kW/ton					
	≥ 300 tons and < 600 tons	kW/ton	≤ 0.576	≤ 0.549	≤ 0.600	≤ 0.400	
	≥ 600 tons	kW/ton	≤ 0.570	≤ 0.539	≤ 0.590	≤ 0.400	
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	PERFORMANCE REQUIRED ^{b, c, d}	TEST PROCEDURE ^{e, f}
Propeller or axial fan open circuit cooling towers	All	95°F Entering Water 85°F Leaving Water 75°F Entering wb	≥ 40.2 gpm/hp	CTI ATC-105 and CTI STD-201
Centrifugal fan open circuit cooling towers	All	95°F Entering Water 85°F Leaving Water 75°F Entering wb	≥ 20.0 gpm/hp	CTI ATC-105 and CTI STD-201
Propeller or axial fan closed circuit cooling towers	All	102°F Entering Water 90°F Leaving Water 75°F Entering wb	≥ 16.1 gpm/hp	CTI ATC-105S and CTI STD-201
Centrifugal closed circuit cooling towers	All	102°F Entering Water 90°F Leaving Water 75°F Entering wb	≥ 7.0 gpm/hp	CTI ATC-105S and CTI STD-201
Air-cooled condensers	All	125°F Condensing Temperature R-22 Test Fluid 190°F Entering Gas Temperature 15°F Subcooling 95°F Entering db	≥ 176,000 Btu/h × hp	AHRI 460

For SI: °C = [(°F)-32]/1.8, L/s × kW = (gpm/hp)/(11.83), COP = (Btu/h × hp)/(2550.7).

db = dry bulb temperature, °F, wb = wet bulb temperature, °F.

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

TABLE C403.2.3(9)
HEAT TRANSFER EQUIPMENT

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

NR = No Requirement

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

C403.2.4 HVAC system controls (Mandatory). Each heating and cooling system shall be provided with thermostatic controls as specified in Section C403.2.4.1, C403.2.4.2, C403.2.4.3, C403.2.4.4, C403.4.1, C403.4.2, C403.4.3 or C403.4.4.

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*. Where humidification or dehumidification or both is provided, at least one humid-

ity control device shall be provided for each humidity control system.

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

- The perimeter system includes at least one thermostatic control *zone* for each building exposure having exterior walls facing only one orientation (within +/-45 degrees) (0.8 rad) for

more than 50 contiguous feet (15 240 mm); and

2. The perimeter system heating and cooling supply is controlled by a thermostat located within the *zones* served by the system.

C403.2.4.1.1 Heat pump supplementary heat. Heat pumps having supplementary electric resistance heat shall have controls that, except during defrost, prevent supplementary heat operation where the heat pump can meet the heating load.

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

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

C403.2.4.3 Off-hour controls. Each *zone* shall be provided with thermostatic setback controls that are controlled by either an automatic time clock or programmable control system.

Exceptions:

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

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

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

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

C403.2.4.4 Shutoff damper controls. Both outdoor air supply and exhaust ducts shall be equipped with motorized dampers that will automatically shut when the systems or spaces served are not in use.

Exceptions:

1. Gravity dampers shall be permitted in buildings less than three stories in height.
2. Gravity dampers shall be permitted for outside air intake or exhaust airflows of 300 cfm (0.14 m³/s) or less.

C403.2.4.5 Mechanical system shutoff.

C403.2.4.5.1 Operable wall or roof openings. Any directly conditioned space with operable wall or roof openings to the outdoors shall be equipped with interlock controls that disable or reset the temperature setpoint for mechanical heating and cooling. The reset setpoint for mechanical heating shall be 55°F and for mechanical cooling shall be 90°F. The system shutoff or setpoint temperature reset shall activate within 5 minutes of any such operable wall or roof opening being opened.

Exception: Interlock controls are not required for systems and spaces as follows:

1. On doors with automatic closing devices.
2. For vestibules or revolving doors.
3. For any space without a thermostatic control (thermostat or a space temperature sensor used to control heating or cooling to the space).

C403.2.4.5.2 Overhead door HVAC shutoff devices. Overhead doors, cargo doors, sliding doors, folding and accordion style wall systems, and other loading dock style doors that open to the outdoors shall be equipped with interlock controls that disable the heating, cooling and humidity control equipment that serves the area or zone adjacent to the door. The shutoff shall activate prior to the door being 25 percent open. A shutoff override, designed to be used when vehicles are parked in the doorway, may be included on doors equipped with weatherseals. The override must automatically deactivate when the vehicle is removed.

Exceptions:

1. Interlock controls are not required in areas where HVAC equipment must remain on for safety, sanitation or other health-related reasons.
2. Interlock controls are not required in areas heated by radiant heating systems.
3. The shutoff override shall activate within 5 minutes in groups U, SI, and B motor vehicle showroom occupancies.

C403.2.4.6 Snow melt system controls. Snow- and ice-melting systems, supplied through energy service to the building, shall include automatic controls capable of shutting off the system when the pavement temperature is above 50°F (10°C) and no precipitation is falling and an automatic or manual control that will allow shutoff when

the outdoor temperature is above 40°F (4°C) so that the potential for snow or ice accumulation is negligible.

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

C403.2.5.1 Demand controlled ventilation. Demand control ventilation (DCV) shall be provided for conditioned spaces larger than 500 square feet (50 m²) and with an average occupant load of 25 people per 1000 square feet (93 m²) of conditioned floor area (as established in Table 403.3 of the *International Mechanical Code*) and served by systems with one or more of the following:

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

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

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

C403.2.6 Heating energy recovery ventilation systems (Prescriptive). Where the supply airflow rate of a fan system exceeds the values specified in Table C403.2.6, the system shall include a heating energy recovery system. The heating 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 heating energy recovery system shall include a bypass or controls that permit operation of the economizer as required by Section C403.4

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

1. Where energy recovery systems are prohibited by the *International Mechanical Code*.
2. Laboratory fume hood systems that include at least one of the following features:

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

6. Where the largest source of air exhausted at a single location at the building exterior is less than 75 percent of the design outdoor air flow rate.

7. Systems expected to operate less than 20 hours per week at the outdoor air percentage covered by Table C403.2.6.

C403.2.7 Duct and plenum insulation and sealing (Mandatory). All supply and return air ducts and plenums shall be insulated with a minimum of R-6 insulation where located in unconditioned spaces and a minimum of R-8 insulation where located outside the building. Where located within a building envelope assembly, the duct or plenum shall be separated from the building exterior or unconditioned or exempt spaces by a minimum of R-8 insulation.

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).

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

**TABLE C403.2.6
ENERGY RECOVERY REQUIREMENT**

PERCENT (%) OUTDOOR AIR AT FULL DESIGN AIRFLOW RATE					
≥ 30% and < 40%	≥ 40% and < 50%	≥ 50% and < 60%	≥ 60% and < 70%	≥ 70% and < 80%	≥ 80%
DESIGN SUPPLY FAN AIRFLOW RATE (cfm)					
NR	NR	NR	NR	≥ 5000	≥ 5000

NR = Not Required

C403.2.7.1 Duct construction. Ductwork shall be constructed and erected in accordance with the *International Mechanical Code*.

C403.2.7.1.1 Low-pressure duct systems. All longitudinal and transverse joints, seams and connections of supply and return ducts operating at a static pressure less than or equal to 2 inches water gauge (w.g.) (500 Pa) shall be securely fastened and sealed with welds, gaskets, mastics (adhesives), mastic-plus-embedded-fabric systems or tapes installed in accordance with the manufacturer's installation instructions. Pressure classifications specific to the duct system shall be clearly indicated on the construction documents in accordance with the *International Mechanical Code*.

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

C403.2.7.1.2 Medium-pressure duct systems. All ducts and plenums designed to operate at a static pressure greater than 2 inches water gauge (w.g.) (500 Pa) but less than 3 inches w.g. (750 Pa) shall be insulated and sealed in accordance with Section C403.2.7. Pressure classifications specific to the duct system shall be clearly indicated on the construction documents in accordance with the *International Mechanical Code*.

C403.2.7.1.3 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 C403.2.7. In addition, ducts and plenums shall be leak-tested in accordance with the SMACNA *HVAC Air Duct*

Leakage Test Manual with the rate of air leakage (CL) less than or equal to 6.0 as determined in accordance with Equation C4-5.

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

where:

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

P = The static pressure of the test.

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

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

Exceptions:

1. Factory-installed piping within HVAC equipment tested and rated in accordance with a test procedure referenced by this code.
2. Factory-installed piping within room fan-coils and unit ventilators tested and rated according to AHRI 440 (except that the sampling and variation provisions of Section 6.5 shall not apply) and AHRI 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.

TABLE C403.2.8^c
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 < 1½	1½ 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).

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

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

C403.2.9 Mechanical systems commissioning and completion requirements (Mandatory). Mechanical systems shall be commissioned and completed in accordance with Section C407.2.

C403.2.10 Air system design and control (Prescriptive). Each HVAC system having a total fan system motor nameplate horsepower (hp) exceeding 5 horsepower (hp) (3.7 kW) shall meet the provisions of Sections C403.2.10.1 through C403.2.10.2.

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

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

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

**TABLE C403.2.10.1(1)
FAN POWER LIMITATION**

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

where:

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

hp = The maximum combined motor nameplate horsepower.

Bhp = The maximum combined fan brake horsepower.

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

For SI: 1 cfm = 0.471 L/s.

where:

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

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

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

**TABLE C403.2.10.1(2)
FAN POWER LIMITATION PRESSURE DROP ADJUSTMENT**

DEVICE	ADJUSTMENT
Credits	
Fully ducted return and/or exhaust air systems	0.5 inch w.c. (2.15 in w.c. for laboratory and vivarium systems)
Return and/or exhaust air flow control devices	0.5 inch w.c.
Exhaust filters, scrubbers, or other exhaust treatment.	The pressure drop of device calculated at fan system design condition
Particulate filtration credit: MERV 9 thru 12	0.5 inch w.c.
Particulate filtration credit: MERV 13 thru 15	0.9 inch. w.c.
Particulate filtration credit: MERV 16 and greater and electronically enhanced filters	Pressure drop calculated at 2x clean filter pressure drop at fan system design condition.
Carbon and other gas-phase air cleaners	Clean filter pressure drop at fan system design condition.
Biosafety cabinet	Pressure drop of device at fan system design condition.
Energy recovery device, other than coil runaround loop	$(2.2 \times \text{energy recovery effectiveness}) - 0.5$ 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	0.15 inch w.c.
Exhaust system serving fume hoods	0.35 inch w.c.
Laboratory and vivarium exhaust systems in high-rise buildings	0.25 inch w.c./100 feet of vertical duct exceeding 75 feet

w.c. = water column

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

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

Exceptions:

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

C403.2.11 Heating outside a building (Mandatory). 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 de-energized when no occupants are present.

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

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

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

1. Individual fan-cooling units with a supply capacity less than the minimum listed in Table C403.3.1(1).
2. Where more than 25 percent of the air designed to be supplied by the system is to spaces that are designed to be humidified above 35°F (1.7 °C) dew-point temperature to satisfy process needs.
3. Systems that serve *residential* spaces where the system capacity is less than five times the requirement listed in Table C403.3.1(1).
4. Systems expected to operate less than 20 hours per week.
5. Where the use of *outdoor air* for cooling will affect supermarket open refrigerated casework systems.

**TABLE C403.3.1(1)
ECONOMIZER REQUIREMENTS**

ECONOMIZER REQUIREMENT
Economizers on all cooling systems $\geq 33,000$ Btu/h ^a

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

- a. The total capacity of all systems without economizers shall not exceed 300,000 Btu/h per *building*, or 20 percent of its air economizer capacity, whichever is greater.

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

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

C403.3.1.1.2 Control signal. Economizer dampers shall be capable of being sequenced with the mechanical cooling equipment and shall not be controlled by only mixed air temperature.

Exception: The use of mixed air temperature limit control shall be permitted for systems controlled from space temperature (such as single-zone systems).

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

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

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

ALLOWED CONTROL TYPES	PROHIBITED CONTROL TYPES
Fixed dry bulb Differential dry bulb Electronic enthalpy ^a Differential enthalpy Dew-point and dry-bulb temperatures	Fixed enthalpy

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

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

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

C403.4.1 Economizers. Economizers shall comply with Sections C403.4.1.1 through C403.4.1.4.

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

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

C403.4.1.2 Maximum pressure drop. Precooling coils and water-to-water heat exchangers used as part of a water economizer system shall either have a water-side pressure drop of less than 15 feet (4572 mm) of water or a secondary loop shall be created so that the coil or heat exchanger pressure drop is not seen by the circulating pumps when the system is in the normal cooling (noneconomizer) mode.

C403.4.1.3 Integrated economizer control. Economizer systems shall be integrated with the mechanical cooling system and be capable of providing partial

cooling even where additional mechanical cooling is required to meet the remainder of the cooling load.

Exceptions:

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

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

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

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

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

TABLE C403.3.1.3(2)
HIGH-LIMIT SHUTOFF CONTROL SETTING FOR AIR ECONOMIZERS

DEVICE TYPE	REQUIRED HIGH LIMIT (ECONOMIZER OFF WHEN):	
	EQUATION	DESCRIPTION
Fixed dry bulb	$T_{OA} > 75^{\circ}\text{F}$	Outdoor air temperature exceeds 75°F
Differential dry bulb	$T_{OA} > T_{RA}$	Outdoor air temperature exceeds return air temperature
Fixed enthalpy	$h_{OA} > 28 \text{ Btu/lb}^a$	Outdoor air enthalpy exceeds 28 Btu/lb of dry air ^a
Electronic Enthalpy	$(T_{OA}, RH_{OA}) > A$	Outdoor air temperature/RH exceeds the "A" setpoint curve ^b
Differential enthalpy	$h_{OA} > h_{RA}$	Outdoor air enthalpy exceeds return air enthalpy
Dew-point and dry-bulb temperatures	$DP_{OA} > 55^{\circ}\text{F}$ or $T_{OA} > 75^{\circ}\text{F}$	Outdoor air dry bulb exceeds 75°F or outside dew point exceeds 55°F (65 gr/lb)

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

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

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

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

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

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

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

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

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

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

Exception: Where a system loop temperature optimization controller is installed and can determine the most efficient operating temperature based on real-time conditions of demand and

capacity, dead bands of less than 20°F (11°C) shall be permitted.

C403.4.3.3.2 Heat rejection. If an open- or closed-circuit cooling tower is used, 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.

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

C403.4.3.3.3 Two-position valve. Each hydronic heat pump on the hydronic system having a total pump system power exceeding 10 horsepower (hp) (7.5 kW) shall have a two-position valve.

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

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

C403.4.3.5 Pump isolation. Chilled water plants including more than one chiller shall have the capability to reduce flow automatically through the chiller plant when a chiller is shut down. Chillers piped in series for the purpose of increased temperature differential shall be considered as one chiller.

Boiler plants including more than one boiler shall have the capability to reduce flow automatically through the boiler plant when a boiler is shut down.

C403.4.4 Heat rejection equipment fan speed control. Each fan powered by a motor of 7.5 hp (5.6 kW) or larger shall have the capability to operate that fan at two-thirds of full speed or less, and shall have controls that automatically change the fan speed to control the leaving fluid temperature or condensing temperature/pressure of the heat rejection device.

Exception: Factory-installed heat rejection devices within HVAC equipment tested and rated in accordance with Tables C403.2.3(6) and C403.2.3(7).

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

1. Thirty percent of the maximum supply air to each *zone*.
2. Three hundred cfm (142 L/s) or less where the maximum flow rate is less than 10 percent of the total fan system supply airflow rate.
3. The minimum ventilation requirements of Chapter 4 of the *International Mechanical Code*.

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

1. *Zones* where special pressurization relationships or cross-contamination requirements are such that VAV systems are impractical.
2. *Zones* or supply air systems where at least 75 percent of the energy for reheating or for providing warm air in mixing systems is provided from a site-recovered or site-solar energy source.
3. *Zones* where special humidity levels are required to satisfy process needs.
4. *Zones* with a peak supply air quantity of 300 cfm (142 L/s) or less and where the flow rate is less than 10 percent of the total fan system supply airflow rate.
5. *Zones* where the volume of air to be reheated, recooling or mixed is no greater than the volume of outside air required to meet the minimum ventilation requirements of Chapter 4 of the *International Mechanical Code*.
6. *Zones* or supply air systems with thermostatic and humidistatic controls capable of operating in sequence the supply of heating and cooling energy to the *zones* and which are capable of preventing reheating, recooling, mixing or simultaneous supply of air that has been previously cooled, either mechanically or through the use of economizer systems, and air that has been previously mechanically heated.

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

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

minimum before mixing of air from the other duct takes place.

C403.4.5.3 Single fan dual duct and mixing VAV systems, economizers. Individual dual duct or mixing heating and cooling systems with a single fan and with total capacities greater than 90,000 Btu/h [(26 375 W) 7.5 tons] shall not be equipped with air economizers.

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

Exceptions:

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

C403.4.6 Heat recovery for service water heating. Condenser heat recovery shall be installed for heating or reheating of service hot water provided the facility operates 24 hours a day, the total installed heat capacity of water-cooled systems exceeds 6,000,000 Btu/hr (1 758 600 W) of heat rejection, and the design service water heating load exceeds 1,000,000 Btu/h (293 100 W).

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

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

Exceptions:

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

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

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

TABLE C403.4.7
MAXIMUM HOT GAS BYPASS CAPACITY

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

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

SECTION C404
SERVICE WATER HEATING

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 (Prescriptive). Water-heating equipment and hot water storage tanks shall meet the requirements of Table C404.2. The efficiency shall be verified through data furnished by the manufacturer or through certification under an approved certification program.

C404.3 Heat traps (Mandatory). 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.

C404.4 Pipe insulation (Mandatory). For automatic-circulating hot water and heat-traced systems, piping shall be insulated with not less than 1 inch (25 mm) of insulation having a conductivity not exceeding 0.27 Btu per inch/h × ft² × °F (1.53 W per 25 mm/m² × K). The first 8 feet (2438 mm) of piping in non-hot-water-supply temperature maintenance systems served by equipment without integral heat traps shall be insulated with 0.5 inch (12.7 mm) of material having a conductivity not exceeding 0.27 Btu per inch/h × ft² × °F (1.53 W per 25 mm/m² × K).

Exception: Heat-traced piping systems shall meet the insulation thickness requirements per the manufacturer's installation instructions. Untraced piping within a heat traced system shall be insulated with not less than 1 inch (25 mm) of insulation having a conductivity not exceeding 0.27 Btu per inch/h × ft² × °F (1.53 W per 25 mm/m² × K).

C404.5 Hot water system controls (Mandatory). Circulating hot water system pumps or heat trace shall be arranged to be turned off either automatically or manually when there is limited hot water demand. Ready access shall be provided to the operating controls.

C404.6 Pools and inground permanently installed spas (Mandatory). Pools and inground permanently installed spas shall comply with Sections C404.6.1 through C404.6.3.

C404.6.1 Heaters. All heaters shall be equipped with a readily accessible on-off switch that is mounted outside of the heater to allow shutting off the heater without adjusting the thermostat setting. Gas-fired heaters shall not be equipped with constant burning pilot lights.

C404.6.2 Time switches. Time switches or other control method that can automatically turn off and on heaters and pumps according to a preset schedule shall be installed on all heaters and pumps. Heaters, pumps and motors that have built in timers shall be deemed in compliance with this requirement.

Exceptions:

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

C404.6.3 Covers. Heated pools and inground permanently installed spas shall be provided with a vapor-retardant cover.

Exception: A vapor-retardant cover is not required for pools deriving over 70 percent of the energy for heating from site-recovered energy, such as a heat pump or solar energy source computed over an operating season.

SECTION C405
ELECTRICAL POWER AND LIGHTING SYSTEMS

C405.1 General (Mandatory). This section covers lighting system controls, the connection of ballasts, the maximum lighting power for interior applications, electrical energy consumption, and minimum acceptable lighting equipment for exterior applications.

Exception: Dwelling units within commercial buildings shall not be required to comply with Sections C405.2 through C405.5 provided that not less than 75 percent of the permanently installed light fixtures, other than low-voltage lighting, shall be fitted for, and contain only, *high-efficacy lamps*.

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

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

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

Exceptions:

1. Areas designated as security or emergency areas that need to be continuously lighted.
2. Lighting in stairways or corridors that are elements of the means of egress.

TABLE C404.2
MINIMUM PERFORMANCE OF WATER-HEATING EQUIPMENT

EQUIPMENT TYPE	SIZE CATEGORY (input)	SUBCATEGORY OR RATING CONDITION	PERFORMANCE REQUIRED ^a	TEST PROCEDURE ^b
Electric tabletop water heaters	≤ 12 kW	Resistance ≥ 20 gal	See footnote (e).	
Electric water heaters	≤ 12 kW ^d	Resistance ≥ 20 gal	See footnote (e).	
	> 12 kW ^d	Resistance ≥ 20 gal	$0.3 + 27/V_m$ %/h	Section G.2 of ANSI Z21.10.3
Gas storage water heaters	$\leq 75,000$ Btu/h	≥ 20 gal	See footnote (e).	
	$> 75,000$ Btu/h	$< 4,000$ (Btu/h)/gal	$80\% E_t$	Sections G.1 and G.2 of ANSI Z21.10.3
Gas instantaneous water heaters	$> 50,000$ Btu/h and $< 200,000$ Btu/h	$\geq 4,000$ (Btu/h)/gal and < 2 gal	See footnote (e).	
	$\geq 200,000$ Btu/h ^c	$\geq 4,000$ (Btu/h)/gal and < 10 gal	$80\% E_t$	Sections G.1 and G.2 of ANSI Z21.10.3
	$\geq 200,000$ Btu/h	$\geq 4,000$ (Btu/h)/gal and ≥ 10 gal	$80\% E_t$ $(Q/800 + 110\sqrt{V})SL$, Btu/h	
Oil storage water heaters	Not allowed			
Oil instantaneous water heaters	Not allowed			
Hot water supply boilers, gas and oil	$\geq 300,000$ Btu/h and $< 12,500,000$ Btu/h	$\geq 4,000$ (Btu/h)/gal and < 10 gal	$80\% E_t$	Sections G.1 and G.2 of ANSI Z21.10.3
Hot water supply boilers, gas		$\geq 4,000$ (Btu/h)/gal and ≥ 10 gal	$80\% E_t$ $(Q/800 + 110\sqrt{V})SL$, Btu/h	Sections G.1 and G.2 of ANSI Z21.10.3
Hot water supply boilers, oil		$\geq 4,000$ (Btu/h)/gal and ≥ 10 gal	$78\% E_t$ $(Q/800 + 110\sqrt{V})SL$, Btu/h	Sections G.1 and G.2 of ANSI Z21.10.3
Pool heaters, oil and gas	All	—	See footnote (e).	ASHRAE 146
Heat pump pool heaters	All	50°F db 44.2°F wb outdoor air 80.0°F entering water	4.0 COP	AHRI 1160
Unfired storage tanks	All	—	R-12.5	(none)

- a. Thermal efficiency (E_t) is a minimum requirement, while standby loss (SL) is maximum Btu/h based on a 70°F temperature difference between stored water and ambient requirements. In the SL equation, V is the rated volume in gallons and Q is the nameplate input rate in Btu/h. V_m is the measured volume in the tank in gallons.
- b. Section G.1 is titled “Test Method for Measuring Thermal Efficiency” and Section G.2 is titled “Test Method for Measuring Standby Loss.”
- c. Instantaneous water heaters with input rates below 200,000 Btu/h must comply with these requirements if the water heater is designed to heat water to temperatures of 180°F or higher.
- d. Electric water heaters with input rates below 12 kW must comply with these requirements if the water heater is designed to heat water to temperatures of 180°F or higher.
- e. In the U.S., the efficiency requirements for water heaters or gas pool heaters in this category or subcategory are specified by the U.S. Department of Energy. Those requirements and applicable test procedures are found in the Code of Federal Regulations 10 CFR Part 430.

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

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

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

1. Areas that have only one luminaire, with rated power less than 100 watts.
2. Areas that are controlled by an occupant-sensing device.
3. Corridors, equipment rooms, storerooms, restrooms, public lobbies, electrical or mechanical rooms.
4. *Sleeping unit* (see Section C405.2.3).
5. Spaces that use less than 0.6 watts per square foot (6.5 W/m²).
6. Daylight spaces complying with Section C405.2.2.3.2.

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

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

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

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

Exceptions:

1. Emergency egress lighting does not need to be controlled by an automatic time switch.
2. Lighting in spaces controlled by occupancy sensors does not need to be controlled by automatic time switch controls.

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

1. The override switch shall be in a readily accessible location;

2. The override switch shall be located where the lights controlled by the switch are visible; or the switch shall provide a mechanism that announces the area controlled by the switch;
3. The override switch shall permit manual operation;
4. The override switch, when initiated, shall permit the controlled lighting to remain on for a maximum of 2 hours; and
5. Any individual override switch shall control the lighting for a maximum area of 5,000 square feet (465 m²).

Exception: Within malls, arcades, auditoriums, single tenant retail spaces, industrial facilities and arenas:

1. The time limit shall be permitted to exceed 2 hours provided the override switch is a captive key device; and
2. The area controlled by the override switch is permitted to exceed 5,000 square feet (465 m²), but shall not exceed 20,000 square feet (1860 m²).

C405.2.2.2 Occupancy sensors. Occupancy sensors shall be installed in all classrooms, conference/meeting rooms, employee lunch and break rooms, private offices, restrooms, storage rooms and janitorial closets, and other spaces 300 square feet (28 m²) or less enclosed by floor-to-ceiling height partitions. These automatic control devices shall be installed to automatically turn off lights within 30 minutes of all occupants leaving the space, and shall either be manual on or shall be controlled to automatically turn the lighting on to not more than 50 percent power.

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.

C405.2.2.3 Daylight zone control. Daylight zones shall be designed such that lights in the daylight zone are controlled independently of general area lighting and are controlled in accordance with either Section C405.2.2.3.1 or Section C405.2.2.3.2. Each daylight control zone shall not exceed 2,500 square feet (232 m²). Contiguous daylight zones adjacent to vertical fenestration are allowed to be controlled by a single controlling device provided that they do not include zones facing more than two adjacent cardinal orientations (i.e., north, east, south, west). Daylight zones under skylights more than 15 feet (4572 mm) from the perimeter shall be controlled separately from daylight zones adjacent to vertical fenestration.

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

C405.2.2.3.1 Manual daylighting controls. Manual controls shall be installed in daylight zones unless automatic controls are installed in accordance with Section C405.2.2.3.2.

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

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

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

C405.2.2.3.3 Multilevel lighting controls. Where multilevel lighting controls are required by this code, the general lighting in the daylight zone shall be separately controlled by at least one multilevel lighting control that reduces the lighting power in response to daylight available in the space. Where the daylit illuminance in the space is greater than the rated illuminance of the general lighting of daylight zones, the general lighting shall be automatically controlled so that its power draw is no greater than 35 percent of its rated power. The multilevel lighting control shall be located so that calibration and setpoint adjustment controls are readily accessible and separate from the light sensor.

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

1. Display and accent light shall be controlled by a dedicated control 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 a master control device at the main room entry that controls all permanently installed luminaires and switched receptacles.
4. Supplemental task lighting, including permanently installed under-shelf or under-cabinet lighting, shall have a control device integral to the luminaires or be

controlled by a wall-mounted control device provided the control device is readily accessible.

5. Lighting for nonvisual applications, such as plant growth and food warming, shall be controlled by a dedicated control that is independent of the controls for other lighting within the room or space.
6. Lighting equipment that is for sale or for demonstrations in lighting education shall be controlled by a dedicated control that is independent of the controls for other lighting within the room or space.

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

C405.3 Tandem wiring (Mandatory). The following luminaires located within the same area shall be tandem wired:

1. Fluorescent luminaires equipped with one, three or odd-numbered lamp configurations, that are recess-mounted within 10 feet (3048 mm) center-to-center of each other.
2. Fluorescent luminaires equipped with one, three or any odd-numbered lamp configuration, that are pendant- or surface-mounted within 1 foot (305 mm) edge-to-edge of each other.

Exceptions:

1. Where electronic high-frequency ballasts are used.
2. Luminaires on emergency circuits.
3. Luminaires with no available pair in the same area.

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

C405.5 Interior lighting power requirements (Prescriptive). A building complies with this section if its total connected lighting power calculated under Section C405.5.1 is no greater than the interior lighting power calculated under Section C405.5.2.

C405.5.1 Total connected interior lighting power. The total connected interior lighting power (watts) shall be the sum of the watts of all interior lighting equipment as determined in accordance with Sections C405.5.1.1 through C405.5.1.4.

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. *Sleeping unit* lighting in hotels, motels, boarding houses or similar buildings.

- 1.3. Emergency lighting automatically off during normal building operation.
- 1.4. Lighting in spaces specifically designed for use by occupants with special lighting needs including the visually impaired visual impairment and other medical and age-related issues.
- 1.5. Lighting in interior spaces that have been specifically designated as a registered interior historic landmark.
- 1.6. Casino gaming areas.
2. Lighting equipment used for the following shall be exempt provided that it is in addition to general lighting and is controlled by an independent control device:
 - 2.1. Task lighting for medical and dental purposes.
 - 2.2. Display lighting for exhibits in galleries, museums and monuments.
3. Lighting for theatrical purposes, including performance, stage, film production and video production.
4. Lighting for photographic processes.
5. Lighting integral to equipment or instrumentation and is installed by the manufacturer.
6. Task lighting for plant growth or maintenance.
7. Advertising signage or directional signage.
8. In restaurant buildings and areas, lighting for food warming or integral to food preparation equipment.
9. Lighting equipment that is for sale.
10. Lighting demonstration equipment in lighting education facilities.
11. Lighting *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.

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

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

C405.5.1.3 Other luminaires. The wattage of all other lighting equipment shall be the wattage of the lighting

equipment verified through data furnished by the manufacturer or other *approved* sources.

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

1. The specified wattage of the luminaires included in the system with a minimum of 30 W/lin ft. (98 W/lin. m);
2. The wattage limit of the system's circuit breaker; or
3. The wattage limit of other permanent current limiting device(s) on the system.

C405.5.2 Interior lighting power. Interior lighting power allowance (watts) is determined according to Table C405.5.2(1) using the Space-by-Space Method, for all areas of the building covered in this permit. For the Space-by-Space Method, the interior lighting power allowance is determined by multiplying the floor area of each space times the value for the space type in Table C405.5.2(1) 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.

**TABLE C405.5.2(1)
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD**

COMMON SPACE-BY-SPACE TYPES	LPD (w/ft²)
Atrium – First 40 feet in height	0.03 per ft. ht.
Atrium – Above 40 feet in height	0.02 per ft. ht.
Audience/seating area – permanent	
For auditorium	0.63
For performing arts theater	2.43
For motion picture theater	1.14
Classroom/lecture/training	1.05
Conference/meeting/multipurpose	1.11
Corridor/transition	0.56
Dining area	
Bar/lounge/leisure dining	0.963
Family dining area	0.801
Dressing/fitting room performing arts theater	0.61
Electrical/mechanical	0.42
Food preparation	1.20
Laboratory for classrooms	1.3
Laboratory for medical/industrial research	1.7
Lobby	0.9
Lobby for performing arts theater	2.0
Lobby for motion picture theater	0.56
Locker room	0.75
Lounge recreation	0.62
Office – enclosed	1.05
Office – open plan	0.93
Restroom	0.98
Sales area	1.37
Stairway	0.69
Storage	0.63

(continued)

**TABLE C405.5.2(1)—continued
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD**

COMMON SPACE-BY-SPACE TYPES (con't)	LPD (w/ft ²)
Workshop	1.59
Courthouse/police station/penitentiary	
Courtroom	1.46
Confinement cells	0.81
Judge chambers	1.05
Penitentiary audience seating	0.28
Penitentiary classroom	1.3
Penitentiary dining	0.96
BUILDING SPECIFIC SPACE-BY-SPACE TYPES	
Automotive – service/repair	0.70
Bank/office – banking activity area	1.0
Dormitory living quarters	0.38
Gymnasium/fitness center	
Fitness area	0.61
Gymnasium audience/seating	0.55
Playing area	1.2
COMMON SPACE-BY-SPACE TYPES	
LPD (w/ft²)	
Healthcare clinic/hospital	
Corridors/transition	1.0
Exam/treatment	1.41
Emergency	2.7
Public and staff lounge	0.78
Medical supplies	0.67
Nursery	0.75
Nurse station	0.64
Physical therapy	0.77
Patient room	0.56
Pharmacy	1.2
Radiology/imaging	1.3
Operating room	2.2
Recovery	1.15
Lounge/recreation	0.8
Laundry – washing	0.57
Hotel	
Dining area	0.59
Guest rooms	0.91
Hotel lobby	1.06
Highway lodging dining	0.59
Highway lodging guest rooms	0.91
Library	
Stacks	1.62
Card file and cataloguing	1.1
Reading area	1.06
Manufacturing	
Corridors/transition	0.4
Detailed manufacturing	1.29
Equipment room	0.74
Extra high bay (> 50-foot floor-ceiling height)	1.05
High bay (25- – 50-foot floor-ceiling height)	1.05
Low bay (< 25-foot floor-ceiling height)	1.01
Museum	
General exhibition	1.05
Restoration	1.02
Parking garage – garage areas	0.19

(continued)

**TABLE C405.5.2(1)—continued
INTERIOR LIGHTING POWER ALLOWANCES:
SPACE-BY-SPACE METHOD**

COMMON SPACE-BY-SPACE TYPES (con't)	LPD (w/ft ²)
Convention center	
Exhibit space	1.23
Audience/seating area	0.82
Fire stations	
Engine room	0.8
Sleeping quarters	0.22
Post office	
Sorting area	0.9
Religious building	
Fellowship hall	0.6
Audience seating	1.53
Worship pulpit/choir	1.53
Retail	
Dressing/fitting area	0.71
Mall concourse	1.1
Sales area	1.44 ^a
BUILDING SPECIFIC SPACE-BY-SPACE TYPES	
LPD (w/ft²)	
Sports arena	
Audience seating	0.4
Court sports area – Class 4	0.7
Court sports area – Class 3	1.2
Court sports area – Class 2	1.9
Court sports area – Class 1	3.0
Ring sports area	2.7
Transportation	
Air/train/bus baggage area	0.50
Airport concourse	0.32
Terminal – ticket counter	0.68
Warehouse	
Fine material storage	0.95
Medium/bulky material	0.49

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

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

Calculate the additional lighting power as follows:

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

where:

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

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

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

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

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

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

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

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

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

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

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

**TABLE C405.6.2(1)
EXTERIOR LIGHTING ZONES**

LIGHTING ZONE	DESCRIPTION
1	Developed areas of national parks, state parks, forest land, and rural areas
2	Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed use areas
3	All other areas
4	High-activity commercial districts in major metropolitan areas as designated by the local land use planning authority

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

SECTION C406 REQUIREMENTS FOR SOLAR READY BUILDINGS (MANDATORY—FOR NEW CONSTRUCTION)

C406.1 General (Mandatory). All newly constructed *commercial buildings* shall comply with the requirements of Sections C406.2 through C406.5.

C406.2 Solar zone. *Solar zones* shall be clearly indicated on the construction documents.

C406.2.1 Location and size of solar zone. The solar zone shall have a minimum total area described as follows. The solar zone shall comply with access, pathway, smoke ventilation and spacing requirements as specified in the Boulder Revised Code. The solar zone total area shall be comprised of one or more rectangular areas that are not less than 80 square feet and no side of any rectangular area shall be less than 5 feet in length.

The solar zone shall be located on:

1. The roof or overhang of the building.
2. The roof or overhang of another structure located within 250 feet of the building on the same parcel or lot.
3. Covered parking installed with the building project.
4. A façade of the building that is less than 15 degrees greater or less than true south.

The solar zone shall cover a total area of not less than 40 percent of the total roof area, as measured by the area of the roof planes. The following roof areas can be excluded when calculating the total roof area of the building:

1. Roof areas with a permanently installed domestic solar water-heating system.
2. Roof areas where the annual solar access is less than 70 percent. For the purpose of this code, solar access means the ratio of solar insolation including shade to the solar insolation without shade. Shading from obstructions located on the roof or any other part of the building shall not be included in the determination of annual solar access.
3. Roof areas with a permanently installed solar electric system having a nameplate DC power rating, measured under standard test conditions, of not less than 1 watt per square foot of roof area.

Exception: Solar zones are not required in buildings where the roof is designed and approved to be used for vehicular traffic or parking or for a heliport.

C406.2.2 Orientation. All sections of the solar zone located on steep sloped roofs shall be oriented between 90 degrees and 270 degrees of true north.

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

		LIGHTING ZONES			
		Zone 1	Zone 2	Zone 3	Zone 4
Base Site Allowance (Base allowance is usable in tradable or nontradable surfaces.)		350 W	400 W	500 W	900 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	0.03 W/ft ²	0.04 W/ft ²	0.06 W/ft ²	0.08 W/ft ²
	Building Grounds				
	Walkways less than 10 feet wide	0.5 W/linear foot	0.5 W/linear foot	0.6 W/linear foot	0.7 W/linear foot
	Walkways 10 feet wide or greater, plaza areas special feature areas	0.1 W/ft ²	0.1 W/ft ²	0.11 W/ft ²	0.14 W/ft ²
	Stairways	0.6 W/ft ²	0.7 W/ft ²	0.7 W/ft ²	0.7 W/ft ²
	Pedestrian tunnels	0.12 W/ft ²	0.12 W/ft ²	0.14 W/ft ²	0.21 W/ft ²
	Building Entrances and Exits				
	Pedestrian vehicular entrances and exits	14 W/linear foot of door width	14 W/linear foot of door width	21 W/linear foot of door width	21 W/linear foot of door width
	Entry canopies	0.2 W/ft ²	0.25 W/ft ²	0.4 W/ft ²	0.4 W/ft ²
	Sales Canopies				
	Free-standing and attached	0.4 W/ft ²	0.4 W/ft ²	0.6 W/ft ²	0.7 W/ft ²
	Outdoor Sales				
	Open areas (including vehicle sales lots)	0.2 W/ft ²	0.2 W/ft ²	0.35 W/ft ²	0.5 W/ft ²
	Street frontage for vehicle sales lots in addition to "open area" allowance	No Allowance	10 W/linear foot	7 W/linear foot	21 W/linear foot
Nontradable Surfaces (Lighting power density calculations for the following applications can be used only for the specific application and cannot be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the "Tradable Surfaces" section of this table.)	Building facades	No Allowance	0.1 W/ft ² of façade area (1.1 W/m ²) or 2.5 W/linear foot (8.2 W/m) of façade length	0.15 W/ft ² of façade area (1.6 W/m ²) or 3.75 W/linear foot (12.3 W/m) of façade length	0.2 W/ft ² of façade area (2.2 W/m ²) or 5.0 W/linear foot (16.4 W/m) of façade length
	Automated teller machines and night depositories	135 W per location plus 45 W per additional ATM per location	135 W per location plus 45 W per additional ATM per location	135 W per location plus 45 W per additional ATM per location	135 W per location plus 45 W per additional ATM per location
	Uncovered entrances and gatehouse inspection stations at guarded facilities	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
	Uncovered loading areas for law enforcement, fire, ambulance and other emergency service vehicles	0.35 W/ft ² of covered and uncovered area	0.35 W/ft ² of covered and uncovered area	0.35 W/ft ² of covered and uncovered area	0.35 W/ft ² of covered and uncovered area
	Drive-up windows/doors	200 W per drive-through	200 W per drive-through	200 W per drive-through	200 W per drive-through
	Parking near 24-hour retail entrances	400 W per main entry	400 W per main entry	400 W per main entry	400 W per main entry

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m².

C406.2.3 Shading.

1. No obstructions, including but not limited to, vents, chimneys, architectural features and roof-mounted equipment, shall be located in the solar zone.
2. Any obstruction located on the roof or any other part of the building that projects above a solar zone shall be located at least twice the distance, measured in the horizontal plane, of the height difference between the highest point of the obstruction and the horizontal projection of the nearest point of the solar zone, measured in the vertical plane.

Exception: Any roof obstruction, located on the roof or any other part of the building that is oriented north of all points on the solar zone.

C406.2.4 Structural design loads on construction documents. For areas of the roof designated as solar zone, the structural design loads for roof dead load and roof live load shall be clearly indicated on the construction documents.

NOTE: The inclusion of any collateral loads for future solar energy systems is not required.

C406.3 Interconnection pathways. The construction documents shall indicate a location for inverters and metering equipment and a pathway for routing of conduit from the solar zone to the point of interconnection with the electrical service.

C406.4 Documentation. A copy of the construction documents or a comparable document indicating the information from Sections C406.2 and C406.3 shall be provided to and maintained by the building owner. The building owner shall provide a copy of the construction documents or a comparable document indicating the information from Sections C406.2 and C406.3 to any purchasers and subsequent owners of the building or any part thereof.

C406.5 Main electrical service panel.

1. The main electrical service panel shall have a minimum bus bar rating of no less than 200 amps.
2. The main electrical service panel shall have a reserved space to allow for the installation of double pole circuit breakers for a future solar electric installation. The minimum reserved amperage shall be determined from Table C406.5.
 - a. **Location.** The reserved space shall be positioned at the opposite (load) end from the input feeder location or main circuit location.
 - b. **Marking.** The reserved spaces shall be permanently marked as "For Future Solar Electric."

**TABLE C406.5
MINIMUM RESERVED AMPERAGE PER SQUARE FOOT
OF PLANNED SOLAR AREA**

INVERTER SYSTEM VOLTAGE	AMPERAGE PER SQUARE FOOT
120	0.125
240	0.063
208	0.042
277	0.054
480	0.018

SECTION C407 SYSTEM COMMISSIONING (MANDATORY)

C407.1 General. This section covers the *commissioning* of the building mechanical systems in Section C403 and electrical power and lighting systems in Section C405.

C407.2 Mechanical systems commissioning and completion requirements. Prior to passing the final mechanical inspection, the *registered design professional* shall provide evidence of mechanical systems *commissioning* and completion in accordance the provisions of this section.

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. Copies of all documentation shall be given to the owner and made available to the *code official* upon request in accordance with Sections C407.2.4 and C407.2.5.

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

1. Mechanical systems in buildings where the total mechanical equipment capacity is less than 480,000 Btu/h (140 690 W) cooling capacity and 600,000 Btu/h (175 860 W) heating capacity.
2. Systems included in Section C403.3 that serve dwelling units and sleeping units in hotels, motels, boarding houses or similar units.

C407.2.1 Commissioning plan. A *commissioning plan* shall be developed by a *registered design professional* or *approved agency* and shall include the following items:

1. A narrative description of the activities that will be accomplished during each phase of commissioning, including the personnel intended to accomplish each of the activities.
2. A listing of the specific equipment, appliances or systems to be tested and a description of the tests to be performed.
3. Functions to be tested, including, but not limited to calibrations and economizer controls.
4. Conditions under which the test will be performed. At a minimum, testing shall affirm winter and summer design conditions and full outside air conditions.
5. Measurable criteria for performance.

C407.2.2 Systems adjusting and balancing. HVAC systems shall be balanced in accordance with generally accepted engineering standards. Air and water flow rates shall be measured and adjusted to deliver final flow rates within the tolerances provided in the product specifications. Test and balance activities shall include air system and hydronic system balancing.

C407.2.2.1 Air systems balancing. Each supply air outlet and *zone* terminal device shall be equipped with means for air balancing in accordance with the requirements of Chapter 6 of the *International Mechanical*

Code. Discharge dampers are prohibited on constant volume fans and variable volume fans with motors 10 hp (18.6 kW) and larger. Air systems shall be balanced in a manner to first minimize throttling losses then, for fans with system power of greater than 1 hp (0.74 kW), fan speed shall be adjusted to meet design flow conditions.

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

C407.2.2.2 Hydronic systems balancing. Individual hydronic heating and cooling coils shall be equipped with means for balancing and measuring flow. Hydronic systems shall be proportionately balanced in a manner to first minimize throttling losses, then the pump impeller shall be trimmed or pump speed shall be adjusted to meet design flow conditions. Each hydronic system shall have either the capability to measure pressure across the pump, or test ports at each side of each pump.

Exceptions:

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

C407.2.3 Functional performance testing. Functional performance testing specified in Sections C407.2.3.1 through C407.2.3.3 shall be conducted.

C407.2.3.1 Equipment. Equipment functional performance testing shall demonstrate the installation and operation of components, systems, and system-to-system interfacing relationships in accordance with approved plans and specifications such that operation, function, and maintenance serviceability for each of the commissioned systems is confirmed. Testing shall include all modes and *sequence of operation*, including under full-load, part-load and the following emergency conditions:

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

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

C407.2.3.2 Controls. HVAC control systems shall be tested to document that control devices, components, equipment, and systems are calibrated, adjusted and operate in accordance with approved plans and specifications. Sequences of operation shall be functionally tested to document they operate in accordance with *approved* plans and specifications.

C407.2.3.3 Economizers. Air economizers shall undergo a functional test to determine that they operate in accordance with manufacturer's specifications.

C407.2.4 Preliminary commissioning report. A preliminary report of commissioning test procedures and results shall be completed and certified by the *registered design professional* or *approved agency* and provided to the building owner. The report shall be identified as "Preliminary Commissioning Report" and shall identify:

1. Itemization of deficiencies found during testing required by this section that have not been corrected at the time of report preparation.
2. Deferred tests that cannot be performed at the time of report preparation because of climatic conditions.
3. Climatic conditions required for performance of the deferred tests.

C407.2.4.1 Acceptance of report. *Buildings*, or portions thereof, shall not pass the final mechanical inspection until such time as the *code official* has received a letter of transmittal from the *building* owner acknowledging that the *building* owner has received the Preliminary Commissioning Report.

C407.2.4.2 Copy of report. The *code official* shall be permitted to require that a copy of the Preliminary Commissioning Report be made available for review by the *code official*.

C407.2.5 Documentation requirements. The *construction documents* shall specify that the *documents* described in this section be provided to the *building* owner within 90 days of the date of receipt of the *certificate of occupancy*.

C407.2.5.1 Drawings. Construction documents shall include the location and performance data on each piece of equipment.

C407.2.5.2 Manuals. An operating and maintenance manual shall be provided and include all of the following:

1. A complete description of the requirements of the facility, including any owner's project requirements or current facility requirements for operation of the building.
2. Facility, systems and assemblies information including:
 - 2.1. Manufacturer's operation and maintenance data for installed equipment systems and assemblies.
 - 2.2. Warranties and certificate of occupancy.
 - 2.3. Contractor and supplier listing and contact information.
3. A facility operations guide, including an operating plan, building and equipment operating schedules, setpoints and ranges, sequences of operation, system and equipment limitations, and emergency procedures.
4. A narrative of how each system is intended to operate, including recommended setpoints.

At least one copy of the operating and maintenance manual shall be in the possession of the owner or the owner's authorized agent and at least one additional copy shall remain with the building.

C407.2.5.3 System balancing report. A written report describing the activities and measurements completed in accordance with Section C407.2.2.

C407.2.5.4 Final commissioning report. A report of test procedures and results identified as "Final Commissioning Report" shall be delivered to the building owner and shall include:

1. Results of functional performance tests.
2. Disposition of deficiencies found during testing, including details of corrective measures used or proposed.
3. Functional performance test procedures used during the commissioning process including measurable criteria for test acceptance, provided herein for repeatability.

Exception: Deferred tests which cannot be performed at the time of report preparation due to climatic conditions.

C407.3 Lighting system functional testing. Commissioning of controls for automatic lighting systems shall comply with the requirements of this Section 407.3.

C407.3.1 Functional testing. Testing shall ensure that control hardware and software are calibrated, adjusted, programmed and in proper working condition in accordance with the construction documents and manufacturer's installation instructions. The construction documents shall state the party who will conduct the required functional testing. Where required by the code official, an approved party independent from the design or construction of the project shall be responsible for the functional testing and shall provide documentation to the code official certifying that the installed lighting controls meet the provisions of Section C405.

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

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

CHAPTER 5

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 C106.

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/I.S.2/A440—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 (2005)	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 (1998)	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—03	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)
560—00	Absorption Water Chilling and Water-heating Packages	Table C403.2.3(7)
840—1998	Unit Ventilators	403.2.8
1160—08	Performance Rating of Heat Pump Pool Heaters	Table C404.2

REFERENCED STANDARDS

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
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—04	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—06	Gas-fired Central Furnaces	Table C403.2.3(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)

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 183—2007	Peak Cooling and Heating Load Calculations in Buildings, Except Low-rise Residential Buildings	C403.2.1
ASHRAE—2004 ISO/AHRI/ASHRAE 13256-1 (2005)	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 (1998)	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)
I 90.1—2010	Energy Standard for Buildings Except Low-rise Residential Buildings	C401.2.1, Table C401.2.2
> 146—2006	Testing and Rating Pool Heaters	Table C404.2

ASTM

ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428-2859

Standard reference number	Title	Referenced in code section number
> C90—08	Specification for Load-bearing Concrete Masonry Units	Table C402.2
D1003—07e1	Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics	C402.3.2.2
E283—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 C402.4.3, C402.4.8
> E779—03	Standard Test Method for Determining Air Leakage Rate by Fan Pressurization	C402.4.1.2.1

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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/I.S.2/A440—11	North American Fenestration Standard/Specification for Windows, Doors and Unit Skylights	Table C402.4.3

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)
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)	Test Method for Thermal Transmittance and Air Infiltration of Garage Doors	Table C402.4.3

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
10 CFR, Part 430, Subpart B, Appendix N—1998	Uniform Test Method for Measuring the Energy Consumption of Furnaces and Boilers	C202
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)
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)

REFERENCED STANDARDS

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—12	International Building Code®	C201.3, C302.2, C402.4.4
IFC—12	International Fire Code®	C201.3
IFGC—12	International Fuel Gas Code®	C201.3
IMC—12	International Mechanical Code®	C201.3, 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, C403.4.5, C407.2.2.1
IPC—12	International Plumbing Code®	C201.3
IRC—12	International Residential Code®	C201.3

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—2010	Energy Standard for Buildings, Except Low-rise Residential Buildings	C401.2.1, Table C402.2.2

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 (2005)	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 (1998)	Water-Source Heat Pumps—Testing and Rating for Performance— Part 2: Water-to-water and Brine-to-water Heat Pumps	C403.2.3(2)

NFRC National Fenestration Rating Council, Inc.
6305 Ivy Lane, Suite 140
Greenbelt, MD 20770

Standard reference number	Title	Referenced in code section number
100—2010	Procedure for Determining Fenestration Products <i>U</i> -factors	C302.1.2, C402.2.1
200—2010	Procedure for Determining Fenestration Product Solar Heat Gain Coefficients and Visible Transmittance at Normal Incidence.	C302.1.3, C402.3.1.1
400—2010	Procedure for Determining Fenestration Product Air Leakage	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—85	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
727—06	Oil-fired Central Furnaces—with Revisions through April 2010	Table C403.2.3(4) <
731—95	Oil-fired Unit Heaters—with Revisions through April 2010.	Table C403.2.3(4) <
1784—01	Air Leakage Tests of Door Assemblies- with Revisions through <i>July 2009</i>	C402.4.4

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	C302.1.4

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

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CHAPTER 1

SCOPE AND ADMINISTRATION

PART 1—SCOPE AND APPLICATION

SECTION R101 SCOPE AND GENERAL REQUIREMENTS

R101.1 Title. This code shall be known as the 2017 *City of Boulder Energy Conservation Code*, and shall be cited as such. It is referred to herein as “this code.”

R101.2 Scope. This code applies to *residential buildings* and the buildings sites and associated systems and equipment.

R101.3 Intent. This code shall regulate the design and construction of buildings for the effective use and conservation of energy over the useful 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.

R101.4 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.

R101.4.1 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.

R101.4.2 Historic buildings. Any building or structure that is listed in the State or National Register of Historic Places; locally designated as an individual landmark; 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 in the National or State Registers of Historic Places either individually or as a contributing building or structure to a historic district by the State Historic Preservation Officer or the Keeper of the National Register of Historic Places; or has been found, through a historic building inventory, to be eligible for local designation as a landmark or to be listed as a contributing building or structure to a local historic district, shall comply with the requirements of this code. The *code official* may approve an alteration or modification to the requirements of this code where the requirement would have a detrimental impact on the special character or special historical, architectural, aesthetic interest or value of the building or structure individually or of the historic district to which the building or structure is contributing or, if the alteration would require a landmark alteration certificate under Chapter 9-11, “His-

toric Preservation,” B.R.C. 1981, but would not meet the applicable standards of Section 9-11-18, “Standards for Landmark Alteration Certificate Applications,” B.R.C. 1981.

R101.4.3 Additions, alterations, or repairs. Additions, alterations or repairs 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(s) of the existing building or building system to comply with this code except where explicitly otherwise required by this code. Additions, alterations or repairs 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.

Exception: The following need not comply provided the energy use of the building is not increased:

1. Storm windows installed over existing fenestration.
2. Glass only replacements in an existing sash and frame.
3. Construction where the existing roof, wall or floor cavity is not exposed.
4. Reroofing for roofs where neither the sheathing nor the insulation is exposed. Roofs without insulation in the cavity and where the sheathing or insulation is exposed during reroofing shall be insulated either above or below the sheathing.
5. 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,
6. Alterations that replace less than 50 percent of the luminaires in a space, provided that such alterations do not increase the installed interior lighting power.
7. Alterations that replace only the bulb and ballast within the existing luminaires in a space provided that the *alteration* does not increase the installed interior lighting power.

R101.4.4 Change in occupancy or use. Spaces undergoing a change in occupancy that would result in an increase in demand for either fossil fuel or electrical energy shall comply with this code.

R101.4.5 Change in space conditioning. Any nonconditioned space that is altered to become *conditioned space* shall be required to be brought into full compliance with this code.

R101.4.6 Mixed occupancy. Where a building includes both *residential* and *commercial* occupancies, the building shall meet the requirements of this code for *commercial buildings*.

R101.5 Compliance. *Residential buildings* shall meet the Residential Provisions of this code, Section R101 through R404. *Commercial buildings* shall meet the Commercial Provisions of this code, Sections C101 through C407.

R101.5.1 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.

R101.5.2 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 the *building thermal envelope* provisions of this code:

1. Those 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*.

SECTION R102 ALTERNATE MATERIALS—METHOD OF CONSTRUCTION, DESIGN OR INSULATING SYSTEMS

R102.1 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.

R102.1.1 Above code programs. The *code official* or other authority having jurisdiction shall be permitted to deem a national, state or local energy efficiency program to exceed the energy efficiency required by this code. Buildings *approved* in writing by such an energy efficiency program shall be considered in compliance with this code. The requirements identified as “mandatory” in Chapter 4 shall be met.

PART 2—ADMINISTRATION AND ENFORCEMENT

SECTION R103 CONSTRUCTION DOCUMENTS

R103.1 General. Construction documents and other supporting data shall be submitted in one or more sets with each application for a permit. The construction documents and designs submitted under the provisions of this code shall be prepared by and bear the stamp of a Colorado licensed professional engineer or architect. Documents submitted for the Energy Rating Index shall be submitted by a *registered design professional* who demonstrates the knowledge and

experience to perform such calculations. Where special conditions exist, the *code official* is authorized to require additional construction documents to be prepared by a Colorado licensed professional engineer or architect.

Exception: The *code official* may waive the submission of construction documents and other supporting data if the official finds that the nature of the work does not require review of the documents or data to obtain compliance. This waiver authority does not apply to documents required to be prepared by a Colorado licensed architect or engineer.

R103.2 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, insulation materials and their *R*-values; fenestration *U*-factors and SHGCs; area-weighted *U*-factor and SHGC calculations; mechanical system design criteria; mechanical and service water heating system and equipment types, sizes and efficiencies; economizer description; equipment and systems controls; fan motor horsepower (hp) and controls; duct sealing, duct and pipe insulation and location; lighting fixture schedule with wattage and control narrative; and air sealing details.

SECTION R104 INSPECTIONS

R104.1 General. Construction or work for which a permit is required shall be subject to inspection by the *code official*.

R104.2 Required approvals. Work shall not be done beyond the point indicated in each successive inspection without first obtaining the approval of the *code official*. The *code official*, upon notification, shall make the requested inspections and shall either indicate the portion of the construction that is satisfactory as completed, or notify the permit holder or his or her agent wherein the same fails to comply with this code. Any portions that do not comply shall be corrected and such portion shall not be covered or concealed until authorized by the *code official*.

R104.3 Final inspection. The building shall have a final inspection and not be occupied until *approved*.

R104.4 Reinspection. A building shall be reinspected when determined necessary by the *code official*.

SECTION R105 VALIDITY

R105.1 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 R106 REFERENCED STANDARDS

R106.1 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 R106.1.1 and R106.1.2.

R106.1.1 Conflicts. Where conflicts occur between provisions of this code and referenced codes and standards, the provisions of this code shall apply.

R106.1.2 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.

R106.2 Conflicting requirements. Where the provisions of this code and the referenced standards conflict, the provisions of this code shall take precedence.

R106.3 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.

R106.4 Other laws. The provisions of this code shall not be deemed to nullify any provisions of local, state or federal law. This code is intended to comply with and be interpreted and enforced so as to comply with 42 U.S.C. Section 6297(f)(3) and any other federal requirements to avoid pre-emption. For purposes of 42 U.S.C. Section 6297(f)(3), “new construction” shall be interpreted to include all work that triggers the requirements established in this code.

SECTION R107 ADMINISTRATION

R107.1 Administration. This code shall be administered in accordance with and as part of Chapter 10-5, “Building Code,” B.R.C. 1981.

CHAPTER 2

DEFINITIONS

SECTION R201 GENERAL

R201.1 Scope. Unless stated otherwise, the following words and terms in this code shall have the meanings indicated in this chapter.

R201.2 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.

R201.3 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*, *International Plumbing Code* or the *International Residential Code* shall have the meanings ascribed to them in those codes.

R201.4 Terms not defined. Terms not defined by this chapter shall have ordinarily accepted meanings such as the context implies.

SECTION R202 GENERAL DEFINITIONS

ABOVE-GRADE WALL. A wall more than 50 percent above grade and enclosing *conditioned space*. 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.

ALTERATION. Any construction or renovation to an existing structure other than repair or addition that requires a permit. Also, a change in a mechanical 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.

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*”).

BASEMENT WALL. A wall 50 percent or more below grade and enclosing *conditioned space*.

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 PERFORMANCE INSTITUTE (BPI). Building Performance Institute, or BPI, is a national standards development organization for residential energy efficiency and weatherization retrofit work accredited by the American Standards Institute (ANSI).

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

BUILDING THERMAL ENVELOPE. The basement walls, exterior walls, floor, roof, and any other building elements that enclose *conditioned space* or provides a boundary between *conditioned 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 × °F) [W/(m² × K)].

CODE OFFICIAL. The code official is the city manager.

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

COMMUNITY SOLAR GARDEN. A solar generation facility where the beneficial use of the electricity generated by the facility belongs to subscribers to the solar generation facility as authorized in §40-2-127, C.R.S.

CONDITIONED FLOOR AREA. The floor area of the floors associated with the *conditioned space*.

CONDITIONED SPACE. An area or room within a building being heated or cooled, containing uninsulated ducts, or with a fixed opening directly into an adjacent *conditioned space*.

CONSTRUCTION VALUATION. The total value of work requiring building, mechanical, plumbing and electrical permits, to be determined consistent with the standards of Subsection 4-20-4(d), B.R.C. 1981. The higher of the two valuations considered under Subsection 4-20-4(d), B.R.C. 1981, shall be the total value of work.

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

CRAWL SPACE WALL. The opaque portion of a wall that encloses a crawl space and is partially or totally below grade.

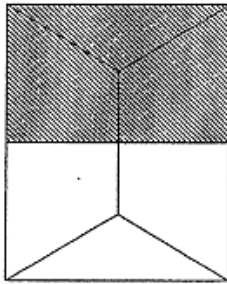
DEFINITIONS

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

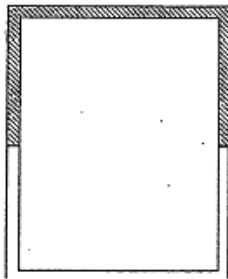
DEMAND RECIRCULATION WATER SYSTEM. A water distribution system where pump(s) prime the service hot water piping with heated water upon demand for hot water.

DEMOLITION OR DEMOLISH. An act or process that removes one or more of the following. The shaded area illustrates the maximum amount that may be removed without constituting demolition.

- a. Fifty percent or more of the roof area as measured in plain view (see diagram):



- b. Fifty percent or more of the exterior walls of a building as measured contiguously around the “building coverage” as defined in Section 9-16-1, “Definitions,” B.R.C., 1981 (see diagram).



A wall shall meet the following minimum standards to be considered a retained exterior wall:

1. The wall shall retain studs or other structural elements, the exterior wall finish and the fully framed and sheathed roof above that portion of the remaining building to which such wall is attached.
2. The wall shall not be covered or otherwise concealed by a wall that is proposed to be placed in front of the retained wall.
3. Each part of the retained exterior walls shall be connected contiguously and without interruption to every other part of the retained exterior walls.

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.

ENERGY ADVISING. Guidance provided by a third-party energy professional to educate the property owner about energy efficiency upgrades and/or improvements that will reduce energy use by the building, improve occupant comfort, and reduce utility bills.

ENERGY ASSESSMENT. A comprehensive review of a building’s thermal envelope, equipment, appliances, lighting, and combustion safety conducted by a *BPI* or *RESNET* accredited professional. Blower door testing and infrared imaging measuring infiltration of the existing building shall be included in the comprehensive review.

ENERGY ASSESSOR. A *BPI* or *RESNET* accredited professional who can conduct an energy assessment of a building’s thermal envelope, heating and cooling systems, ventilation, and lighting, and recommend energy efficiency improvements to the building to reduce the building’s 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 RATING INDEX (ERI). The ERI value is defined as a numerical score where 100 is equivalent to a home designed to be minimally compliant with 2006 IECC and 0 is equivalent to a net zero energy (NZE) home. An ERI is determined by an energy simulation tool, where each integer value on the scale represents a 1 percent change in the total energy use of the rated design relative to the total energy use of the ERI reference design. The ERI must be determined in accordance with the ANSI/RESNET/ICC 301-2014 Standard.

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

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.

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

FENESTRATION. Skylights, roof windows, vertical windows (fixed or moveable), opaque doors, glazed doors, glazed block and combination opaque/glazed doors. Fenestration includes products with glass and nonglass glazing materials.

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 ($\text{Btu/h} \times \text{ft} \times ^\circ\text{F}$) [$\text{W}/(\text{m} \times \text{K})$].

FLOOR AREA. The total square footage of all levels as measured from the inside finished surface of the walls, excluding courts, unconditioned garages, and uninhabitable crawl spaces and attics.

HEATED SLAB. Slab-on-grade 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-EFFICACY LAMPS. Compact fluorescent lamps, T-8 or smaller diameter linear fluorescent lamps, or lamps with a minimum efficacy of:

1. 60 lumens per watt for lamps over 40 watts;
2. 50 lumens per watt for lamps over 15 watts to 40 watts; and
3. 40 lumens per watt for lamps 15 watts or less.

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.

INSULATING SHEATHING. An insulating board with a core material having a minimum *R*-value of *R*-2.

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.

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-VOLTAGE LIGHTING. Lighting equipment powered through a transformer such as a cable conductor, a rail conductor and track lighting.

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

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”).

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

RESIDENTIAL BUILDING. For this code, includes detached one- and two-family *dwelling units*, attached multiple single-family *dwelling units* with separate means of egress from each *dwelling unit* and no common area in the building, and Group R-3 and R-4 buildings three stories or less in height above grade plane, and accessory structures to such *residential buildings*.

RESIDENTIAL ENERGY SERVICES NETWORK (RESNET). Residential Energy Services Network, or RESNET, is a recognized national standards development organization for building energy efficiency rating and certification systems.

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.

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 ($h \times \text{ft}^2 \times ^\circ\text{F/Btu}$) [$(\text{m}^2 \times \text{K})/\text{W}$].

SERVICE WATER HEATING. Supply of hot water for purposes other than comfort heating.

SKYLIGHT. Glass or other transparent or translucent glazing material installed at a slope of less than 60 degrees (1.05 rad) from horizontal. Glazing material in skylights, including unit skylights, solariums, sunrooms, roofs and sloped walls is included in this definition.

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 TEST CONDITIONS. A fixed set of conditions for which PV module performance is rated. These conditions are 1000 W/m² incident solar radiation, 25°C cell temperature, 0.0 wind speed, and air mass 1.5 spectrum.

SUNROOM. A one-story structure attached to a dwelling with a glazing area in excess of 40 percent of the gross area of the structure’s exterior walls and roof.

THERMAL ISOLATION. Physical and space conditioning separation from *conditioned space(s)*. The *conditioned space(s)* shall be controlled as separate zones for heating and cooling or conditioned by separate equipment.

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

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 ($\text{Btu/h} \times \text{ft}^2 \times ^\circ\text{F}$) [$\text{W}/(\text{m}^2 \times \text{K})$].

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.

VISIBLE TRANSMITTANCE [VT]. The ratio of visible light entering the space through the fenestration product assembly to the incident visible light, Visible Transmittance,

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includes the effects of glazing material and frame and is expressed as a number between 0 and 1.

WHOLE HOUSE MECHANICAL VENTILATION SYSTEM. An exhaust system, supply system, or combination thereof that is designed to mechanically exchange indoor air with outdoor air when operating continuously or through a programmed intermittent schedule to satisfy the whole house ventilation rates.

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

GENERAL REQUIREMENTS

SECTION R301 DESIGN CONDITIONS

R301.1 Interior design conditions. The interior design temperatures used for heating and cooling load calculations shall be a maximum of 70°F (21°C) for heating and minimum of 75°F (24°C) for cooling.

SECTION R302 MATERIALS, SYSTEMS AND EQUIPMENT

R302.1 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.

R302.1.1 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. The insulation installer shall sign, date and post the certification in a conspicuous location on the job site.

R302.1.1.1 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 a minimum of 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.

R302.1.2 Insulation mark installation. Insulating materials shall be installed such that the manufacturer's *R*-value mark is readily observable upon inspection.

R302.1.3 Fenestration product rating. *U*-factors of fenestration products (windows, doors and skylights) shall be determined in accordance with NFRC 100 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 R302.1.3(1) or R302.1.3(2). 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 R302.1.3(3).

R302.1.4 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 (CFR Title 16, Part 460) in units of h × ft² × °F/Btu at a mean temperature of 75°F (24°C).

**TABLE R302.1.3(1)
DEFAULT GLAZED FENESTRATION U-FACTOR**

FRAME TYPE	SINGLE PANE	DOUBLE PANE	SKYLIGHT	
			Single	Double
Metal	1.20	0.80	2.00	1.30
Metal with Thermal Break	1.10	0.65	1.90	1.10
Nonmetal or Metal Clad	0.95	0.55	1.75	1.05
Glazed Block	0.60			

**TABLE R302.1.3(2)
DEFAULT DOOR U-FACTORS**

DOOR TYPE	U-FACTOR
Uninsulated Metal	1.20
Insulated Metal	0.60
Wood	0.50
Insulated, nonmetal edge, max 45% glazing, any glazing double pane	0.35

TABLE R302.1.3(3)
DEFAULT GLAZED FENESTRATION SHGC AND VT

	SINGLE GLAZED		DOUBLE GLAZED		GLAZED BLOCK
	Clear	Tinted	Clear	Tinted	
SHGC	0.8	0.7	0.7	0.6	0.6
VT	0.6	0.3	0.6	0.3	0.6

R302.2 Installation. All materials, systems and equipment shall be installed in accordance with the manufacturer's installation instructions and the *International Building Code* or *International Residential Code*, as applicable.

R302.2.1 Protection of exposed foundation insulation. Insulation applied to the exterior of basement walls, crawl-space 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 a minimum of 6 inches (153 mm) below grade.

R302.3 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.

CHAPTER 4

RESIDENTIAL ENERGY EFFICIENCY

SECTION R401 GENERAL

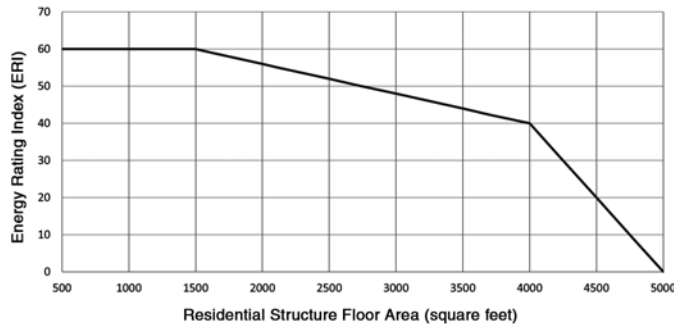
R401.1 Scope. This chapter applies to *residential buildings*.

R401.2 Compliance (Mandatory).

R401.2.1 New buildings. New buildings with a floor area of less than 500 square feet shall comply with all mandatory and prescriptive requirements in this chapter. New buildings with a floor area of 500 square feet or larger shall comply with all mandatory requirements of this chapter and are required to achieve the applicable *Energy Rating Index (ERI)* established in this section and shown in Table R401.2.1. The applicable *Energy Rating Index* shall be determined in accordance with the ANSI/RESNET/ICC 301-2014 Standard and is based on floor area.¹

1. Floor area of 500 to 1,499 square feet (SQFT):
 $ERI = 60$
2. Floor area of 1,500 to 3,999 square feet: $ERI = 60 - (SQFT \text{ floor area} - 1,500) * 0.008$
3. Floor area of 4,000 to 4,999 square feet: $ERI = 40 - (SQFT \text{ floor area} - 4,000) * 0.04$
4. Floor area $\geq 5,000$ square feet: $ERI = 0$

**TABLE R401.2.1
ENERGY RATING INDEX REQUIREMENTS FOR
NEW RESIDENTIAL BUILDINGS**



R401.2.2 Additions. *Additions* to an existing structure must comply with all mandatory requirements of this chapter and also the following:

1. Floor area of *addition* < 1,000 square feet: If the floor area is less than 1,000 square feet, the *addition* shall comply with all mandatory and prescriptive requirements in this chapter.
2. Floor area of *addition* $\geq 1,000$ square feet: If the floor area is 1,000 square feet or larger, the entire structure

(the addition and the existing structure) shall meet the *ERI* requirement, which shall be calculated consistent with the following²:

- 2.1. $ERI = 115 - (\text{points per total finished floor area} - (\text{points per } \% \text{ increase in total finished floor area}))$
- 2.2. The *ERI* (points per total finished floor area) shall be established consistent with the requirements of Table R401.2.2.2(1). The point values of Table R401.2.2.2(1) are applied in ranges and only within those ranges. For example, for a home with a total conditioned square footage of 2,200 square feet, the first 1,999 square feet would have 0.016 *ERI* points per square foot while the next 201 square feet or would have 0.007 *ERI* points per square foot.
- 2.3. The *ERI* points for each percentage of increase in square footage shall be established consistent with the requirements of Table R401.2.2.2(2). The point values of Table R401.2.2.2(2) are applied in ranges and only within those ranges. For example, an *addition* that creates a 30 percent increase in square footage will have 25 percent of the increase associated with 80 points and the next 5 percent of increase associated with 10 *ERI* points per percentage increase.
- 2.4. The applicable *ERI* shall be determined in accordance with the ANSI/RESNET/ICC 301-2014 Standard.
- 2.5. Table R401.2.2.2(3) summarizes the *ERI* requirements, but is illustrative only as it does not show the applicable *ERI* for all possible scenarios.
- 2.6. For the purposes of this Section R.401.2.2, the term total finished floor area refers to the square footage of the building after any demolition and additions associated with the project are completed.

**TABLE R401.2.2.2(1)
ERI POINTS PER TOTAL FINISHED FLOOR AREA**

FLOOR AREA RANGE (square feet)	ERI POINTS (per square foot)
1,000 to 1,999	0.016
2,000 to 3,999	0.007
$\geq 4,000$	0.019

¹. The exact *Energy Rating Index* requirements may be calculated using the City of Boulder *ERI* Worksheet for New Buildings by entering the building floor area. The city of Boulder *ERI* Worksheet for New Buildings can be found on the City of Boulder website.

². The exact *Energy Rating Index* requirements may be calculated using the City of Boulder *ERI* Worksheet for Additions by entering the existing square footage of the proposed *addition*. The City of Boulder *ERI* Worksheet for Additions can be found on the City of Boulder website.

TABLE R401.2.2.2(2)
ERI POINTS PER ONE PERCENT INCREASE
IN TOTAL FINISHED FLOOR AREA

% OF ADDITION TO TOTAL FINISHED FLOOR AREA	ERI POINTS (per square foot)
< 26%	80
26% to 75%	10
> 75%	15

R401.2.3 Alterations or repairs. *Alterations and repairs* to existing buildings shall comply with all mandatory requirements of this chapter and the prescriptive requirements established in Table R401.2.3, which are determined by *construction valuation*.

R401.2.4 Two or more building permits within 24 months. Any two or more building permits for the same *dwelling unit* that are applied for in any 24-month period shall be considered as one permit for the purpose of determining and meeting the requirements of this Section R401.2. Permits issued for *repairs* only are exempt from the requirements of this Section R401.2.4.

R401.2.5 Where meeting the required ERI on the property of the building is practically infeasible, the *code official* shall have the authority to approve the purchase of a *community solar garden* subscription to achieve the required ERI provided that:

community solar garden subscription to achieve the required ERI provided that:

1. The contract for a *community solar garden* subscription is at least 20 years in duration.
2. The property of the building shall be identified in the contract as the physical location to which the subscription is attributed.
3. The subscription is of a size that is required to meet the applicable ERI under this code. The submittal document for such request shall include a report and analysis by a registered design professional demonstrating the capacity of on-site solar photovoltaic panels necessary to achieve the applicable ERI rating. That capacity is the size of the *community solar garden* subscription that must be purchased to meet the requirements of this chapter.
4. The ERI that can be achieved on the property through practically feasible energy efficient design and construction, including building systems and equipment, without a *community solar garden* subscription is no greater than 50 points for new construction and no greater than 60 points for *alterations and additions*.

The building shall remain the location to which the *community solar garden* electricity generation of that subscription is attributed.

TABLE R401.2.2.2(3)
SUMMARY TABLE OF ENERGY RATING INDEX REQUIREMENTS
FOR EXISTING STRUCTURES TO WHICH AN ADDITION IS ADDED (ILLUSTRATIVE ONLY)

		Percent of Increase in Square Footage																			
		5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
Total Proposed Conditioned Square Footage	500	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
	750	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
	1000	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
	1250	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	70	69	68	67	67
	1500	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	67	66	66	65	64	63	63
	1750	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	64	63	63	62	62	61	60	59	59
	2000	NR	NR	NR	NR	NR	NR	NR	NR	NR	61	61	60	60	59	59	58	57	56	56	55
	2250	NR	NR	NR	NR	NR	NR	NR	NR	60	59	59	58	58	57	57	56	55	55	54	53
	2500	NR	NR	NR	NR	NR	NR	NR	59	58	58	57	57	56	56	55	54	54	53	52	51
	2750	NR	NR	NR	NR	NR	NR	NR	57	56	56	55	55	54	54	53	53	52	51	50	50
	3000	NR	NR	NR	NR	NR	NR	56	55	55	54	54	53	53	52	52	51	50	49	49	48
	3250	NR	NR	NR	NR	NR	NR	54	53	53	52	52	51	51	50	50	49	48	48	47	46
	3500	NR	NR	NR	NR	NR	53	52	52	51	51	50	50	49	49	48	47	47	46	45	44
	3750	NR	NR	NR	NR	NR	51	50	50	49	49	48	48	47	47	46	46	45	44	43	43
	4000	NR	NR	NR	NR	49	49	48	48	47	47	46	46	45	45	44	44	43	42	41	41
	4250	NR	NR	NR	NR	45	44	44	43	43	42	42	41	41	40	39	39	38	37	37	36
	4500	NR	NR	NR	NR	40	39	39	38	38	37	37	36	36	35	35	34	33	33	32	31
	4750	NR	NR	NR	NR	35	35	34	34	33	33	32	32	31	31	40	29	29	28	27	26
	5000	NR	NR	NR	34	30	30	29	29	28	28	27	27	26	26	25	25	24	23	22	22

*NR = Not Required

**TABLE R401.2.3
ENERGY EFFICIENCY REQUIREMENTS FOR ALTERATIONS AND REPAIRS TO EXISTING BUILDINGS**

CONSTRUCTION VALUATION IS < 26% OF VALUE ^a OF EXISTING BUILDING	CONSTRUCTION VALUATION IS 26-50% OF VALUE ^a OF EXISTING BUILDING	CONSTRUCTION VALUATION IS > 50% OF VALUE ^a OF EXISTING BUILDING
All prescriptive requirements of this chapter for the scope of the <i>alteration</i> or <i>repair</i> and <i>energy advising</i> ^{b, c}	All prescriptive requirements of this chapter for the scope of the <i>alteration</i> or <i>repair</i> and an <i>energy assessment</i> ^{b, d}	New construction ERI requirements for entire <i>dwelling unit</i> per R401.2.1
	Air sealing and insulation in ceiling and walls for entire <i>dwelling unit</i> (R402.4) ^b	
	Crawl space insulation, vapor barrier, and ventilation for entire <i>dwelling unit</i> (R402.2.10) ^b	

- a. The applicant shall demonstrate the value of the existing building by submitting the actual value of the structure determined by the Boulder County Assessor's Office or the fair market value of the building determined by a real estate appraiser licensed in Colorado. An appraisal by a licensed real estate appraiser shall include both a sales comparison approach and cost approach. The City of Boulder must be an authorized user of the appraisal. The appraisal is subject to review and approval by the city manager.
- b. Not required if an addition under the same permit triggers ERI requirements for the entire building pursuant to R401.2.2.
- c. Homeowner must contact a qualified energy advisor, as defined by the city manager, and discuss the construction project to learn how efficiency opportunities can be maximized.
- d. Homeowner must obtain an energy assessment for the building from a qualified energy assessor, as defined by the city manager, before submitting a building permit application.

Within seven days of the request by the city manager, the owner of the property shall provide proof of the continuing subscription to a *community solar garden* attributed to the property that is required to meet the energy efficiency standards of this chapter. Failure to provide such proof shall constitute a violation under the Boulder Revised Code.

In an administrative enforcement action, evidence of failure of the owner of the property to provide proof to the city manager of a continuing subscription to a *community solar garden* as required for the building to meet the requirements of this chapter shall constitute prima facie evidence that such owner violated the provisions of this section.

R401.3 Documentation. (Mandatory).

R401.3.1 Certificate. A permanent certificate shall be completed and posted on or in the electrical distribution panel by the builder or registered design professional. The certificate shall not cover or obstruct the visibility of the circuit directory label, service disconnect label or other required labels. The certificate shall list the predominant *R*-values of insulation installed in or on ceiling/roof, walls, foundation (slab, *basement wall*, crawl space wall and/or floor) and ducts outside conditioned spaces; *U*-factors for fenestration and the solar heat gain coefficient (SHGC) of fenestration, and the results from any required duct system and building envelope air leakage testing done on the building. Where there is more than one value for each component, the certificate shall list the value covering the largest area. The certificate shall list the types and efficiencies of heating, cooling and service water heating equipment. Where a gas-fired unvented room heater, electric furnace, or baseboard electric heater is installed in the residence, the certificate shall list "gas-fired unvented room heater," "electric furnace" or "baseboard electric heater," as appropriate. An efficiency shall not be *listed* for gas-fired unvented room heaters, electric furnaces or electric baseboard heaters.

R401.3.2 Homeowner manual. The builder or owner's agent shall provide the owner with a binder of all equipment and appliance manufacturers' installation manuals,

except for manuals that are required to be affixed to the equipment. This includes the *energy assessment* report and/or *ERI* certificate. If the *code official* approved a *community solar garden* subscription attributed to the property as a means to meet the requirements of this chapter, the manual shall include any requirements for a continued subscription to a *community solar garden* necessary to meet the requirements of this chapter.

SECTION R402 BUILDING THERMAL ENVELOPE

R402.1 General (Prescriptive). The *building thermal envelope* shall meet the requirements of Sections R402.1.1 through R402.1.4.

R402.1.1 Insulation and fenestration criteria. The *building thermal envelope* shall meet the requirements of Table R402.1.1.

R402.1.2 *R*-value computation. Insulation material used in layers, such as framing cavity insulation and insulating sheathing, shall be summed to compute the component *R*-value. The manufacturer's settled *R*-value shall be used for blown insulation. Computed *R*-values shall not include an *R*-value for other building materials or air films.

R402.1.3 *U*-factor alternative. An assembly with a *U*-factor equal to or less than that specified in Table R402.1.3 shall be permitted as an alternative to the *R*-value in Table R402.1.1.

R402.1.4 Total UA alternative. If the total *building thermal envelope* UA (sum of *U*-factor times assembly area) is less than or equal to the total UA resulting from using the *U*-factors in Table R402.1.3 (multiplied by the same assembly area as in the proposed building), the building shall be considered in compliance with Table R402.1.1. The UA calculation shall be done using a method consistent with the ASHRAE *Handbook of Fundamentals* and shall include the thermal bridging effects of framing materials. The SHGC requirements shall be met in addition to UA compliance.

**TABLE R402.1.1
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT^a**

FENESTRATION <i>U</i> -FACTOR ^b	SKYLIGHT ^b <i>U</i> -FACTOR	GLAZED FENESTRATION SHGC ^b	CEILING <i>R</i> -VALUE	WOOD FRAME WALL <i>R</i> -VALUE	MASS WALL <i>R</i> -VALUE ^g	FLOOR <i>R</i> -VALUE	BASEMENT ^c WALL <i>R</i> -VALUE	SLAB ^d <i>R</i> -VALUE & DEPTH	CRAWL SPACE ^e WALL <i>R</i> -VALUE
0.30	0.55	NR	49	20 or 13+5 ^f	13/17	30 ^c	15/19	10, 2 ft	15/19

For SI: 1 foot = 304.8 mm.

- R*-values are minimums. *U*-factors and SHGC are maximums. When insulation is installed in a cavity that is less than the label or design thickness of the insulation, the installed *R*-value of the insulation shall not be less than the *R*-value specified in the table.
- The fenestration *U*-factor column excludes skylights. The SHGC column applies to all glazed fenestration.
- "15/19" means R-15 continuous insulation on the interior or exterior of the home or R-19 cavity insulation at the interior of the basement wall. "15/19" shall be permitted to be met with R-13 cavity insulation on the interior of the basement wall plus R-5 continuous insulation on the interior or exterior of the home.
- R-5 shall be added to the required slab edge *R*-values for heated slabs.
- Or insulation sufficient to fill the framing cavity, R-19 minimum.
- First value is cavity insulation, second is continuous insulation or insulated siding, so "13+5" means R-13 cavity insulation plus R-5 continuous insulation or insulated siding. If structural sheathing covers 40 percent or less of the exterior, continuous insulation *R*-value shall be permitted to be reduced by no more than R-3 in the locations where structural sheathing is used – to maintain a consistent total sheathing thickness.
- The second *R*-value applies when more than half the insulation is on the interior of the mass wall.

**TABLE R402.1.3
EQUIVALENT *U*-FACTORS^a**

FENESTRATION <i>U</i> -FACTOR	SKYLIGHT <i>U</i> -FACTOR	CEILING <i>U</i> -FACTOR	FRAME WALL <i>U</i> -FACTOR	MASS WALL <i>U</i> -FACTOR ^b	FLOOR <i>U</i> -FACTOR	BASEMENT WALL <i>U</i> -FACTOR	CRAWL SPACE WALL <i>U</i> -FACTOR
0.30	0.55	0.026	0.057	0.082	0.033	0.050	0.055

- Nonfenestration *U*-factors shall be obtained from measurement, calculation or an approved source.
- When more than half the insulation is on the interior, the mass wall *U*-factors shall be a maximum of 0.065.

R402.2 Specific insulation requirements (Prescriptive). In addition to the requirements of Section R402.1, insulation shall meet the specific requirements of Sections R402.2.1 through R402.2.12.

R402.2.1 Ceilings with attic spaces. When Section R402.1.1 would require R-38 in the ceiling, R-30 shall be deemed to satisfy the requirement for R-38 wherever the full height of uncompressed R-30 insulation extends over the wall top plate at the eaves. Similarly, R-38 shall be deemed to satisfy the requirement for R-49 wherever the full height of uncompressed R-38 insulation extends over the wall top plate at the eaves. This reduction shall not apply to the *U*-factor alternative approach in Section R402.1.3 and the total UA alternative in Section R402.1.4.

R402.2.2 Ceilings without attic spaces. Where Section R402.1.1 would require insulation levels above R-30 and the design of the roof/ceiling assembly does not allow sufficient space for the required insulation, the minimum required insulation for such roof/ceiling assemblies shall be R-30. This reduction of insulation from the requirements of Section R402.1.1 shall be limited to 500 square feet (46 m²) or 20 percent of the total insulated ceiling area, whichever is less. This reduction shall not apply to the *U*-factor alternative approach in Section R402.1.3 and the total UA alternative in Section R402.1.4.

R402.2.3 Eave baffle. For air permeable insulations in vented attics, a baffle shall be installed adjacent to soffit and eave vents. Baffles shall maintain an opening equal or greater than the size of the vent. The baffle shall extend

over the top of the attic insulation. The baffle shall be permitted to be any solid material.

R402.2.4 Access hatches and doors. Access doors from conditioned spaces to unconditioned spaces (e.g., attics and crawl spaces) shall be weather-stripped and insulated to a level equivalent to the insulation on the surrounding surfaces. Access shall be provided to all equipment that prevents damaging or compressing the insulation. A wood framed or equivalent baffle or retainer is required to be provided when loose fill insulation is installed, the purpose of which is to prevent the loose fill insulation from spilling into the living space when the attic access is opened, and to provide a permanent means of maintaining the installed *R*-value of the loose fill insulation.

R402.2.5 Mass walls. Mass walls for the purposes of this chapter shall be considered above-grade walls of concrete block, concrete, insulated concrete form (ICF), masonry cavity, brick (other than brick veneer), earth (adobe, compressed earth block, rammed earth) and solid timber/logs.

R402.2.6 Steel-frame ceilings, walls, and floors. Steel-frame ceilings, walls, and floors shall meet the insulation requirements of Table R402.2.6 or shall meet the *U*-factor requirements of Table R402.1.3. The calculation of the *U*-factor for a steel-frame envelope assembly shall use a series-parallel path calculation method.

R402.2.7 Floors. Floor insulation shall be installed to maintain permanent contact with the underside of the sub-floor decking.

R402.2.8 Basement walls. Walls associated with conditioned basements shall be insulated from the top of the *basement wall* down to 10 feet (3048 mm) below grade or to the basement floor, whichever is less. Walls associated with unconditioned basements shall meet this requirement unless the floor overhead is insulated in accordance with Sections R402.1.1 and R402.2.7.

R402.2.9 Slab-on-grade floors. Slab-on-grade floors with a floor surface less than 12 inches (305 mm) below grade shall be insulated in accordance with Table R402.1.1. The insulation shall extend downward from the top of the slab on the outside or inside of the foundation wall. Insulation located below grade shall be extended the distance provided in Table R402.1.1 by any combination of vertical insulation, insulation extending under the slab or insulation extending out from the building. Insulation extending away from the building shall be protected by pavement or

by a minimum of 10 inches (254 mm) of soil. The top edge of the insulation installed between the *exterior wall* and the edge of the interior slab shall be permitted to be cut at a 45-degree (0.79 rad) angle away from the *exterior wall*. Slab-edge insulation is not required in jurisdictions designated by the *code official* as having a very heavy termite infestation.

R402.2.10 Crawl space walls. As an alternative to insulating floors over crawl spaces, crawl space walls shall be permitted to be insulated when the crawl space is not vented to the outside. Crawl space wall insulation shall be permanently fastened to the wall and extend downward from the floor to the finished grade level and then vertically and/or horizontally for at least an additional 24 inches (610 mm). Exposed earth in unvented crawl space foundations shall be covered with a continuous Class I vapor retarder in accordance with the *International Building Code* or *International Residential Code*, as applicable. All joints of the vapor retarder shall overlap by 6 inches (153 mm) and be sealed or taped. The edges of the vapor retarder shall extend at least 6 inches (153 mm) up the stem wall and shall be attached to the stem wall.

R402.2.11 Masonry veneer. Insulation shall not be required on the horizontal portion of the foundation that supports a masonry veneer.

R402.2.12 Sunroom insulation. All *sunrooms* enclosing conditioned space shall meet the insulation requirements of this code.

Exception: For *sunrooms* with *thermal isolation*, and enclosing conditioned space, the following exceptions to the insulation *requirements* of this code shall apply:

1. The minimum ceiling insulation *R*-values shall be R-24. <
2. The minimum wall *R*-value shall be R-13. Wall(s) separating a *sunroom* with a *thermal isolation* from *conditioned space* shall meet the *building thermal envelope* requirements of this code. <

R402.3 Fenestration (Prescriptive). In addition to the requirements of Section R402, fenestration shall comply with Sections R402.3.1 through R402.3.6.

R402.3.1 U-factor. An area-weighted average of fenestration products shall be permitted to satisfy the *U*-factor requirements.

R402.3.2 Glazed fenestration SHGC. An area-weighted average of fenestration products more than 50-percent glazed shall be permitted to satisfy the SHGC requirements.

R402.3.3 Glazed fenestration exemption. Up to 15 square feet (1.4 m²) of glazed fenestration per dwelling unit shall be permitted to be exempt from *U*-factor and SHGC requirements in Section R402.1.1. This exemption shall not apply to the *U*-factor alternative approach in Section R402.1.3 and the Total UA alternative in Section R402.1.4.

R402.3.4 Opaque door exemption. One side-hinged opaque door assembly up to 24 square feet (2.22 m²) in area is exempted from the *U*-factor requirement in Section R402.1.1. This exemption shall not apply to the *U*-factor

TABLE R402.2.6
STEEL-FRAME CEILING, WALL AND FLOOR INSULATION
(R-VALUE)

WOOD FRAME R-VALUE REQUIREMENT	COLD-FORMED STEEL EQUIVALENT R-VALUE ^a
Steel Truss Ceilings^b	
R-30	R-38 or R-30 + 3 or R-26 + 5
R-38	R-49 or R-38 + 3
R-49	R-38 + 5
Steel Joist Ceilings^b	
R-30	R-38 in 2 × 4 or 2 × 6 or 2 × 8 R-49 in any framing
R-38	R-49 in 2 × 4 or 2 × 6 or 2 × 8 or 2 × 10
Steel-Framed Wall 16" O.C.	
R-13	R-13 + 4.2 or R-19 + 2.1 or R-21 + 2.8 or R-0 + 9.3 or R-15 + 3.8 or R-21 + 3.1
R-13 + 3	R-0 + 11.2 or R-13 + 6.1 or R-15 + 5.7 or R-19 + 5.0 or R-21 + 4.7
R-20	R-0 + 14.0 or R-13 + 8.9 or R-15 + 8.5 or R-19 + 7.8 or R-19 + 6.2 or R-21 + 7.5
R-20 + 5	R-13 + 12.7 or R-15 + 12.3 or R-19 + 11.6 or R-21 + 11.3 or R-25 + 10.9
R-21	R-0 + 14.6 or R-13 + 9.5 or R-15 + 9.1 or R-19 + 8.4 or R-21 + 8.1 or R-25 + 7.7
Steel Framed Wall, 24" O.C	
R-13	R-0 + 9.3 or R-13 + 3.0 or R-15 + 2.4
R-13 + 3	R-0 + 11.2 or R-13 + 4.9 or R-15 + 4.3 or R-19 + 3.5 or R-21 + 3.1
R-20	R-0 + 14.0 or R-13 + 7.7 or R-15 + 7.1 or R-19 + 6.3 or R-21 + 5.9
R-20 + 5	R-13 + 11.5 or R-15 + 10.9 or R-19 + 10.1 or R-21 + 9.7 or R-25 + 9.1
R-21	R-0 + 14.6 or R-13 + 8.3 or R-15 + 7.7 or R-19 + 6.9 or R-21 + 6.5 or R-25 + 5.9
Steel Joist Floor	
R-13	R-19 in 2 × 6, or R-19 + 6 in 2 × 8 or 2 × 10
R-19	R-19 + 6 in 2 × 6, or R-19 + 12 in 2 × 8 or 2 × 10

a. Cavity insulation *R*-value is listed first, followed by continuous insulation *R*-value.

b. Insulation exceeding the height of the framing shall cover the framing.

alternative approach in Section R402.1.3 and the total UA alternative in Section R402.1.4.

R402.3.5 Sunroom U-factor. All *sunrooms* enclosing conditioned space shall meet the fenestration requirements of this code.

Exception: For *sunrooms* with *thermal isolation* and enclosing conditioned space, the following exceptions to the fenestration requirements of this code shall apply:

1. The maximum fenestration *U*-factor shall be 0.45.
2. The maximum skylight *U*-factor shall be 0.70. New fenestration separating the *sunroom* with *thermal isolation* from *conditioned space* shall meet the *building thermal envelope* requirements of this code.

R402.3.6 Replacement fenestration. 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 R402.1.1.

R402.4 Air leakage (Mandatory). The building thermal envelope shall be constructed to limit air leakage in accordance with the requirements of Sections R402.4.1 through R402.4.4.

R402.4.1 Building thermal envelope. The *building thermal envelope* shall comply with Sections R402.4.1.1 and R402.4.1.2. The sealing methods between dissimilar materials shall allow for differential expansion and contraction.

R402.4.1.1 Installation. The components of the *building thermal envelope* as listed in Table R402.4.1.1 shall be installed in accordance with the manufacturer's instructions and the criteria listed in Table R402.4.1.1, as applicable to the method of construction. Where required by the *code official*, an *approved* third party shall inspect all components and verify compliance.

R402.4.1.2 Testing. The building or dwelling unit shall be tested and verified as having an air leakage rate of not exceeding 3 air changes per hour. Testing shall be conducted with a blower door at a pressure of 0.2 inches w.g. (50 Pascals). Where required by the *code official*, testing shall be conducted by an *approved* third party. A written report of the results of the test shall be signed by the party conducting the test and provided to the *code official*. Testing shall be performed at any time after completion of all penetrations of the *building thermal envelope*.

During testing:

1. Exterior windows and doors, fireplace and stove doors shall be closed, but not sealed, beyond the intended weather stripping or other infiltration control measures;
2. Dampers including exhaust, intake, makeup air, backdraft and flue dampers shall be closed, but

not sealed beyond intended infiltration control measures;

3. Interior doors, if installed at the time of the test, shall be open;
4. Exterior doors for continuous ventilation systems and heat recovery ventilators shall be closed and sealed;
5. Heating and cooling systems, if installed at the time of the test, shall be turned off; and
6. Supply and return registers, if installed at the time of the test, shall be fully open.

R402.4.2 Fireplaces. New wood-burning fireplaces shall have tight-fitting flue dampers and outdoor combustion air.

R402.4.3 Fenestration air leakage. Windows, skylights and sliding glass doors shall have an air infiltration rate of no more than 0.3 cfm per square foot (1.5 L/s/m²), and swinging doors no more than 0.5 cfm per square foot (2.6 L/s/m²), when tested according to NFRC 400 or AAMA/WDMA/CSA 101/I.S.2/A440 by an accredited, independent laboratory and *listed* and *labeled* by the manufacturer.

Exception: Site-built windows, skylights and doors.

R402.4.4 Recessed lighting. Recessed luminaires installed in the *building thermal envelope* shall be sealed to limit air leakage between conditioned and unconditioned spaces. All recessed luminaires shall be IC-rated and *labeled* as having an air leakage rate not more than 2.0 cfm (0.944 L/s) when tested in accordance with ASTM E283 at a 1.57 psf (75 Pa) pressure differential. All recessed luminaires shall be sealed with a gasket or caulk between the housing and the interior wall or ceiling covering.

R402.5 Maximum fenestration U-factor and SHGC (Mandatory). The area-weighted average maximum fenestration *U*-factor permitted using tradeoffs from Section R402.1.4 shall be 0.48 for vertical fenestration and 0.75 for skylights.

SECTION R403 SYSTEMS

R403.1 Controls (Mandatory). At least one thermostat shall be provided for each separate heating and cooling system.

R403.1.1 Programmable thermostat. Where the primary heating system is a forced-air furnace, at least one thermostat per dwelling unit shall be capable of controlling the heating and cooling system on a daily schedule to maintain different temperature setpoints at different times of the day. This thermostat shall include the capability to set back or temporarily operate the system to maintain *zone* temperatures down to 55°F (13°C) or up to 85°F (29°C). The thermostat shall initially be programmed with a heating temperature setpoint no higher than 70°F (21°C) and a cooling temperature setpoint no lower than 78°F (26°C).

**TABLE R402.4.1.1
AIR BARRIER AND INSULATION INSTALLATION**

COMPONENT	CRITERIA ^a
Air barrier and thermal barrier	A continuous air barrier shall be installed in the building envelope. Exterior thermal envelope contains a continuous air barrier. Breaks or joints in the air barrier shall be sealed. Air-permeable insulation shall not be used as a sealing material.
Ceiling/attic	The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier sealed. Access openings, drop down stair or knee wall doors to unconditioned attic spaces shall be sealed.
Walls	Corners and headers shall be insulated and the junction of the foundation and sill plate shall be sealed. The junction of the top plate and top of exterior walls shall be sealed. Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier. Knee walls shall be sealed.
Windows, skylights and doors	The space between window/door jambs and framing and skylights and framing shall be sealed.
Rim joists	Rim joists shall be insulated and include the air barrier.
Floors (including above-garage and cantilevered floors)	Insulation shall be installed to maintain permanent contact with underside of subfloor decking. The air barrier shall be installed at any exposed edge of insulation.
Crawl space walls	Where provided in lieu of floor insulation, insulation shall be permanently attached to the crawl space walls. Exposed earth in unvented crawl spaces shall be covered with a Class I vapor retarder with overlapping joints taped.
Shafts, penetrations	Duct shafts, utility penetrations, and flue shafts opening to exterior or unconditioned space shall be sealed.
Narrow cavities	Batts in narrow cavities shall be cut to fit, or narrow cavities shall be filled by insulation that on installation readily conforms to the available cavity space.
Garage separation	Air sealing shall be provided between the garage and conditioned spaces.
Recessed lighting	Recessed light fixtures installed in the building thermal envelope shall be air tight, IC rated, and sealed to the drywall.
Plumbing and wiring	Batt insulation shall be cut neatly to fit around wiring and plumbing in exterior walls, or insulation that on installation readily conforms to available space shall extend behind piping and wiring.
Shower/tub on exterior wall	Exterior walls adjacent to showers and tubs shall be insulated and the air barrier installed separating them from the showers and tubs.
Electrical/phone box on exterior walls	The air barrier shall be installed behind electrical or communication boxes or air sealed boxes shall be installed.
HVAC register boots	HVAC register boots that penetrate building thermal envelope shall be sealed to the sub-floor or drywall.
Fireplace	An air barrier shall be installed on fireplace walls. Fireplaces shall have gasketed doors.

a. In addition, inspection of log walls shall be in accordance with the provisions of ICC-400.

- > **R403.1.2 Heat pump supplementary heat.** Heat pumps having supplementary electric-resistance heat shall have controls that, except during defrost, prevent supplemental heat operation when the heat pump compressor can meet the heating load.

R403.2 Ducts (Mandatory). Ducts and air handlers shall be in accordance with Sections R403.2.1 through R403.2.3.

- > **R403.2.1 Insulation.** Supply ducts in attics shall be insulated to a minimum of R-8. All other ducts shall be insulated to a minimum of R-6.

Exception: Ducts or portions thereof located completely inside the *building thermal envelope*.

R403.2.2 Sealing. Ducts, air handlers, and filter boxes shall be sealed. Joints and seams shall comply with either the *International Mechanical Code* or *International Residential Code*, as applicable.

Exceptions:

1. Air-impermeable spray foam products shall be permitted to be applied without additional joint seals.
2. Where a duct connection is made that is partially inaccessible, three screws or rivets shall be equally spaced on the exposed portion of the joint so as to prevent a hinge effect.

- 3. Continuously welded and locking-type longitudinal joints and seams in ducts operating at static pressures less than 2 inches of water column (500 Pa) pressure classification shall not require additional closure systems.

Duct tightness shall be verified by either of the following:

- 1. Postconstruction test: Total leakage shall be less than or equal to 4 cfm (113.3 L/min) per 100 square feet (9.29 m²) of conditioned floor area when tested at a pressure differential of 0.1 inches w.g. (25 Pa) across the entire system, including the manufacturer’s air handler enclosure. All register boots shall be taped or otherwise sealed during the test.
- 2. Rough-in test: Total leakage shall be less than or equal to 4 cfm (113.3 L/min) per 100 square feet (9.29 m²) of conditioned floor area when tested at a pressure differential of 0.1 inches w.g. (25 Pa) across the system, including the manufacturer’s air handler enclosure. All registers shall be taped or otherwise sealed during the test. If the air handler is not installed at the time of the test, total leakage shall be less than or equal to 3 cfm (85 L/min) per 100 square feet (9.29 m²) of conditioned floor area.

Exception: The total leakage test is not required for ducts and air handlers located entirely within the building thermal envelope.

R403.2.2.1 Sealed air handler. Air handlers shall have a manufacturer’s designation for an air leakage of no more than 2 percent of the design air flow rate when tested in accordance with ASHRAE 193.

R403.2.3 Building cavities (Mandatory). Building framing cavities shall not be used as ducts or plenums.

R403.3 Mechanical system piping insulation (Mandatory). Mechanical system piping capable of carrying fluids above 105°F (41°C) or below 55°F (13°C) shall be insulated to a minimum of R-3.

R403.3.1 Protection of piping insulation. Piping insulation exposed to weather shall be protected from damage, including that caused by sunlight, moisture, equipment maintenance, and wind, and shall provide shielding from solar radiation that can cause degradation of the material. Adhesive tape shall not be permitted.

R403.4 Service hot water systems (Mandatory). Energy conservation measures for service hot water systems shall be in accordance with Sections R403.4.1 and R403.4.2.

R403.4.1 Circulating hot water systems. Circulating hot water systems shall be provided with an automatic or readily accessible manual switch that can turn off the hot-water circulating pump when the system is not in use.

R403.4.2 Hot water pipe insulation. Insulation for hot water pipe with a minimum thermal resistance (R-value) of R-3 shall be applied to the following:

- 1. Piping larger than 3/4 inch nominal diameter.
- 2. Piping serving more than one dwelling unit.
- 3. Piping from the water heater to kitchen outlets.
- 4. Piping located outside the conditioned space.
- 5. Piping from the water heater to a distribution manifold.
- 6. Piping located under a floor slab.
- 7. Buried piping.
- 8. Supply and return piping in recirculation systems other than demand recirculation systems.
- 9. Piping with run lengths greater than the maximum run lengths for the nominal pipe diameter given in Table R403.4.2.

All remaining piping shall be insulated to at least R-3 or meet the run length requirements of Table R403.4.2.

TABLE R403.4.2
MAXIMUM RUN LENGTH (feet)^a

Nominal Pipe Diameter of Largest Diameter Pipe in the Run (inch)	3/8	1/2	3/4	> 3/4
Maximum Run Length	30	20	10	5

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

a. Total length of all piping from the distribution manifold or the recirculation loop to a point of use.

R403.5 Mechanical ventilation (Mandatory). The building shall be provided with ventilation that meets the requirements of the *International Residential Code* or *International Mechanical Code*, as applicable, or with other approved means of ventilation. Outdoor air intakes and exhausts shall have automatic or gravity dampers that close when the ventilation system is not operating.

R403.5.1 Whole-house mechanical ventilation system fan efficacy (Prescriptive). Mechanical ventilation system fans shall meet the efficacy requirements of Table R403.5.1.

Exception: Where mechanical ventilation fans are integral to tested and listed HVAC equipment, they shall be powered by an electronically commutated motor.

TABLE R403.5.1
MECHANICAL VENTILATION SYSTEM FAN EFFICACY

FAN LOCATION	AIR FLOW RATE MINIMUM (CFM)	MINIMUM EFFICACY (CFM/WATT)	AIR FLOW RATE MAXIMUM (CFM)
Range hoods	Any	2.8 cfm/watt	Any
In-line fan	Any	2.8 cfm/watt	Any
Bathroom, utility room	10	1.4 cfm/watt	< 90
Bathroom, utility room	90	2.8 cfm/watt	Any

For SI: 1 cfm = 28.3 L/min.

R403.6 Equipment Sizing (Mandatory). Heating and cooling equipment shall be sized in accordance with ACCA Manual S based on building loads calculated in accordance with ACCA Manual J or other *approved* heating and cooling calculation methodologies. The output capacity of heating and cooling equipment shall not be greater than that of the smallest available equipment size that exceeds the loads calculated, including allowable oversizing limits. New or replacement heating and cooling equipment shall have an efficiency rating equal to or greater than the minimum required by federal law for the geographic location where the equipment is installed.

R403.7 Snow melt system controls (Mandatory). Snow- and ice-melting systems, supplied through energy service to the building, shall include automatic controls capable of shutting off the system when the pavement temperature is above 50°F, and no precipitation is falling and an automatic or manual control that will allow shutoff when the outdoor temperature is above 40°F.

R403.8 Pools and inground permanently installed spas (Mandatory). Pools and inground permanently installed spas shall comply with Sections R403.8.1 through R403.8.3.

R403.8.1 Heaters. All heaters shall be equipped with a readily *accessible* on-off switch that is mounted outside of the heater to allow shutting off the heater without adjusting the thermostat setting. Gas-fired heaters shall not be equipped with constant burning pilot lights.

R403.8.2 Time switches. Time switches or other control method that can automatically turn off and on heaters and pumps according to a preset schedule shall be installed on all heaters and pumps. Heaters, pumps and motors that have built in timers shall be deemed in compliance with this requirement.

Exceptions:

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

R403.8.3 Covers. Heated pools and inground permanently installed spas shall be provided with a vapor-retardant cover.

R403.9 Heating outside a building (Mandatory). 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 de-energized when no occupants are present.

cent of the permanently installed lighting fixtures shall contain only high efficacy lamps.

Exception: Low-voltage lighting shall not be required to utilize high-efficiency lamps.

R404.1.1 Lighting equipment (Mandatory). Fuel gas lighting systems shall not have continuously burning pilot lights.

SECTION R404 ELECTRICAL POWER AND LIGHTING SYSTEMS (MANDATORY)

R404.1 Lighting equipment (Mandatory). A minimum of 75 percent of the lamps in permanently installed lighting fixtures shall be high-efficacy lamps or a minimum of 75 per-

CHAPTER 5

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 R106.

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/I.S.2/A440—11	North American Fenestration Standard/ Specifications for Windows, Doors and Unit Skylights	R402.4.3

ACCA

Air Conditioning Contractors of America
2800 Shirlington Road, Suite 300
Arlington, VA 22206

Standard reference number	Title	Referenced in code section number
Manual J—11	Residential Load Calculation Eighth Edition.	R403.6
Manual S—10	Residential Equipment Selection	R403.6

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
ASHRAE—2009	ASHRAE Handbook of Fundamentals	R402.1.4
ASHRAE 193—2010	Method of Test for Determining the Airtightness of HVAC Equipment.	R403.2.2.1

ASTM

ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428-2859

Standard reference number	Title	Referenced in code section number
E283—04	Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls and Doors Under Specified Pressure Differences Across the Specimen	R402.4.4

REFERENCED STANDARDS

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/I.S.2/A440—11	North American Fenestration Standard/Specification for Windows, Doors and Unit Skylights.	R402.4.3

ICC

International Code Council, Inc.
500 New Jersey Avenue, NW
6th Floor
Washington, DC 20001

Standard reference number	Title	Referenced in code section number
ANSI/RESNET/ICC 301—2014	Standard for the Calculation and Labeling of the Energy Performance of Low-Rise Residential Buildings using the Energy Rating Index, March 7, 2014, republished 2016	R202, R401.2.1, R401.2.2
IBC—12	International Building Code®	R201.3, R302.2, R402.2.10
ICC 400—12	Standard on the Design and Construction of Log Structures	Table R402.4.1.1
IFC—12	International Fire Code®	R201.3
IFGC—12	International Fuel Gas Code®	R201.3
IMC—12	International Mechanical Code®	R201.3, R403.2.2, R403.5
IPC—12	International Plumbing Code®	R201.3
IRC—12	International Residential Code®	R201.3, R302.2, R402.2.10, R403.2.2, R403.5

NFRC

National Fenestration Rating Council, Inc.
6305 Ivy Lane, Suite 140
Greenbelt, MD 20770

Standard reference number	Title	Referenced in code section number
100—2010	Procedure for Determining Fenestration Products <i>U</i> -factors	R302.1.3
200—2010	Procedure for Determining Fenestration Product Solar Heat Gain Coefficients and Visible Transmittance at Normal Incidence.	R302.1.3
400—2010	Procedure for Determining Fenestration Product Air Leakage	R402.4.3

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	R302.1.4

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.	R402.4.3

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